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Heavy Vehicle Management: Signal Coordination

Mohammed Al Eisaei[1], Sara Moridpour[2], Richard Tay[3]

[1]Mohammed Al Eisaei, Civil, Environmental and Chemical Engineering, RMIT University, Melbourne, 3001, Australia

[2]Sara Moridpour, Civil, Environmental and Chemical Engineering, RMIT University, Melbourne, 3001, Australia

[3]Richard Tay, Business, IT and Logistics, RMIT University, Melbourne, 3001, Australia

Email for correspondence: s3216566@student.rmit.edu.au

Abstract

Road freight is considered as an important aspect of the growing Australian economy. Between the years 2009 and 2014, there has been an increase of approximately 15% in the number of registered heavy vehicles which include Light Rigid, Heavy Rigid and Articulated Vehicles. The increase in number of heavy vehicles suggests an increase of heavy vehicle traffic in Australia. Due to the operational (acceleration/deceleration, manoeuvrability) and physical (length, size) characteristics of heavy vehicles, they impose negative impacts on surrounding traffic which include increased traffic congestion, traffic safety and environmental impacts such as increased vehicular emissions. Signal optimisation is examined to assess its validity as a tool in managing heavy vehicle movements. Signal coordination which is a form of optimisation can be simply explained as providing cascading green lights on a road to move a platoon of vehicles, without the need to stop at red lights. Signal coordination is known for reducing the number of vehicle stops, delay times, fuel consumption and vehicular emissions. However, those results focused on light vehicles. This research would mainly focus on signal coordination for heavy vehicles in an urban corridor and evaluating the influence of heavy vehicle signal coordination of traffic congestion. The road section that is used in this research is a section of Princes Highway in Melbourne, Australia. This section is 8.8 km long and 13 signalised intersections exist within that distance. This section is selected since it is one of the main corridors in Melbourne with high percentage of heavy vehicles. In addition, many traffic signals exist in the selected section of highway. Based on the results that were yielded in this study, it can be said that signal coordination can be considered as an effective freight management method; which provides reduced congestion rates at road sections with interrupted traffic flows.

Keywords: Heavy Vehicle; Signal Coordination; Congestion.

1. Introduction

Signal optimisation can be explained by altering signal design parameters in order to reduce the delay time at intersections. Signal coordination is considered a form of signal optimisation, where offsets of traffic signals are coordinated in one travel direction to provide cascading green lights for the drivers without stopping at a red light. Coordination methods can be divided in two ways, which are fixed and dynamic. A fixed coordination method would be comprised of pre-set offset times, while a dynamic method would rely on sensory data usually obtained from detectors to adjust the offset times based on the traffic flow. The major benefits of signal coordination are improving delay times, reducing congestion, controlling speeds of vehicles, reducing fuel consumption and vehicular emissions. The three main parameters of signal coordination are cycle time, green split and offset time. This research will mainly focus on signal coordination for heavy vehicles in an urban corridor and evaluating the influence of heavy vehicle signal coordination of traffic congestion. The reason for addressing heavy vehicles is because between the years 2009 and 2014, there has been an increase of approximately 15% in the number of registered heavy vehicles in Australia (Australian Bureau of Statistics, 2014).

This paper will examine relevant literature in the second section of the study and address the limitations which have been found. The third section will present the data set which has been used in this study along with a brief description of the study area. The fourth section will explain the model development in VISSIM and the application of signal coordination. The fifth section of the paper will present the results achieved from applying signal coordination under different heavy vehicle compositions. The sixth and final section of the study will provide the main findings of the study and future directions.

2. Literature Review

Jovanis and Gregor (1986) aimed in their study to compare pre-timed signal coordination and actuated signal coordination on an arterial road, without losing sight of the Level of Service (LOS) on side streets of the arterial. The 4-lane Pershing Road in Decatur, Illinois, United States of America was selected as the arterial where this study was conducted. However, only 2.1 km of the arterial formed the test area with 6 signalised intersections and 3 un-signalised intersections. Traffic data was acquired through a previous study. However, the midday peak traffic data indicated unsaturated traffic conditions, therefore all traffic flow volumes were increased by 50% leading to degrees of saturation which ranged between 0.76 and 0.41. Cycle lengths which ranged between 40 and 140 seconds were considered in the study, and an evaluation of each cycle length in relation to the side street LOS was performed in order to select the most suitable cycle times for both pre-timed and actuated control methods. The assessment indicated that an 80 s cycle time was the most efficient in terms of maintaining high LOS values for the side street. In addition, the 60 s cycle time was also adopted since it showed efficient LOS on side streets compared to the other cycle times. Therefore, the comparison was made between the pre-timed and actuated methods of signal control using two cycle times of 60 s and 80 s; whilst maintaining LOS of A, C and E on side streets. Arterial delay (sec/veh/signal), side street delay (sec/veh/signal) and system delay (sec/veh) were the performance measures used to compare the achieved results from each cycle time. The microsimulation software NETSIM was used to aid in traffic simulation and achieve the relevant delay times.

The results were attained for each of the simulations, and they indicated that actuated signals can reduce delay at signalised intersections. In the 60 s cycle time scenario, the best pre-timed result was achieved with a LOS of E on the side streets where 47 sec/trip was attained; while the best actuated result was 53 sec/trip with a LOS of E on the side streets. In the 80 s cycle time scenario, the best pre-timed result was 49 sec/trip with a LOS of E on the side streets; while the best actuated result was 57 sec/trip with a LOS of C on the side streets. Through the comparison analysis, it was found that a strong relation exists between the LOS on side streets and the pre-timed control method. In the 80 s scenario, a reduction of 63% was achieved when the LOS on the side streets was reduced from A to E. In addition, it was found that if a LOS of A was maintained on the side streets, the arterial road experienced increased delays when compared to LOS of C and E. It was concluded that the pre-timed control strategy proved more efficient in terms of system delay in this case study, when compared to an actuated control strategy; whilst maintaining LOS of C and E which provided the most efficient results.

Patel et al. (2011) aimed to improve delay on a quadrilateral network through the use of different phase sequencing and equal cycle time. In order to get the best signal coordination between signals in this study, an equal amount of cycle time was assigned to each of the signals. Then, the appropriate cycle times were determined by taking the average cycle time of all four traffic signals in the developed study area. However, it was noted by the authors that shorter cycle times should be assigned in the case of traffic signals being in close distance to one another in order to achieve better performance. Two other important factors were the equal phase timings and the phase sequence; both of which helped in minimising delay and attaining more efficient signal coordination in terms of delay time.

The results were attained after applying equal cycle times to all four signals in the developed study area and assigning different phase sequencing to the network. Considerable reductions in delay were noticed throughout the results (63% reduction in delay was the most notable). However, since the methodology was not based on actual traffic data and no microsimulation modelling was used; the results acclaimed did not incorporate various traffic characteristics which microsimulation software usually takes into consideration such as vehicle types, lane restrictions and several other factors which would impact delay time.

