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Leveraging AI in Traffic Engineering to Enhance Bicycle Mobility in Urban Areas

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Abstract: More With the rise of AI-driven technologies, urban cycling is becoming more accessible and appealing to many due to benefits such as health improvement and cost efficiency. Governments worldwide are promoting cycling as a sustainable transportation option to address environmental challenges. Ensuring seamless bicycle mobility in cities is essential to incentivize cycling. AI-powered Traffic Engineering can significantly enhance the flow of bicycle traffic in urban areas by optimizing infrastructure and safety. This article explores the benefits of cycling and the rationale for investing in AI-integrated cycling infrastructure. It provides examples of smart solutions such as AI-based vehicle-cycle segregation (including London's Cycle Superhighways), protected intersections enhanced by machine learning algorithms, and Intelligent Transport Systems (ITS) that incorporate AI for dynamic traffic management. Their implementation and impact on cyclists and overall traffic flow are analyzed, demonstrating that these advanced systems reduce accidents, boost road efficiency, and make cycling more enjoyable. Quantitative data on these improvements is also presented. In conclusion, AI-enabled Traffic Engineering solutions play a vital role in enhancing bicycle mobility and safety in urban environments.

Keywords: AI-Driven Traffic Engineering, Urban Bicycle Mobility, Intelligent Transport Systems.

Disciplines: Artificial Intelligence. **Subjects:** Traffic Engineering.

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1 INTRODUCTION

Bicycle is commonly regarded as a good mean of transport because it offers many benefits to the entire society. Unlike motor-powered vehicles, bicycle is much more environmental friendly, such as public transport (e.g., [11], [4]), freight trucks (e.g., [12], [5]), passenger vehicles, aviation and railway (e..g, [10]). Firstly, according to [3], Cyclists are generally healthier, and they have a smaller number of sick leaves. Cycling could improve the physical condition of cyclists, which could save $128 health care cost per person per year (as a median value) [9]. Secondly, it is a greener mean of transport. On the one hand, cycling does not produce any emission. On the other hand, if more people opt to cycle, the traffic congestion on motorways would be alleviated, hence the emission is reduced. The monetized benefit of cycling in the European Union is summarized in Table 1. Moreover, The EU has set air quality standards for different pollutant, many of which come from the emission of diesel engines. Using bicycles could protect the environment and reduce the possibility of being fined.

Benefit	Estimated Value (billion euros)
CO2 emissions savings	0.6 – 5.6
Reduction of air pollution	0.435
Reduction of noise pollution	0.3
Fuel savings	4.0
Longer and healthier lives	73
Less sickness absence at the workplace	5
Bicycle market	13,2
Cycle tourism	44
Easing of road congestion	6,8
Saving on construction and maintenance costs for road infrastructure for motorised vehicles	2,9
Total annual benefits	150 - 155 bn euros

TABLE 1 MONETIZED SAVINGS IN THE EU DUE TO CYCLING (ECF)

Because of the benefits cycling offers, the governments around the world incentivise the use of bicycles and there is expected be an increase in demand for cycling in the future. Enhance the cycling mobility is particularly important to fulfil the future demand. This can be achieved by appropriate design of cyclist infrastructure and other traffic engineering works. According to [12], there is a hierarchy of cyclists' need as shown in Figure 1. Cyclist infrastructure design has to consider these factors, especially speed and safety. This article will use several case studies to explain how traffic engineering measurement could increase the efficiency of the cycling network, how is safety achieved and how they

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contribute to other factors.

