A Brief Review on Strategies to Increase Cycling: Utilization of Space Underneath the Elevated Highways/Railways for Cycling and Other Strategies

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Abstract: Cycling has won the heart of people starting from finding solutions to reduce CO_2 emissions to the atmosphere. Lack of strategies to mitigate the barriers and challenges of cycling is a worldwide problem. This paper aims to identify the worldwide trends towards cycling, the potential to use elevated structures and space beneath, and implement new cycling strategies for Sri Lanka to increase cycling usage. Leftover space beneath elevated highway/railway structures has the potential to develop as separated cycling infrastructure. Utilizing the space beneath the elevated highways/railways as a cycle lane can minimize the effect of the bad weather patterns and some other negative points. The review implies that future elevated highway/railway structures can be integrated to accommodate diverse functions beneath them for effective use.

Keywords: Sustainable Transport, Cycling, Elevated Structures, Space Beneath

1. INTRODUCTION

Global warming has become a serious threat to the world. Rising sea level, food shortage, unpredictable weather patterns are counted as some effects of this phenomena (Nunez, 2019). Emission of greenhouse gases (GHG) into the atmosphere causes the global warming carbon dioxide is one main causes. As per the Intergovernmental Panel on Climate Change fifth assessment report (2014), 87% of all human produced carbon dioxide emissions come from the burning of fossil fuels like coal, natural gas and oil. Transportation sector is the second largest emitter of carbon dioxide by burning fossil fuels after the economic sector.

The transport sector was responsible for 22% of global CO_2 emissions worldwide according to the statistical data, (International Energy Agency, 2012). Global transport related CO_2 emissions are expected to increase by 57% in the 2005 – 2030 timeframe, representing the fastest growing source of greenhouse gas emissions worldwide. (International Energy Agency, 2009). Hence, the sustainable transport modes, which emit less or no carbon dioxide could evolve to possibly reduce GHG intensity in the air (Sims *et al*., 2014).

Cycling is a sustainable transportation mode which has a potential to reduce transport related emissions. It emits zero carbon and air pollution is zero. The fuel consumption can also be reduced with the usage of cycles for daily travelling. A case study in Mexico has noted a tangible reduction of the GHG emissions of around 3% of urban transport of persons and 0.5% of total emissions by the practice of the bicycle for utilitarian a leisure purposes and multimodality bike-public transport (Bussiere *et al*., 2010).

Cyclist may have better physical health and fitness condition than a normal person. A research carried out by a team of investigators at the University of Glasgow to find the health benefits associated with different transport modes, tracked 263,450 people for five years who traveled to work and lived in England, Scotland or Wales. The result of the investigation revealed that, commuters who cycled to work had a 41% lower risk of dying from all causes than people who drove or took public transport. They also had a 46% lower risk of developing and a 52% lower risk of dying from cardiovascular disease, and a 45% lower risk of developing and a 40% lower risk of dying from cancer. Hence extraordinary health benefits can be attained through riding bicycle daily (Murnane, 2017). Therefore, cycling can be considered as a better solution in multiple perspectives including environmental, health and social.

Encouraging cycling as a daily transport mode will be beneficials in many aspects. There are many challenges which needs to be identified. One challenge is space treated specially for cycling infrastructures. As a solution for spatial challenges one potential is usage of space below elevated highway/railway structures. Hence this research considers such potential to investigate the potential of using space below elevated structures. The objectives of the research are as follow.

1) Identify potential space availability below elevated highway/railway structures for cycling.
2) Investigate about design challenges for cycling in above spaces.
3) Identifying general strategies for cycling.

2. GENERAL OVERVIEW FOR CYCLING

2.1 Worldwide Trends Towards Cycling

World Studies of cycling as a transport mode has developed in several decades ago. Starting from finding solutions for burning environmental problems with a sustainable concept, cycling has won the heart of people as a solution for sustainable transport. Many countries who have signed Kyoto Protocol agreement are reducing their carbon dioxide emission by using non-motorized vehicles for travelling.

One example is Canadians who use their bikes for a higher percentage of trips and their cars for a lower percentage of trips, reduced Canadian GHG emissions from transportation sources (Pucher and Buehler, 2006).

Several steps were taken by Canadians to make a growth in cycling levels of their country. Cycling facilities have been enormous as intersections were facilitated with push-button-activated bike traffic lights, the safety of cycling is promoted in many schools, free bicycling safety instruction materials are distributed and bikes and bike helmets are offered for winners of various cycling safety competitions (Pucher and Buehler, 2006).