Chen et al. (2011) aimed in their study to optimise traffic signal performance on an arterial using Dynamic Speed guidance and Dynamic Signal timing (DSDS). The DSDS framework consisted of two modules which were the speed guidance module and the signal adjustment module. The system was put in place to provide a dynamic traffic signal performance based on the operational characteristics of the arterial road, through providing vehicle drivers with the appropriate speeds using variable message signs (VMS). The vehicle would arrive to the said intersection in the arterial and the signal adjustment module would compute the best decision which would be either splitting or prolonging the green phase. Afterwards, the speed guidance module would compute the best operational speed to maintain signal coordination and display the speed through the VMS. Figure 1 illustrates the DSDS framework.

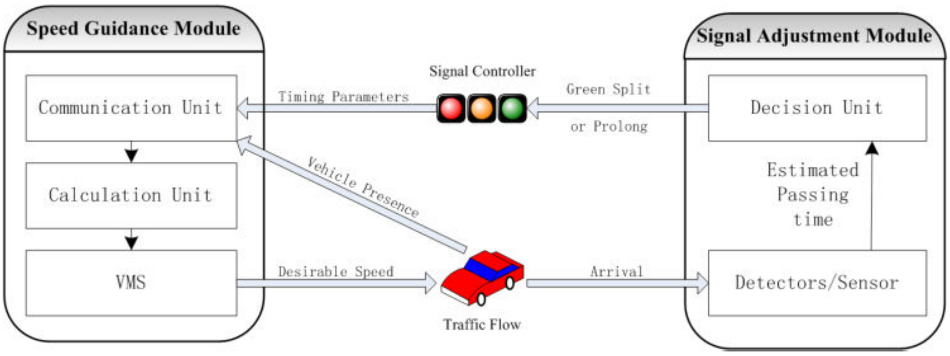

Figure 1: DSDS framework logical structure (Chen et al., 2011)

In order to test the DSDS, a section of Cao'an Highway in Shanghai was selected to apply the system; where 5 intersections were addressed in the highway's section. They used VISSIM to apply DSDS to the arterial corridor; where traffic characteristics such as traffic demand, traffic composition, desired speed, etc. where all incorporated and calibrated with field data.

A comparative analysis was performed to validate the level of improved efficiency based on the number of stops and the delay as measures of efficiency throughout 40 minutes of the study area. The comparative analysis addressed four scenarios which were the original scenario which consisted of a non-coordinated signal approach, the coordinated signal approach, a dynamic speed and fixed signal (DSFS) system and finally the DSDS. The results indicated that the DSDS achieved the most efficient results compared to the other three scenarios; and that could be justified by the strategy's efficient use of green time. However, the strategy has achieved the most efficient results based on the VISSIM simulation and was not applied to the field. Since the system mainly depends on the drivers adhering to the VMS speeds, driver acceptance of the system could alter the achieved results.

Kelly (2012) aimed in the study to compare between the uses of a normal setup for signals (no signal coordination) against signal coordination, and evaluated the effects from both setups. The traffic data in the study was from the city of Manchester in the UK; specifically the busy suburb of 'Chorlton-cum-Hardy'. Using the software S-Paramics, the traffic data was applied and a model was built in addition to an origin/destination matrix representing hourly flows for a 24 hour period. A number of 18 intersections were incorporated in the model of the Manchester suburb, and the model was applied to the time period (10PM-7AM).

The results achieved when comparing signal coordination to a regular setup showed greater efficiency in the network in terms of pollutants emitted by vehicles; but most importantly a reduction in delay time over the entire network was reduced by 35.2%. Another important result was that intersecting signally coordinated roads was possible in this study. Perhaps the attained results would encourage the use of signal coordination to improve the level of efficiency on a transportation network, however the model that was built was not based on the morning period where traffic volumes are much larger than the night period; therefore the delay time reduction achieved in the night period would most probably decrease if applied to the morning period traffic.

Zhou and Cai (2014) introduced a genetic algorithm approach to optimising the performance of a single intersection along with two microsimulation software programs which were PARAMICS and Comprehensive Modal Emissions Model (CMEM). The CMEM software was used in order to model the estimated emissions and fuel consumption at the intersection, while PARAMICS was used to evaluate the intersection's performance in terms of delay. Zhou et al. was able to incorporate the CMEM model into PARAMICS by writing a PARAMICS plug in program of the CMEM model and calling it during the traffic simulation process in order to measure the emissions and fuel consumption at the intersection. The optimisation was implemented in order to satisfy three categories which were: vehicle emissions and fuel consumption, the economic evaluation of the intersection and finally the genetic algorithm which minimises vehicle emissions, fuel consumption and delay time.

To implement the genetic algorithm optimisation, the four leg JiangNanXi-BaoGang intersection in Haishu District, Guangzhou, China was selected. Green time was set to a range between 10s and 70s, while a 3s all red interval was allocated to the model simulation; however, no amber time was allocated in the model which contributes as a weakness to the model simulation since amber time should always be allocated due to intersection safety reasons. After numerous runs of the model, an optimal timing plan was attained at the intersection. In order to evaluate the validity of the results, Zhou et al. compared the obtained results with the Webster model, which minimises the delay time in order to calculate the timing scheme. The proposed model showed a 9.27% reduction in comprehensive economic cost compared to the Webster model, which included emissions, fuel consumption and delay time. The Webster model only showed better performance regarding delay time in one of the four phases in the sequence, therefore the proposed model provided a better performance regarding overall delay time which approximately reduced the overall delay time of the intersection by 15%; however not having allocated an amber time to the model would have affected the results attained from the proposed model since the amber phase must be implemented at all intersections in order to ensure the safety of the intersection.

3. Data Set & Study Area

VicRoads which is the roads and traffic authority in Victoria, Australia supplied the data required for this research. Traffic volumes were supplies by VicRoads along with turning movements for the morning peak period along the study's road segment. In addition, as 13 signalized intersections exist within the study area; VicRoads also supplied the signal design and phasing diagrams for each of the intersections. One aspect was missing from the data, and rather an important one which was vehicle composition. Due to that data not being available, a traffic count was required in order for the research to continue. A morning field visit was performed to the study area and manual counts were recorded of the number of different heavy vehicles in the peak period. The number of heavy vehicles recorded on that day was applied to the total traffic volumes and turning movements supplied by VicRoads in order to determine the vehicle composition. Table 1 presents the detailed vehicle composition values of the morning peak period.

Table 1. Morning Peak Period Vehicle Composition.

Vehicle	Percentage
Passenger Car	94.87
Rigid Vehicle	4.40
Heavy Combination Vehicle	0.70
Multi Combination Vehicle	0.03

The road section that is used in this research is a section of Princes Highway in Melbourne, Australia. This section is 8.8 km long and 13 signalized intersections exist within that distance. This section is selected since it is one of the main corridors in Melbourne with high percentage of heavy vehicles. In addition, many traffic signals exist in the selected section of highway which forms interrupted traffic flows.