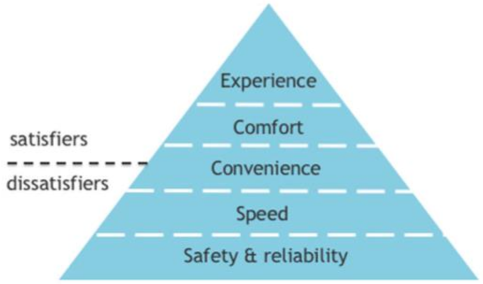

FIGURE 1 HIERARCHY OF CYCLISTS' NEED

2 SAFETY AND RELIABILITY

Although cycling has many advantages, it is not a safe transport mode. In 2016, there were 2015 cyclists killed in the EU countries, accounting for 8% of the total road fatalities. This share percentage is increasing year by year. It was only 6% in 2008 [8]. In the UK, cycling only accounts for 2% of the transport mode share, but it contributes to 8% casualties in 2018. The European Commission published a statistic in 2018, investigating the accident causations between 2005 and 2008 with the data of 1006 accidents in the EU as shown in Figure 2.1.

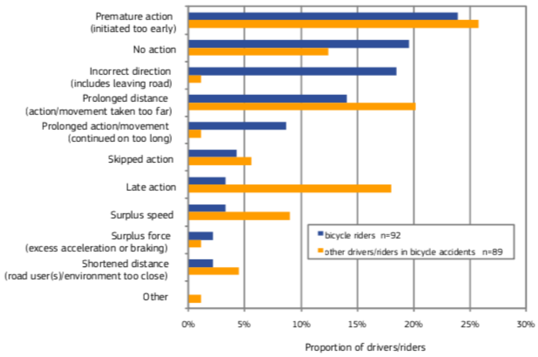

FIGURE 2.1 REASONS OF ROAD CASUALTIES

Some of the casualties are due to personal reasons, some other casualties can be avoided by better traffic engineering measurements. For example, strategies could be adopted to make manoeuvre safer. They will be mentioned later in this report.

One of the main reasons commuters opt not to cycle is that they have a perception that the road is unsafe. According to [1], 61% of interviewees perceive cycling as dangerous. Therefore, the road should not only be safe to cyclist, but should also be perceived to be safe [3].

2.1 CASE STUDIES – SEGREGATION

Segregation is a type of road design to separate the stream of cyclists from vehicles as shown in Figure 2.2. This type of design is widely controversial but commonly seen. It is commonly used because, firstly, people could perceive a sense of security when isolated from vehicles, the comfort level will improve by 2.62 times [11]. This increases the attractiveness of the cyclist lane. Secondly, the road is actually safer according to [6]. According to his research, there is a relationship between the collision rate and the variation from the mean speed. He concluded that the accident rate will increase either if the speed of a vehicle is smaller or if it is greater than the average speed of vehicles. The average speed of male cyclists and female cyclists are 15.9 and 12.32 mph respectively [2]. Whereas the vehicle travelling speed in urban area is 25.4 mph [10]. The speed gap could possibly result in a high accident rate in non-segregated road. Segregation design could reduce of the interaction of cyclists with vehicles, hence minimize the effect of speed gap. Road safety study has confirmed the conclusion. Research shows that in Denmark, segregated cyclist lanes could reduce fatality by 35% (Traffic Choices, N.D.), risk of serious collision reduced by 72% [2].

FIGURE 2.2 VEHICLE CYCLE SEGREGATION [20]

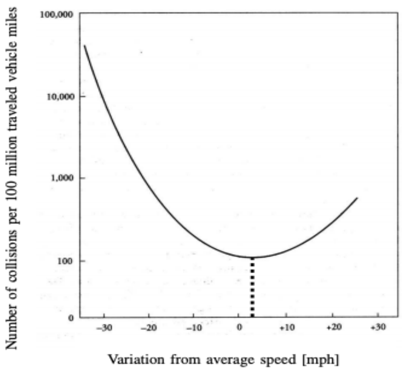

FIGURE 2.3 SOLOMON'S CURVE

An example of segregation is the Cycle Superhighway (CS) project in London. Most of the Cycle Superhighways are segregated from the motorway. It is proven to enhance safety and perception of safety. Over 90% people agree that they feel safe cycling on CS as shown in Figure 2.4 [8]. No collisions causing casualties along the CS route 3 and 7 in the first year after construction [7]. [5] has shown that based on the estimation of cycle collision rates, the Cycle

Superhighways 'are not more dangerous or safer than the control roads'.