Preveza, a small touristic city in Northwestern Greece uses the bicycle prominently when compared to other Greek cities. Karanikola et al. (2018) conducted face-to-face interviews with Preveza residents. More than half of the residents use bicycles as their transportation and stated that bicycles are an inexpensive way of transport in the city and had the opinion that the state should encourage bicycle use by supporting subvention in bicycle acquisition. Two-thirds of the residents evaluated the cycling facilities of their city as adequate, but unsafe for young cyclists who do not follow the rules of transport. In contrast, adult cyclists were more loyal to the code but stated that drivers did not respect their presence on the roads.

Future work on cycling should be focused on exploring best practice policy in the financing of local bicycling improvements. Although cycling has increased over the years, there are barriers for cycling. A study in Sweden has listed some barriers to increase utilitarian cycling, such as lacking sufficient fitness, long distances, being tired, too much effort, difficulties with trip chaining, shopping and picking up children with the help of their bicycles, bad weather, being too busy, lack of time, lack of daylight, inconvenience, too dangerous and too much traffic. (Stromberg and Karlsson, 2016). If there are effective solutions to overcome cycling related barriers in a proper manner, cycling will be a favorable transportation mode.

Aldred et al. (2019) studied the barriers to investing in cycling in England. In England, between 2001 and 2011 the proportion of commutes made by cycling hardly grew. Low investment in cycling infrastructures was the contributory factor towards the change. Based on qualitative data from an online survey of over 400 stakeholders alongside and seven in-depth interviews it was pointed out that changes in the cycling trend of England continue to be blocked by chronic barriers including a lack of funding and leadership. The author's recommendation was to study barriers to investing in sustainable transport modes, thereby finding ways of overcoming drawbacks. A study in the USA explored that the implementation of a wide range of infrastructure, programs to promote cycling and increase cycling safety have led to growth in cycling (Pucher *et al*., 2011).

In Rochester Lack of bicycle-only routes and roadway accommodations was identified as a key barrier for cycling. Other challenges for cyclists are the extended period of winter road conditions and unpredictable precipitation events. Other psychological and physical barriers exist that limit ridership numbers in Rochester, including safety concerns, and lack of infrastructure (Pucher and Buehler, 2007).

Proper infrastructure facilities can promote cycling for daily travelling purpose and can mitigate most of the cycling related issues (Buehler and Dill, 2015; Akar and Clifton, 2009; Goodno *et al*., 2013). Integrated developments which combine multiple development scenarios together will be the best solution in handling these facility developments.

The proposed cycling strategy by the Senate Department for Urban Development and the Environment in Berlin recommended that bicycle parking facilities should be created at the bus and tram stations in residential areas. Bicycle parking facilities must be created in such a way as to ensure that safety and operational areas, particularly exit and escape routes, are not restricted or obstructed. Options for providing an additional number of supervised or lockable bicycle parking spaces should be examined. The replacement of traffic light systems with the standard right of way for cycling on selected commuter routes and in the network of minor roads also suggested.

At the present time under the Covid-19 situation, people are more reluctant to use public transports for shorter distances due to social distancing. Cycling seems to be a better option for respecting social distancing guidelines while traveling safely. Berlin was one of the first cities to implement pop-up bike lanes to evolve more efficiently to mobility patterns caused due to pandemic situation. The city of Berlin supplies practical advice and guidelines to other cities to learn how to plan safe, temporary infrastructure that can be implemented in only 10 days. And also, Belgium, France, Milan, Boston, and many other cities have been facilitating cycling under this crisis. This rapidly growing transport solution will enable citizens to enjoy its numerous benefits for health, the environment, air quality, road safety, and accessibility. (Union Cycliste Internationale, 2020)

2 .1 Accidents Related to Cyclists

In regards with the literature on bicycling and road safety, a research conducted in Netherlands suggested that physically separated bicycle facility network led to reduce risk among cyclists. Hence bicycling on cycle tracks is safer than bicycling on roads (Wegman *et al*., 2012).

Lusk *et al*. (2013) studied United States bicycle facility guidelines published between 1972 and 1999 to determine whether cycle tracks (physically separated, bicycle-exclusive paths adjacent to sidewalks) were recommended, whether they were built, and their crash rate. Extensive data on cycle track design, usage, and crash history from local communities were identified and collected from 19 cycle tracks in the United States. Crash rate estimation was done using bicycle counts and crash data on identified tracks. According to the author American Association of State Highway and Transportation Officials Guideline (AASHTO Guideline) is not explicitly based on rigorous and up-to-date research. In the United States, bicycling on cycle tracks is safer than bicycling on roads. The overall crash rate was 2.3 (95% confidence interval [CI]= 1.7, 3.0) per 1 million bicycle kilometers. When the Vancouver expansion factors were applied, the crash rate was 2.1 (95% CI=1.6, 2.8). Optimal design features of cycle tracks could identify through further research.