4. Model Development

4.1. VISSIM

VISSIM is a microscopic simulation software package which can be used to simulate more than just one type of traffic. Different vehicles and modes of transport can be incorporated within the model such as light vehicles, heavy vehicles, public transport, bicycles, etc. Various outputs can be generated from the simulation which varies between traffic engineering, urban planning and 3d visualization. Signal timing and intersection design are also features which can be employed within the software. In addition, VISSIM's capabilities of analysing traffic characteristics and driving behaviour in both interrupted and uninterrupted traffic flows are considered crucial.

4.2. Corridor Modelling and Validation

Using the data supplied by VicRoads and the vehicle composition data, a preliminary VISSIM model was constructed. In order to test the validity of the model; traffic performance measure results of the model were compared with observed results. The observed results were supplied by VicRoads. In this study, the traffic performance measures were average travel times and average speeds along Princes Highway. Table 2 shows the comparison between the model's results and observed results in terms of average travel time.

Table 2. Comparison of Average Travel Time between Model's Results and Observed Results (sec).

Link	Model (sec)	Observed (sec)	Discrepancy (%)
Blackburn/McNaughton	52.14	54.00	3.44
McNaughton/Westall	31.78	31.00	2.45
Westall/Centre	125.79	122.00	3.01
Centre/Police	9.40	9.00	4.25
Police/Smith	66.25	69.00	3.99
Smith/Corrigan	50.34	49.00	2.66
Corrigan/Browns	66.37	69.00	3.81
Browns/Dunblane	24.24	25.00	3.04
Dunblane/Elonera	62.34	61.00	2.15
Elonera/Heatherton	72.10	74.00	2.57
Heatherton/Gladstone	65.05	68.00	4.34

VicRoads also supplied the observed average speed values between intersections along the study area. Table 3 shows the comparison between the model's results and observed results in terms of average speed.

Table 3. Comparison of Average Speed between Model's Results and Observed Results (km/hr).

Link	Model (km/hr)	Observed (km/hr)	Discrepancy (%)
Blackburn/McNaughton	26.44	25.56	3.33%
McNaughton/Westall	30.41	31.17	2.44%
Westall/Centre	46.22	47.65	3.00%
Centre/Police	49.85	52.06	4.25%
Police/Smith	66.74	64.18	3.84%
Smith/Corrigan	64.20	65.95	2.65%
Corrigan/Browns	50.61	48.75	3.68%
Browns/Dunblane	60.51	62.41	3.04%
Dunblane/Elonera	46.44	47.46	2.15%
Elonera/Heatherton	55.51	54.12	2.50%
Heatherton/Gladstone	52.85	50.65	4.16%

A discrepancy of less than 5% in terms of both performance measures was set as the target in this research. As the results show that the target was met for both average travel time and average speed; the model was deemed to be validated and therefore restriction strategies could be applied.

5. Signal Coordination

Implementing signal coordination in the study area was done through the signal programming feature provided by VISSIM. Signal coordination was implemented to serve vehicles moving towards the Melbourne CBD. As the model was evaluated during the morning peak period, it was deemed more efficient to implement signal coordination between 07:00 AM and 08:00 AM, because traffic volumes travelling to the Melbourne CBD are higher.

Initially, all signal controllers in the network are performing with no offset values; which can be described as an uncoordinated scenario. Starting from the observed vehicle composition, offset values are assigned to the traffic signals. The first traffic signal is assigned an offset value of 0, as it was considered the starting point of the model. The following 12 traffic signals leading to the Melbourne CBD are assigned offset values based on the distance between each traffic signal, which are referred to as preliminary offset values in this study. The preliminary offset values take into consideration two main inputs, which are speed and distance. The design speed in the model is set at 80 km/hr, while the distance between each traffic signal varies. Utilising speed and distance values, the preliminary offset values are calculated between each traffic signal.

Firstly, the model is run under the preliminary offset values. After analysing the vehicles movement characteristics (acceleration/deceleration) in the network, it is apparent that vehicles are not passing through the green waves provided by signal coordination. The reason for that is because preliminary offset values are based on a travelling speed of 80km/hr; however, due to the model being run in the congested morning peak period, vehicles are travelling at lower speeds. The offset values are adjusted by either slightly increasing or decreasing the offset values to adapt to the lower speeds in the corridor. Those adjustments are necessary in order to ensure that signal coordination was allowing the maximum number of vehicles to pass through the green waves produced by signal coordination.

The heavy vehicle composition was increased in this study in order to test the efficiency of signal coordination under high heavy vehicle compositions. The heavy vehicle composition was increased at 10% increments starting from the observed vehicle composition reaching up to a 30% heavy vehicle composition. The increases were done based whilst maintaining each vehicle type ratio found in Table 1.

For each of the four heavy vehicle composition scenarios, three signal coordination setups are implemented with each setup being assessed based on three traffic measurements including average speed, average travel time and average delay time. Firstly, a signal coordination setup which targets enhancing the aforementioned traffic measurements for passenger cars. Secondly, a signal coordination setup which targets enhancing the aforementioned traffic measurements of heavy vehicles. Finally, a signal coordination setup which provided a balance between the two vehicle types which is referred to in this study as the optimal signal coordination. The reason for going through the aforementioned process, was to ensure that the most efficient result on a network level is achieved and that no vehicle type is favoured over the other. A summary of the three setups is provided for each heavy vehicle composition scenario. The optimal signal coordination setup is the only setup which will be discussed in detail in this research. It was considered unnecessary and redundant to present the detailed findings of the passenger car and heavy vehicle oriented signal coordination setups.

5.1. Observed Vehicle Composition Results

5.1.1. Passenger Car Oriented Signal Coordination

Figure 2 presents the results achieved by signal coordination when targeting passenger cars as the main vehicle type to benefit from the signal set up. As presented in the figure, it is apparent that passenger cars have achieved more efficient results in terms of all three performance measures when compared to heavy vehicles. Passenger cars experienced more than 12% increase in average speed, while average travel and delay times are reduced more than 16% and 20% respectively. Looking at the results on a network level, average speed increased by 12.58%, while average travel and delay times are reduced 16.13% and 20.01%, respectively.