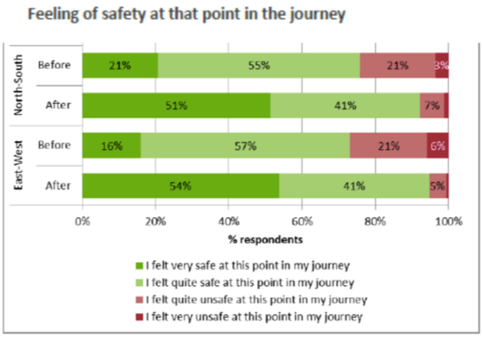

FIGURE 2.4 PERCEPTION OF SAFETY AT CS

Drivers are less favour of segregation, because the space for motors will be taken away by cyclists and they worry that it would cause congestion. Effect of segregation on efficiency will be mentioned in sector 3.

2.2 CASE STUDIES – PROTECTED INTERSECTION

Almost 2/3 of severe bike accidents occur at or near junctions (Transport Research Laboratory, 2009). However, in many major cities, cycle lanes disappear near the junction, where safety infrastructure is most needed. Hazards arise when cyclists want to go straight while other road users turn left or right. In right hand side driving countries, as shown in Figure 2.5A, if a road user who turns left overlooks the cyclist or misjudge the distance, accident might occur. In Figure 2.6B, problem arises when drivers, especially large vehicle drivers, do not give adequate space to cyclists (Bicycle Lawyer, 2019).

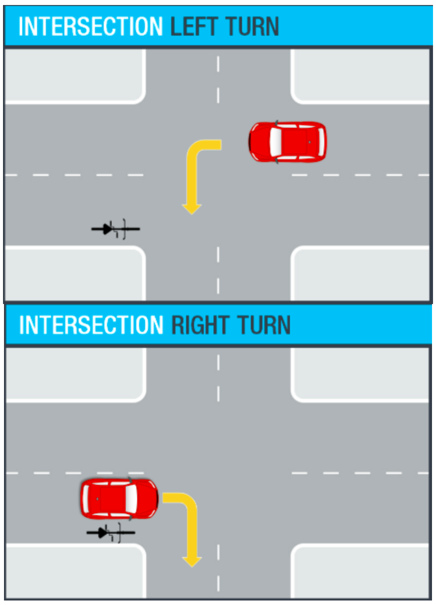

FIGURE 2.5 A&B HAZARDS ILLUSTRATION

[2] demonstrated a safer Dutch junction design which could reduce the risk as shown in Figure 2.6.

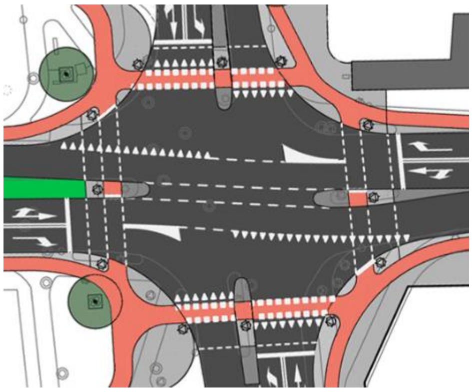

FIGURE 2.6 DUTCH CYCLE INTERSECTION DESIGN [2]

In this type of cycle design, cyclists are separated from the vehicle stream by islands in the links and also in the junction. There are 4 cycle crossings at this junction. Traffic light phases are designed to avoid conflict between vehicles and cycles, or at least phases are designed to give cyclists and pedestrians early green. Right turn is done without interacting with the traffic. Left turn is slightly more complicated, has to be done in two stages. Cyclists need to go straight first, then turn left and go across the other crossing. The advantage of this junction design is that cyclists only use their predefined routes so that vehicles would be aware of cyclist when crossing the junction. By isolating the cycle route, cyclists have minimum interaction with the traffic flow.

This type of design is also transferrable to roundabouts, T-junctions and unsignalized junctions as shown in Figure 2.7.