Causal exploration of Bike Accidents in the Bay Area was examined by Bryden *et al*. (2012). The statistically significant contributing factors to accidents involving cyclists in the city of San Francisco were determined under this research. Five years of bicycle crash data from the city of San Francisco were analyzed. Different factors to the likelihood of an accident occurring, the corresponding severity, and the party at fault were studied using multinomial logistic regression. The study concluded that accidents occurred closest to an intersection would be more likely to end in injury or fatality.

As a model city for bicycle infrastructure, Copenhagen, Denmark has shown that investment in bicycle infrastructure decreases casualty rates. The 2017 Copenhagen City of Cyclists report states that cyclists felt 60% safer after the city installed separated bicycle tracks. This improvement increased cyclist numbers by 15-20%, about the same percentage of decreased cyclist casualties in Copenhagen during the same time. Many key intersections already provide advance stop lines, traffic signal priority, and special blue lane markings for cyclists (Pucher and Buehler, 2007)

3. POTENTIAL USAGE OF ELEVATED STRUCTURES AND SPACE BENEATH

In urban transport infrastructures developments, elevated structures have become common due to several factors such as scarcity of land for new developments, less ground disturbance and lower risk of flood disturbances. Recently most of highways and railways are designed as elevated structures as it has benefits over other designs such as increased ground level connectivity and creation of linear parks and connected quiet streets for safer walking and cycling. Moreover, according to Woodcock and Martin, Elevated rail has lower capital costs compared to trenched and tunneled alternatives (Woodcock and Martin, 2016). Elevated railways are important elements in urban structure and their aesthetics, as well as function are immensely important for local residents (Eva Kido, 2018). These structures can be iconic structures to its city and as well as this approach will bring extra profit for the communities.

But in most cases, the space underneath the structure is a grim place dominated by grey concrete and parked cars without any effective use. However, it has a good potential to additionally shape urban landscapes for social and ecological benefit. Therefore, the elevated structures should be designed simultaneously with other urban developments in order to accommodate diverse functions beneath it for an effective use.

Six impacts related to elevated highways in the urban area have mentioned by Saouma (2008) cited in Anur and Ahmad (2017). In there, segregate community or neighborhood, a physical and psychological barrier & visual intrusion, produce undefined space which often misused, allow minimum natural lighting & poor ventilation at space under the elevated structure and generate negative spaces or lost spaces can be identified as negative impacts of elevated transport structures.

A study on exploring possible usage for elevated highway interstitial spaces was done by Anuar and Ahmad in 2018. According to them an improved understanding of the typologies and characteristics of these interstitial spaces shall aid in the improvement of their future usage. Their findings suggest that location and characteristics are the most significant variables which determine types of activities and level of users' adaptation towards the ambience of undefined spaces created by the elevated highways (Anuar and Ahmad, 2018).

Research to study the activities under the flyovers was done focusing on the activities that took place under the flyovers in the Malaysian context. However, from the study it was identified that each area has its own unique characters, therefore activities that are distinctively unique to that area should be allowed to expand in order to create places with identity rather than homogenous spaces of traditional planning. The authors highlighted the need for future research on the physical characteristics and the more complex community background. (Qamaruz-Zaman *et al*., 2012).

Viljoen from Sweden has described 39 types of commodities by integrating the elevated railway structures and urban life to contribute beyond the main function of transport. Covering up the concrete structures of elevated transit structures with plants, using wayfinding around it to encourage walking along the trail that connects surrounding trails and neighborhoods, delivering services beneath it, making an ice skate rink beneath it, making a bicycle path beneath it and filtering rainwater from it to prevent flooding are some of the space utilization methods described in the particular study. (Viljoen, 2018).

In Japan Nakameguro Station facilities were refurbished and developed in 2016 and 2017. The new development consists mainly of shops and restaurants located under the 700 m-long viaducts. The dark interior below the track has been changed into bright spaces. Local people and visitors now enjoy the place, of various excellent shops, and restaurants (Eva Kido, 2018)

3.1 Potential of Use of Space Under Elevated Highways/Railways for Cycling Infrastructure

In considering potential options to utilize the space beneath the elevated structures, making a bicycle lane could be a best sustainable option. Berlin Radbahn U1 cycle lane project is a model example of how to recognize the new potential in existing but untapped resources in urban areas, and how to integrate this into an eco-friendly overall approach. The project Radbahn U1 bicycle path takes up a discourse on the appeal of cycling in urban traffic. The vision of the project is to transform the area under Berlin's elevated U1 rail line into a cycle path over nine kilometers along with one of Berlin's main arterial roads through three districts and numerous lively neighborhoods. The idea of a covered bike path may remove barriers to cycling and increase ridership in Berlin. Further, the cycle route is to be created with ancillary spaces like green spaces, recreational spaces, and bike service stations. (Viljoen, 2018; Finger, 2017).