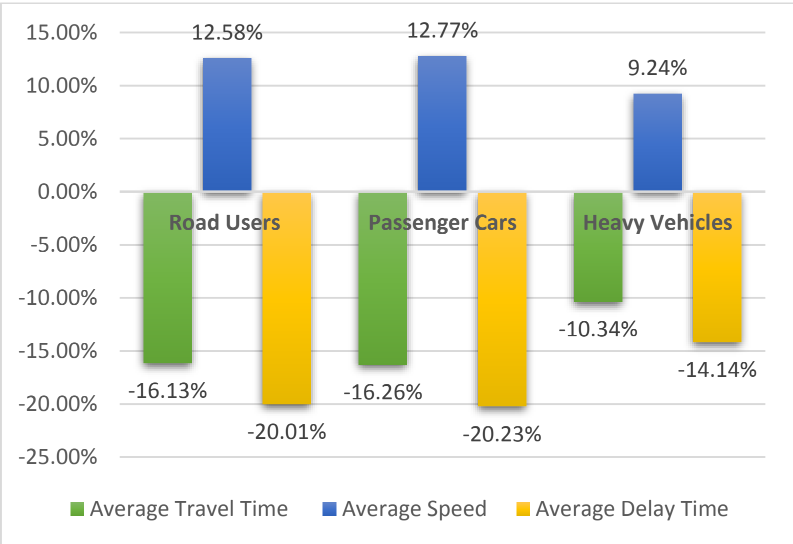

Figure 2: Traffic Performance of Passenger Cars, Heavy Vehicles and the Whole Network (Passenger Car Oriented Signal Coordination)

5.1.2. Heavy Vehicle Oriented Signal Coordination

Comparing the results achieved by heavy vehicles in Figure 3 to Figure 2, it can be said that heavy vehicles have performed more efficiently. This particular signal set up targeted heavy vehicles, therefore more efficient results are achieved by heavy vehicles in terms of the performance measures. Passenger cars suffered very slightly under this set up. Average speed slightly decreased under this set up when compared to Figure 2. Average travel time and delay time also slightly increased under this signal set up. However, the differences are very small that they can be considered negligible.

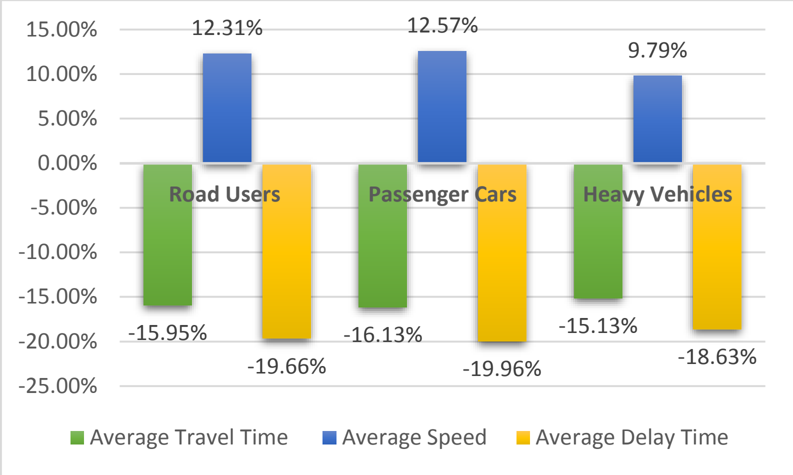

Figure 3: Traffic Performance of Passenger Cars, Heavy Vehicles and the Whole Network (Heavy Vehicle Oriented Signal Coordination)

5.1.3. Optimal Signal Coordination

The most efficient results are achieved under this signal coordination set up. Both passenger cars and heavy vehicles achieved more efficient results as it is seen from Figure 4. Comparing the network average results under this signal program yields more efficient results compared to the previous two signal programs. Therefore, this particular signal program is selected as the optimal signal set up under the observed vehicle composition. The detailed traffic measurement results for different vehicle types are presented in Figure 5.

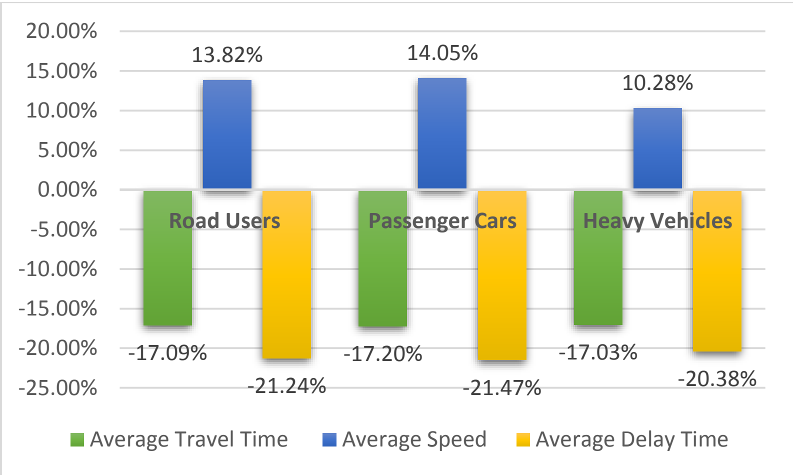

Figure 4: Traffic Performance of Passenger Cars, Heavy Vehicles and the Whole Network (Optimal Signal Coordination)

Analysing the results achieved from the optimal signal coordination set up from Figure 5 shows that almost all types of vehicles benefit from signal coordination. Heavy combination vehicles experienced a slight decrease in average speed of 0.58% throughout the network. Despite the minimal decrease in speed which can be considered as negligible, heavy combination vehicles still experienced lesser average travel and delay times. All other vehicle types experienced positive results in terms of the three performance measures. Consequently, the average network results are positive as the average speed throughout the network increased over 13%. While average travel time and delay time are reduced by more than 17% and 21%, respectively. Under the observed vehicle composition, almost all vehicle types experienced roughly similar positive results; except for heavy combination vehicles.

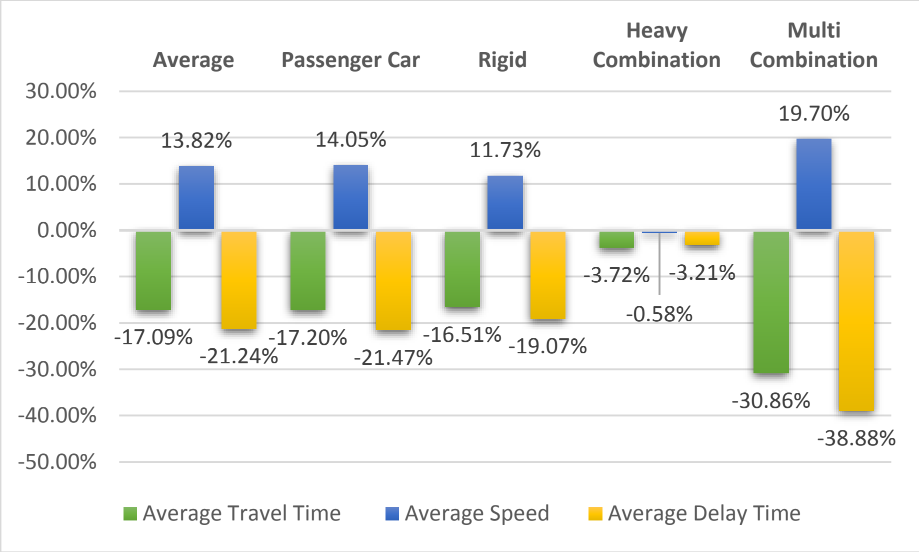

Figure 5: Optimal Signal Coordination Results on Traffic Performance Measures by Vehicle Type

5.2. 10% Heavy Vehicle Composition Results

5.2.1. Passenger Car Oriented Signal Coordination

Utilising the passenger car oriented signal coordination passenger cars achieved more efficient results in terms of the three performance measures when compared to heavy vehicles. The conclusion can be drawn from Figure 6. Passenger cars experienced an increase of over 16% in terms of average speed; while experiencing a reduction in terms of average travel and delay times of 18.86% and 22.50% respectively. In regards to the traffic network as a whole, average speed increased more than 15%, while average travel and delay times are reduced by more than 18% and 21%, respectively.