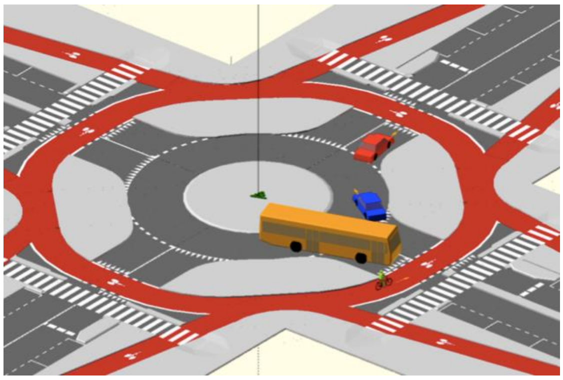

FIGURE 2.7 PROTECTED T JUNCTION AND ROUNDABOUT

[11] used VisSIM model to study the safety effects of adopting protected intersection and compare with the existing traditional intersection. The potential conflicts, which represent potential bike accidents, at the intersection are simulated. It is found that when the relative flow of bikes is 15%, a protected intersection would reduce the number of conflicts by 80%. Since the number of conflicts in the model is a reflection of potential accidents, the protected junction design is expected to be safer than the traditional design.

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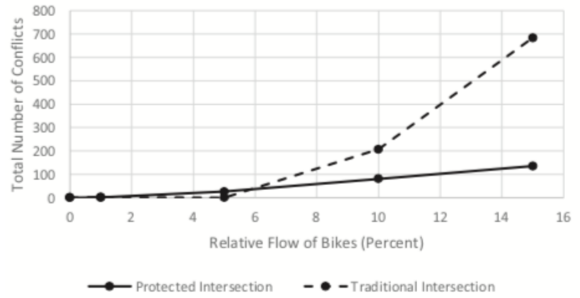

FIGURE 2.8 RELATIVE FLOW OF BIKES AND THE NUMBER OF CONFLICTS

3 SPEED AND EFFICIENCY

Cyclists in major cities such as London might have to cycle on motorways. They have to move through the gap of motor vehicles as shown in Figure 3.1. When the road is congested, it is hard and slow to find a space to pass through. It is even more unpleasant when a cyclist reaches the bus stop, as they might have to wait until the bus departs as shown in Figure 3.2 [1].

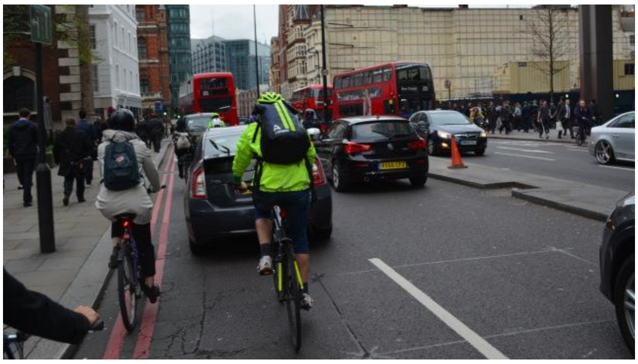

FIGURE 3.1 MIXED BICYCLES AND VEHICLES (ASEASYASRIDINGABIKE, 2019).

FIGURE 3.2 BUSES BLOCKING CYCLES (ASEASYASRIDINGABIKE, 2019).

Moreover, at junctions or roundabouts, cyclists probably have to push their bicycles if they wish to turn right (or turn left in right hand side driving countries), as it is considered dangerous to make a turn directly [1]. All these problems would keep cyclists waiting and significantly reduce the efficiency of the road. There are some good Traffic Engineering practices to enhance the mobility of bicycles.

3.1 CASE STUDIES – SEGREGATION

Segregation will not only make cyclists safer, but also make their journey faster. CS could reduce the cyclist journey time by 5% [8]. Meanwhile, some people fear that the construction of segregated cycle ways would occupy a large proportion of road surface, hence reduce the efficiency of the road. Indeed, as the motorway gets narrower, the vehicle travel speed will be slower. According to the simulation result of East-West Cycle Superhighway from TfL (2015), although cycling will be more streamlined, in some areas the vehicle travel duration would be significantly prolonged.