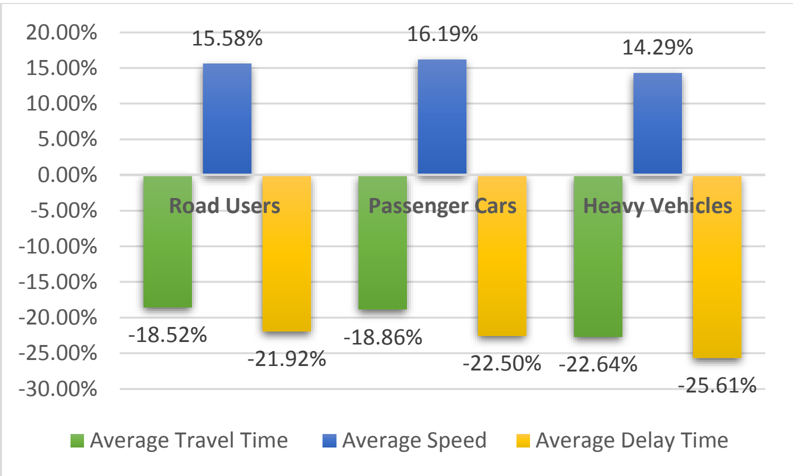

Figure 6: Traffic Performance of Passenger Cars, Heavy Vehicles and the Whole Network (Passenger Car Oriented Signal Coordination)

5.2.2. Heavy Vehicle Oriented Signal Coordination

Under the heavy vehicle oriented signal coordination set up, heavy vehicles performed more efficiently when compared to their performance in the previous set up in Figure 6. Figure 7 illustrates that heavy vehicles have even achieved more efficient results in terms of average delay time when compared passenger cars. Heavy vehicles experienced a reduction of 24.59% in average delay time, while passenger cars experienced a reduction of 24.30%. Passenger cars achieved more efficient results in terms of average speed and average delay time. However, they are very small differences when comparing the results. On a network level, average speed increased just over 17%, while average travel and delay times are reduced more than 19% and 23%, respectively.

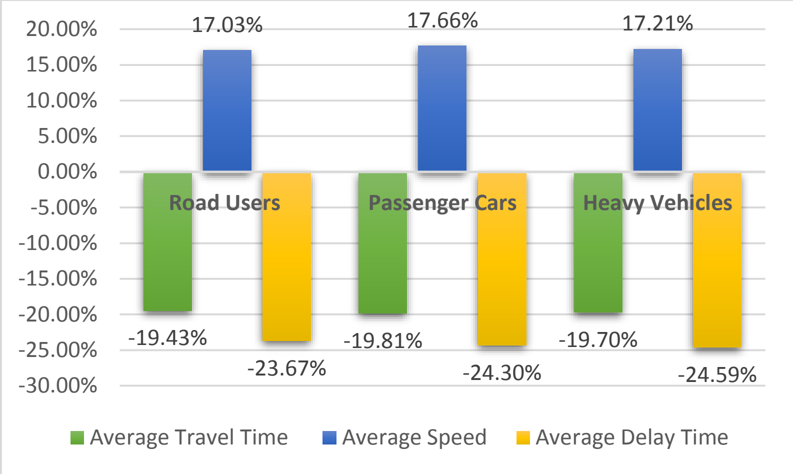

Figure 7: Traffic Performance of Passenger Cars, Heavy Vehicles and the Whole Network (Heavy Vehicle Oriented Signal Coordination)

5.2.3. Optimal Signal Coordination

Figure 8 illustrates the results yielded from applying the optimal signal coordination set up. Results on a network level show that this particular set up was the most efficient when compared to the previous two set ups. Average speed was increased 17.18%, while average travel and delay times are reduced 19.90% and 23.77%, respectively. In terms of performance based on the vehicle type, passenger cars have experienced more positive results under this set up when compared to the results achieved in Figure 6. However, heavy vehicles experienced slightly reduced results when compared to the results achieved in Figure 7. Despite the minimal decrease in the traffic performance of heavy vehicles, this set up has yielded the most efficient results on a network level. The detailed traffic measurement results for different vehicle types are presented in Figure 9.

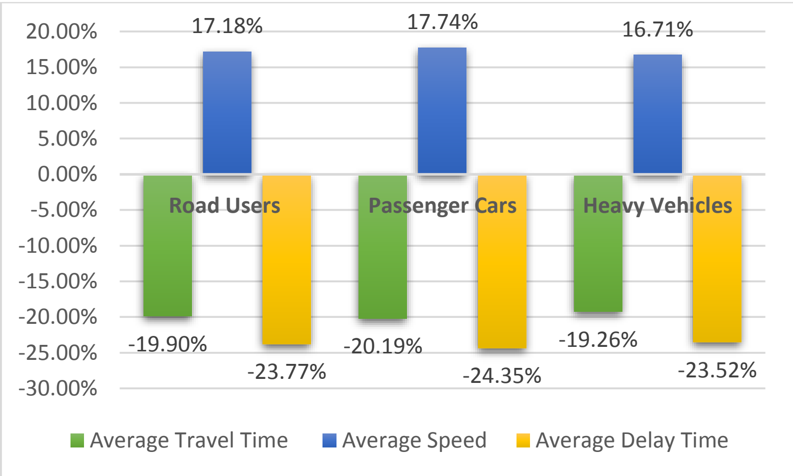

Figure 8: Traffic Performance of Passenger Cars, Heavy Vehicles and the Whole Network (Optimal Signal Coordination)

One of the main changes which occurred when increasing the heavy vehicle composition was the positive impact that signal coordination had on the heavy combination vehicles. As opposed to the minimalistic results which heavy combination vehicles yielded under the observed vehicle composition; the vehicle type yielded much more efficient results under the 10% heavy vehicle composition. Heavy combination vehicles experienced an increase of 5.85% in terms of average speed. In addition, a reduction of 20.42% and 19.53% was experienced by heavy combination vehicles in terms of average travel and delay times respectively. All other vehicle types experienced positive results as well which accumulated to an increase of more than 17% in terms of average speed throughout the network. While also reducing average travel and delay times by more than 19% and 23%, respectively on a network level.

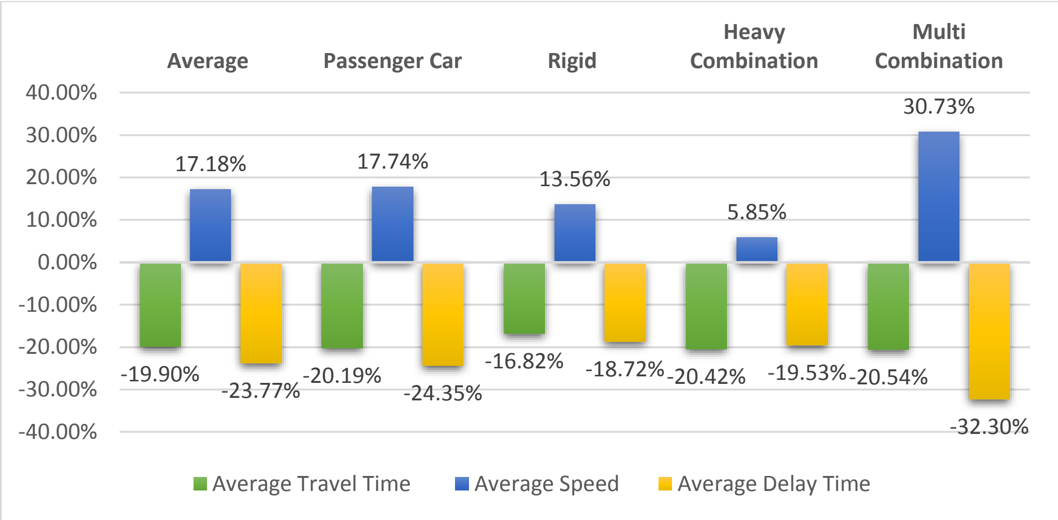

Figure 9: Optimal Signal Coordination Results on Traffic Performance Measures by Vehicle Type

5.3. 20% Heavy Vehicle Composition Results

5.3.1. Passenger Car Oriented Signal Coordination

Under a high heavy vehicle composition of 20%, passenger cars have yielded lower results compared to heavy vehicles as it is illustrated in Figure 10. Despite the fact the heavy vehicles outperformed passenger cars; this set up was the one which passenger cars yielded the most efficient results. Passenger cars experienced an increase of 17.66% in average speed, which reduced average travel and delay times by 19.62% and 23.66% respectively. Heavy vehicles experienced an increase of 19.26% in average speed, which reduced average travel and delay times 25.06% and 25.49% respectively. On a network level, average speed was increased approximately 17%; while average travel and delay times are reduced more than 19% and 22%, respectively.

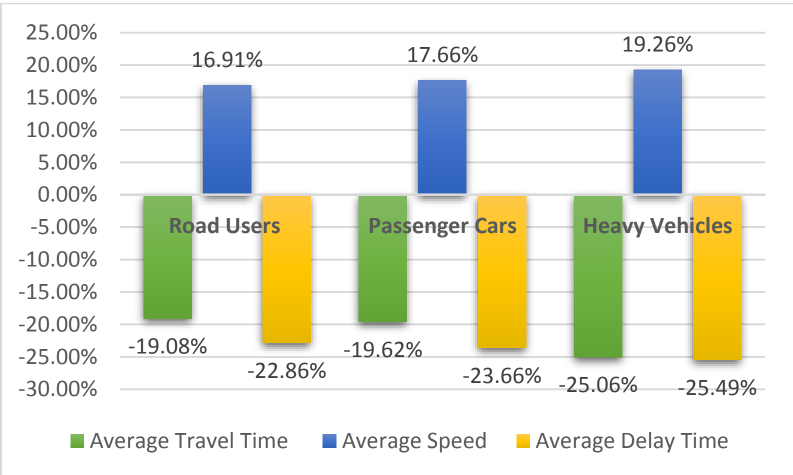

Figure 10: Traffic Performance of Passenger Cars, Heavy Vehicles and the Whole Network (Passenger Car Oriented Signal Coordination)

5.3.2. Heavy Vehicle Oriented Signal Coordination

Figure 11 illustrates that heavy vehicles have outperformed passenger cars in each of the traffic performance measures. Applying the heavy vehicle oriented signal coordination lead to an increase of 21.79% in terms of average speed for heavy vehicles. Furthermore, heavy vehicles experienced a reduction in average travel and delay times of 25.67% and 27.32% respectively. Average speed has increased 16.83% for passenger cars, while average travel and delay times are reduced 19.48% and 23.16% respectively. On a network level, average speed was increased more than 16%. Average travel and delay times are reduced more than 18% and 22%, respectively.

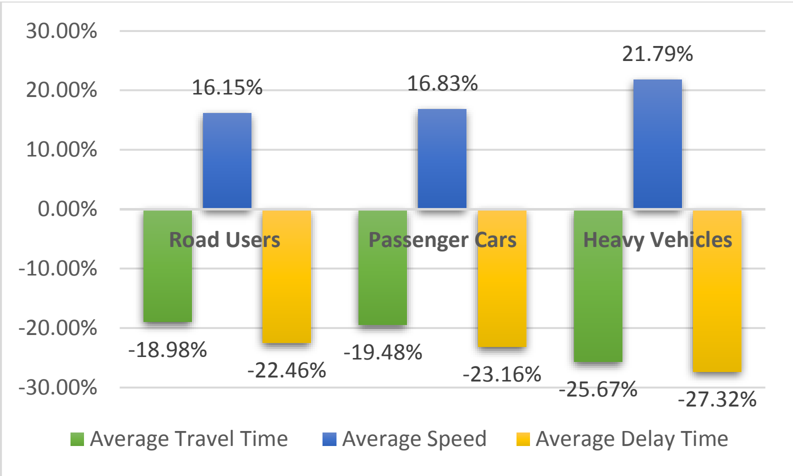

Figure 11: Traffic Performance of Passenger Cars, Heavy Vehicles and the Whole Network (Heavy Vehicle Oriented Signal Coordination)

5.3.3. Optimal Signal Coordination

Utilising the optimal signal coordination set up yielded the most efficient results on a network level. Figure 12 illustrates that on a network level, average speed was increased 21.13%; while average travel and delay times are reduced 21.73% and 26.13% respectively. In terms of individual vehicle type results; both passenger cars and heavy vehicles have outperformed the results yielded in their respective oriented signal coordination set up. Passenger cars experienced an increase of 21.85% in terms of average speed, which lead to a reduction of 22.21% and 26.81% in average travel and delay times. Average speed has increased 25.27% in heavy vehicles, with average travel and delay times being reduced by 29.27% and 31.03% respectively.