Correct as at 23 September 2014	(A) Base Model - current situation on street				(B) Future base model - Expected situation on-street Dec 2016 without scheme				(C) Future journey times Dec 2016 with scheme				(D) Difference between Future with scheme (C) and base (A)		(E) Difference between future with scheme (C) and future base (B)	
	Current journeys		AM	PM	Journeys modelled		AM	PM	Journeys modelled		AM	PM	AM	PM	AM	PM
Traffic Average journey times (minutes:seconds)	Limehouse Link tunnel to Hyde Park Corner	Westbound	34:34	30:51	Limehouse Link tunnel to Hyde Park Corner	Westbound	32:39	29:55	Limehouse Link tunnel to Hyde Park Corner	Westbound	50:28	44:20	15:54	13:29	17:49	17:25
		Eastbound	27:51	30:38		Eastbound	26:06	31:49		Eastbound	35:29	35:06	7:38	4:28	9:23	3:17
	East Smithfield to St Margaret Street (Parliament Square exit)	Westbound	18:15	17:06	East Smithfield to St Margaret Street (Parliament Square exit)	Westbound	16:30	13:18	East Smithfield to St Margaret Street (Parliament Square exit)	Westbound	18:34	23:14	0:19	6:08	2:04	9:56
		Eastbound	14:50	16:37		Eastbound	12:25	15:54		Eastbound	11:51	12:45	-2:59	-3:52	-0:34	-3:09
	Westminster Bridge to Hyde Park Corner (Knightsbridge)	Westbound	8:03	8:01	Westminster Bridge to Hyde Park Corner (Knightsbridge)	Westbound	7:51	7:42	Westminster Bridge to Hyde Park Corner (Knightsbridge)	Westbound	8:03	8:35	0:00	0:34	0:12	0:53
		Eastbound	7:02	7:37		Eastbound	6:37	7:07		Eastbound	16:00	13:59	8:58	6:22	9:23	6:52
	Lancaster Gate to A40 Westway	Northbound	4:36	5:04	Lancaster Gate to A40 Westway	Northbound	4:41	5:10	Lancaster Gate to A40 Westway	Northbound	4:20	4:53	-0:16	-0:11	-0:21	-0:17
		Southbound	4:36	4:51		Southbound	4:30	4:15		Southbound	6:16	5:18	1:40	0:27	1:46	1:02
Buses A sample of journey times on four routes through the scheme area (minutes:seconds) Difference against base (A), expressed as a range in column D	Route 15 (between Tower Hill and Byward Street)	Westbound	10:00	9:54	Future base data available for general traffic journeys only				Route 15 (between Tower Hill and Byward Street)	Westbound			0-1m	(2-5m)	Future base data available for general traffic journeys only	
		Eastbound	5:06	7:16						Eastbound			(0-1m)	(0-1m)		
	Route 453 (between Westminster Bridge and Trafalgar Square, via Parliament Square)	Northbound	8:18	8:06					Route 453 (between Westminster Bridge and Trafalgar Square, via Parliament Square)	Northbound			2-5m	1-2m		
		Southbound	8:24	10:48						Southbound			7-10m	1-2m		
	Route 16 (between Park Lane and Grosvenor Place)	Northbound	2:24	2:42					Route 16 (between Park Lane and Grosvenor Place)	Northbound			(0-1m)	3-1m		
		Southbound	2:06	2:12						Southbound			0-1m	3-1m		
	Route 94 (between Lancaster Gate and Westbourne Terrace)	Westbound	3:18	3:30					Route 94 (between Lancaster Gate and Westbourne Terrace)	Westbound			1-2m	2-5m		
		Eastbound	8:48	5:48						Eastbound			(1-2m)	(1-2m)		
Cycling Average journey times (minutes)	Royal Mint Street to Hyde Park Corner	Westbound	32	32					Royal Mint Street to Hyde Park Corner	Westbound	30	29	-2	-3		
		Eastbound	31	31						Eastbound	31	29	0	-2		
	Royal Mint Street to St Margaret Street (Parliament Square exit)	Westbound	20	20					Royal Mint Street to St Margaret Street (Parliament Square exit)	Westbound	19	17	-1	-3		
		Eastbound	21	21						Eastbound	17	16	-4	-5		
	Parliament Square to Hyde Park Corner	Westbound	11	12					Parliament Square to Hyde Park Corner	Westbound	11	11	0	-1		
		Eastbound	10	10						Eastbound	15	13	5	3		
	Lancaster Gate to A40 Westway	Northbound	7	7					Lancaster Gate to A40 Westway	Northbound	5	4	-2	-3		
		Southbound	7	7						Southbound	5	5	-2	-2		
Pedestrians Traffic signal cycle times and associated wait times (seconds) NOTE: Future base would be same as current base without scheme	Tower Hill - Minories - Shorter Street	Max. cycle time	88	88	Tower Hill - Minories - Shorter Street	Max. cycle time	88	88	Tower Hill - Minories - Shorter Street	Max. cycle time	96	96	8	8	8	8
		Max. wait time	82	82		Max. wait time	82	82		Max. wait time	90	90	8	8	8	8
	Upper Thames Street - Queen Street - Queen Street Place	Max. cycle time	104	104	Upper Thames Street - Queen Street - Queen Street Place	Max. cycle time	104	104	Upper Thames Street - Queen Street - Queen Street Place	Max. cycle time	104	104	0	0	0	0
		Max. wait time	98	98		Max. wait time	98	98		Max. wait time	98	98	0	0	0	0
	Parliament Square - Parliament Street - Bridge Street	Max. cycle time	112	112	Parliament Square - Parliament Street - Bridge Street	Max. cycle time	112	112	Parliament Square - Parliament Street - Bridge Street	Max. cycle time	120	112	8	0	8	0
		Max. wait time	105	105		Max. wait time	105	105		Max. wait time	114	106	9	1	9	1
	Knightsbridge - Hyde Park Corner - Grosvenor Place	Max. cycle time	96	96	Knightsbridge - Hyde Park Corner - Grosvenor Place	Max. cycle time	96	96	Knightsbridge - Hyde Park Corner - Grosvenor Place	Max. cycle time	96	104	0	8	0	8
		Max. wait time	90	90		Max. wait time	90	90		Max. wait time	90	98	0	8	0	8