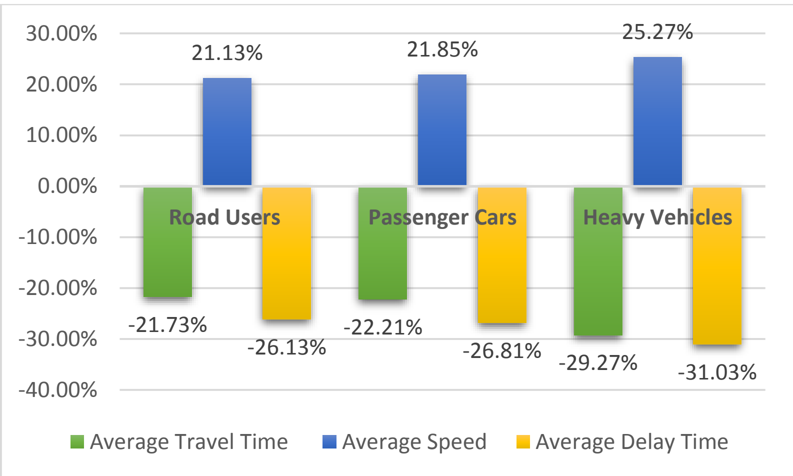

Figure 12: Traffic Performance of Passenger Cars, Heavy Vehicles and the Whole Network (Optimal Signal Coordination)

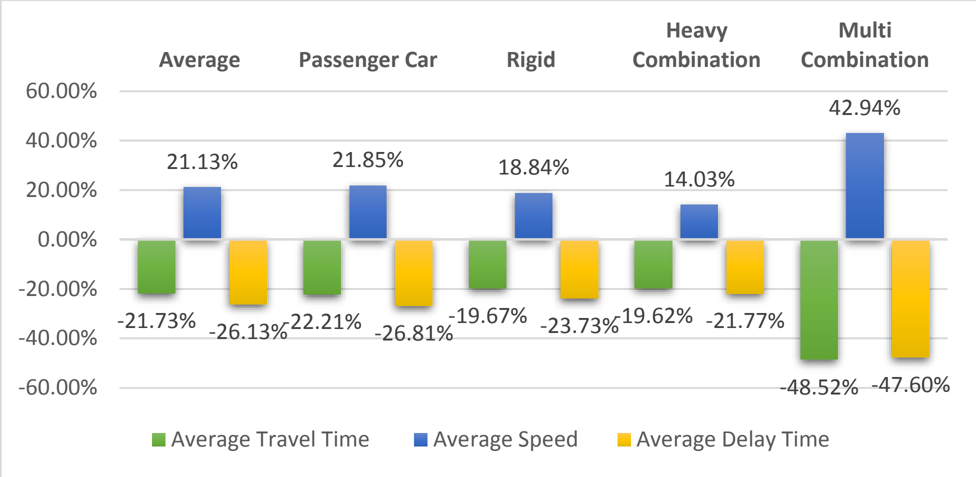

Figure 13: Optimal Signal Coordination Results on Traffic Performance Measures by Vehicle Type

Taking a look at the detailed results Figure 13, it is apparent that all vehicle types have yielded positive results in terms of the traffic performance measures. Rigid vehicles average speed increased 18.84%, with average travel and delay times reduced 19.67% and 23.73%. Heavy combination vehicles experienced an increase in average speed of 14.03%, and a reduction of 19.62% and 21.77% in terms of average travel and delay times respectively. Multi combination vehicles yet again was the vehicle type to most benefit from signal coordination. Average speed was increased 42.94%, leading to a reduction of 48.52% and 47.60% in average travel and delay times respectively. It is apparent from the results so far that with increasing the heavy vehicle composition, the positive impacts from applying signal coordination also increases.

5.4 30% Heavy Vehicle Composition Results

5.4.1. Passenger Car Oriented Signal Coordination

Figure 14 illustrates the results yielded from applying the passenger car oriented signal coordination set up under a heavy vehicle composition of 30%. It is apparent from the figure that passenger cars have yielded more efficient results when compared to the results of heavy vehicles. In terms of average speed, passenger cars experienced an increase of 29.96%; while heavy vehicles experienced an increase of 25.87%. In terms of average travel time, passenger cars have experienced a reduction of 27.43%; while heavy vehicles experienced a reduction of 23.45%. Finally, in terms of average delay time; passenger cars experienced a reduction of 31.08% while heavy vehicles experienced a reduction of 25.12%. On a network level, average speed has increased more than 28%; leading to a reduction in average travel and delay times of more than 26% and 29%, respectively.

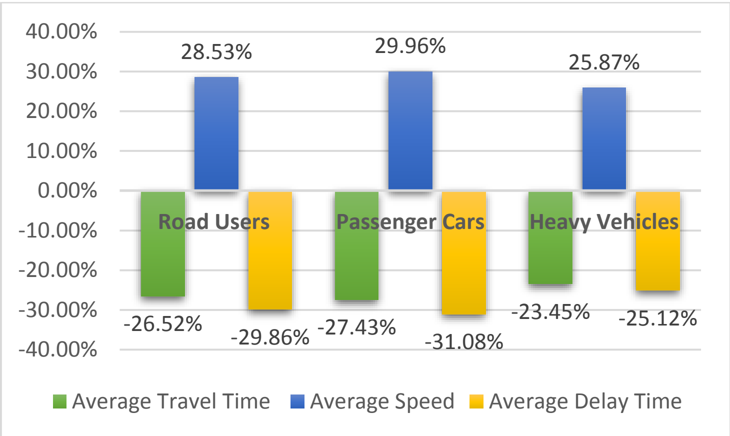

Figure 14: Traffic Performance of Passenger Cars, Heavy Vehicles and the Whole Network (Passenger Car Oriented Signal Coordination)

5.4.2. Heavy Vehicle Oriented Signal Coordination

Comparing the results yielded in Figure 15 to Figure 14, it is apparent that heavy vehicles heave performed more efficiently under the heavy vehicle oriented signal coordination. Despite the improved results by heavy vehicles, passenger cars still outperformed heavy vehicles again under this set up. Passenger cars have yielded a 31.54% increase in average speed, while heavy vehicles yielded an increase of 29.20%. In terms of average travel and delay times, passenger cars experienced a reduction of 28.20% and 32.14% respectively. Heavy vehicles on the other hand experienced a reduction 25.71% and 27.32% in terms of average travel and delay times respectively. Looking at the network as a whole, average speed has increased more than 30%. Average travel and delay times are reduced more than 27% and 31%, respectively.

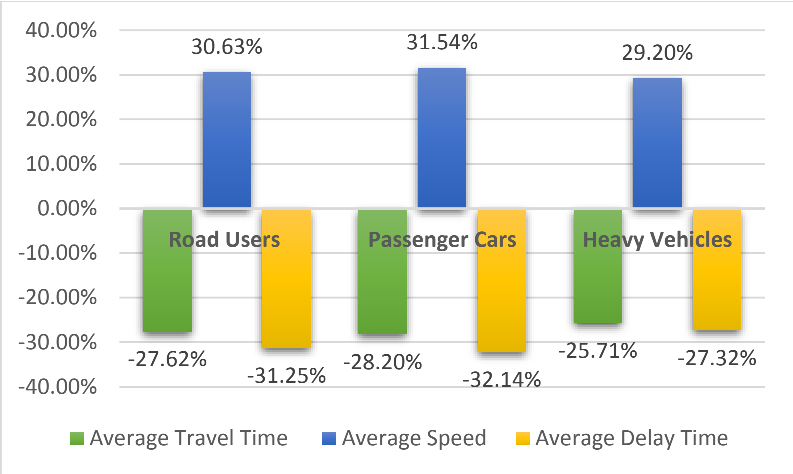

Figure 15: Traffic Performance of Passenger Cars, Heavy Vehicles and the Whole Network (Heavy Vehicle Oriented Signal Coordination)

5.4.3. Optimal Signal Coordination

The optimal signal coordination setup depicted in Figure 16 has yielded the most efficient results on a network level. The results are marginally higher when compared to the network results yielded under the heavy vehicle oriented signal coordination set up in Figure 15. On a network level, average speed has increased more than 30%; leading to a reduction in average travel and delay times of more than 27% and 31%, respectively. Both passenger cars and heavy vehicles have also performed more efficiently when compared to the previous signal coordination set ups. Passenger cars experienced an increase of 31.95% in average speed, while heavy vehicles experienced an increase of 29.53%. In terms of average travel and delay times, passenger cars experienced a reduction of 28.82% and 33.20% respectively. In heavy vehicles, the reduction was 27.04% and 29.68%, respectively for travel and delay times.

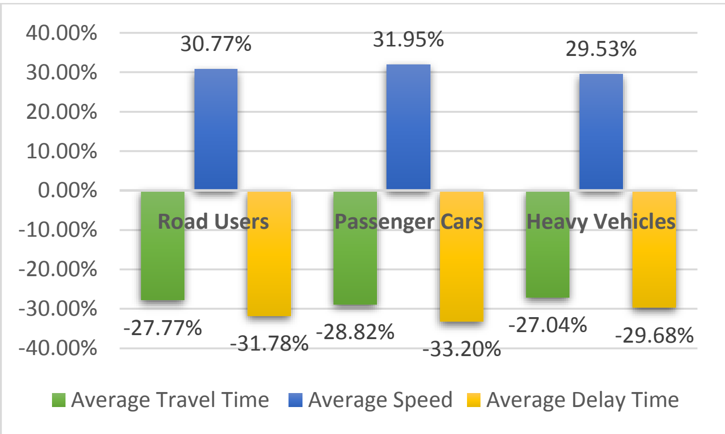

Figure 16: Traffic Performance of Passenger Cars, Heavy Vehicles and the Whole Network (Optimal Signal Coordination)

The effect of applying the optimal signal coordination has reflected positively on all vehicle types as it is shown in Figure 17. The results of passenger cars and the network as a whole have been previously explained. Rigid vehicles experienced an increase in average speed of 28.52%. Average speed was also increased in heavy combination and multi combination vehicles 26.11% and 33.95% respectively. In terms of average travel time, rigid vehicles experienced a reduction of 25.43%. While the reduction in heavy and multi combination vehicles was 25.03% and 30.64% respectively. In terms of average delay time regarding rigid vehicles, the reduction was 28.73%. Heavy and multi combination vehicles experienced a reduction in average delay time of 28.28% and 32.02% respectively.

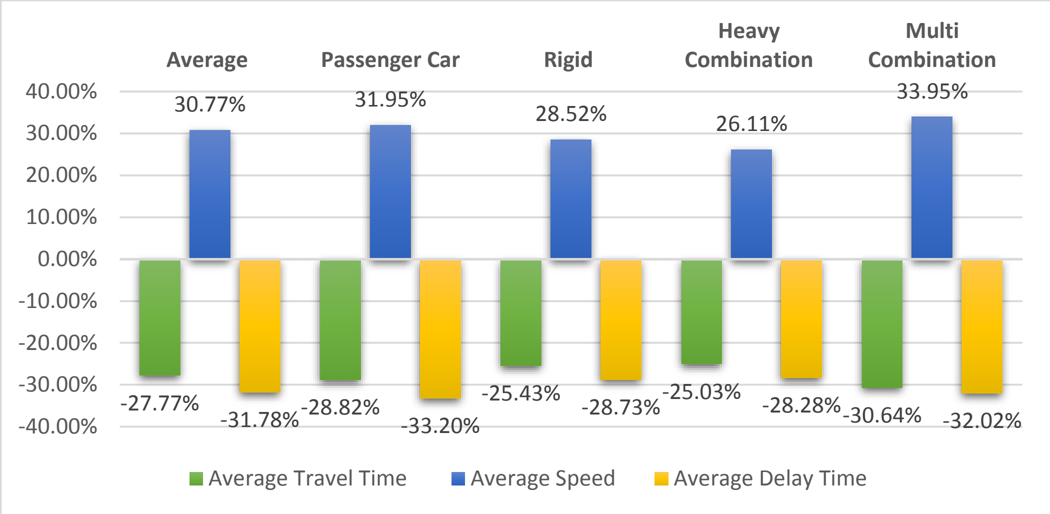

Figure 17: Optimal Signal Coordination Results on Traffic Performance Measures by Vehicle Type

6. Conclusions

Signal coordination was evaluated in VISSIM as a method to reduce congestion on a road section with interrupted traffic flows. In addition, the VISSIM model was run six times with different heavy vehicle compositions. Based on the results that are yielded from the model, it is apparent that signal coordination can be considered as an effective management method for roads with high heavy vehicle compositions. However, it is vital to highlight that with every heavy vehicle composition increase; the signal coordination setup was adjusted through varying the offset values in order to adapt to the increases in heavy vehicle compositions.

The following list summarises the main conclusions drawn from applying signal coordination to the morning peak period:

- The positive impacts of signal coordination increased with every 5% increase in heavy vehicle composition. This result indicates that signal coordination can be used as a freight management method which provides reduced congestions on arterial roads with interrupted traffic flows.
- Signal coordination has provided all types of vehicles used in this research with positive results. A conclusion which was drawn based on the detailed results provided in the chapter. A result which shows that signal coordination can be used to enhance the efficiency levels of the entire traffic network, instead of focusing on a specific type of vehicle.

Finally, a conclusion can be drawn about the validity of signal coordination as an efficient freight management method. Based on the results yielded in this research, it is apparent that signal coordination has positive impacts on all three performance measures used in the study. Therefore, signal coordination can be considered as an effective freight management method; which provides reduced congestion rates at road sections with interrupted traffic flows.

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