FIGURE 3.3 SIMULATION RESULT OF TRAFFIC FLOW BEFORE AND AFTER THE CONSTRUCTION OF CYCLE SUPERHIGHWAY

However, a study shows that even if the travel duration of vehicles is prolonged, the road efficiency could possibly increase because of increased cyclists. With appropriate infrastructure, the movement of cyclists becomes more convenient and the perception of safety is increased. Therefore, more people are attracted to cycling. There is a 54% increase in number of cyclists on East-West CS and a 32% increase in North-South CS [8]. Since the announcement of the CS in 2008, the number of cycle journey in London as a whole has increased from 0.5 million to 0.73 million in 2016 as shown in Figure 3.3 [7]. It is projected to increase in the future when more cycle infrastructures are placed.

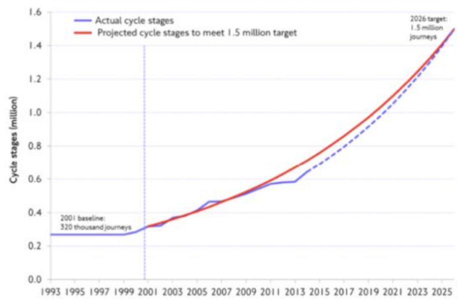

FIGURE 3.4 NUMBER OF CYCLE JOURNEYS IN LONDON

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The increase in number of cyclists actually enhance the efficiency of the road because the road efficiency of the cycle way is higher than that of a motorway. For example, according to [2], 50% of the people using the new East-West and North-South routes are cyclists, while the cycle routes only occupy 30% of the road surface. These new routes could carry 5% more people than without segregated cycle way. It is expected that in the future, as cycling become safer and more convenient, more people would opt to cycle than driving, hence the traffic condition on motorways would be better [2].

3.2 Intelligent Transport System

It is a government policy to prioritize public transport and cycling. By using Intelligent Transport System (ITS), cyclists could be given higher priority over private vehicles. In London, Split Cycle and Offset Optimisation Technique (SCOOT) is used [7]. SCOOT is a real time adaptive traffic control system. It could adjust the traffic signals according to current traffic conditions or give priority to certain types of vehicles. It collects information of the presence of the road users and their speed by using sensors. According to the data, the system would optimise the offset, the cycle time and the split.

According to the presentation of [4], Cycle SCOOT includes two detectors at the upstream and the stopline respectively as shown in Figure 3.5 The data will be recorded as demand in the system, forming a queue model at the cycle route. SCOOT will optimise the green and red time for all road users.

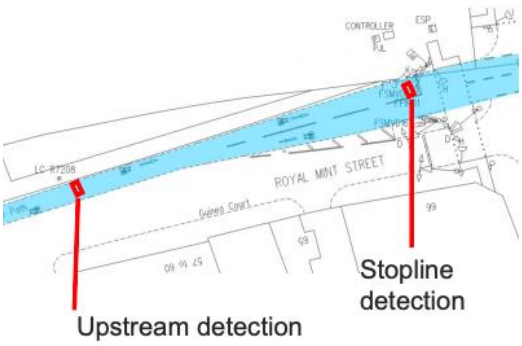

FIGURE 3.5 DETECTOR LOCATIONS

Modelling result has shown that with little negative effect on vehicles, the waiting time of cyclists is significantly reduced after implementing SCOOT as shown in Figure 3.6. On-site measurement concluded that the cyclist waiting time is dropped by 6% as shown in Figure 3.4 [2].

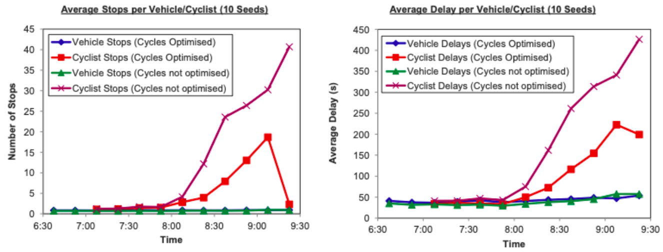

FIGURE 3.6 AVERAGE DELAY OF VEHICLE AND CYCLISTS WITH OR WITHOUT SCOOT

With similar principle, Copenhagen will also implement an ITS system to prioritize bicycles. According to the report of [3], Copenhagen will use ITS on 380 signals. The green light would be extended between 8 to 30 seconds to allow bicycles to go through. Moreover, the system also provides a 'green wave' to cyclists. A pack of cyclists would always encounter green lights if a constant speed is maintained. This ITS system is expected to reduce the cyclist journey time by 10%.

According to [12], there is also a proposal to use ITS to improve other aspects of the bike journey. The data of cyclists, including their behaviour, routes, intensities and parking information, shall be collected and be stored in CyclingDataHub (CDH). These data can be analysed for safety research, road design and developing mobile app. The mobile app could fulfil the needs of cyclists. For example, the most optimum route for motor vehicles may not be optimum for cyclists due to road conditions, the app could find the route to cycle. The App may also show data of available cycle parking spaces. However, due to privacy concerns and the cost of data collection, this plan may take a long time to be implemented.

4 CONCLUSION

Cycling has many advantages over private vehicle transport, therefore, under the incentive policy of governments, it is gaining increasing popularity. Traffic Engineering is fundamental to allow bicycles to move around the city and fulfil the basic demands of cyclists. Engineers around the world invented many Traffic Engineering solutions to meet the demands, especially the speed and safety requirements. These solutions have reduced the accident rate, improved the traffic flow efficiency and made cycling a more pleasant experience in urban areas. In the future, as the traffic condition evolves, there might be more challenges to solve. Traffic Engineering solutions, especially new ideas, would be crucial to enhance the mobility of cyclists in urban areas.

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The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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