Berlin Radbahn project has several recommendations such as to create minimum number of parking slots in each section of the track to attain uniform ridership, to provide an on-street bike track, to provide safe crossing zones in the form of fully marked intersections, to provide points of attraction such as coffee shop or snack outlet and to provide green aesthetic coverage by plants along with a provision to halt and gather. Moreover, there is a suggestion to integrate an energy harvesting technology that generates electricity when bicycle's role over the pavement. (Iyer, 2018).

4. SRI LANKAN STUDIES ON CYCLING

4.1 Sri Lankan Modal Share

In Sri Lankan transport industry, major public transport modes are passenger bus service and train service. According to a household survey conducted by Colombo Metropolitan Transport Study team for western region have analyzed that around 38% of trips are made by private modes of transport, including cars, taxis, three wheelers and motorcycles while approximately 40% are made by buses and railways. The remaining 22% of the trips are made by non-motorized modes of transport including walk, bicycle, and others (De Silva, 2017).

4.2 Promotion of Cycling in Sri Lanka

But as a part of the project "world bike to work day", Sri Lankan government promoted several bicycle lanes in cities including Malabe and Katubedda areas. But the particular implementation has not been an effective approach to encourage people in using bicycles. Irrespective of the presence of your riders from nearby universities, both these lanes show low level of active usage.

A study revealed that the bicycle usage was low among various groups although the bicycle possession was substantial, accounting to 83% among general public (Bandara *et al.*, 2016).

4.3 Studies on Cycling Infrastructures in Sri Lanka

Bicycle was a dominant daily transport mode in Sri Lanka in the past. Even now in rural areas like Anuradhapura, Trincomalee, Jaffna residents use bicycles for their daily transport. But in urban areas cycling is mainly done as a recreational activity. The social beliefs such as bicycle as a poor man's vehicle deter the use of the bicycle for daily travelling.

Weerasinghe (2010) have done a study on promotion of bicycles for school children in Eastern province. From the collected data it was identified that 34% of students come on foot between 2 to 10 kilometer and 8% of students have to walk 2 to 10 kilometers to board a bus. In terms of parking facilities, the study revealed that 68% of cycling students did not have parking facilities. Despite that data collection indicated that a good percentage of those who owned bicycles use it for travelling to tuition class and for other purposes. In addition, it is identified that facilities available for bicycle repair is adequate in that area. The study finally pointed that proving bicycles to school children in the Eastern province as the most viable solution.

A study on the bicycle lane has identified poor road conditions, lack of facilities for cyclists, long distances, absence of safe parking, sweating, and social stigma as factors for the lesser usage of the lane. (Bandara *et al.,* 2016). These may deter people from using bicycles as a transport mode. According to the survey responses, heavy congestion, poor driver discipline, road line crossings, intersections, underpasses, and overpasses of different transport modes were created conflicts for the cycling lanes. To overcome these conflicts, they have made few recommendations. Such recommendations include raised bicycle lanes separated from the motorized way where possible, bicycle lane width between 1.5 m and 2.0 m, providing green shelter for the bicycle lanes to minimize sweating, and at least 4km bicycle lane surrounding the institutions like universities where potential bicycle usage is anticipated (Bandara *et al*., 2016).

The bicycle lane in Katubbeda starts from Piliyandala junction and end at the Kospalana Bridge. After that cyclist have to share the motorways for the remaining part of their journey (Niranjala and Kankanamge, 2018). Other reasons for the lower usage include the existence of bends and absence of significant buffer width to safe guard cyclist from tress passing vehicles except while lane marking. Increment in accidents in the particular area; Katubedda area, using bicycle lane space to park vehicles and as well as using bicycle lane to bypass the traffic were mentioned as difficulties in bicycle lanes (Niranjala and Kankanmge, 2018).

4.4 Future Proposals of Cycling for Sri Lanka

In Sri Lanka, there is a proposal to have cycle pathways in the Colombo area covering six key corridors namely Moratuwa, Piliyandala, Kottawa, Kaduwela, Kadawatha, and Kandana. The proposal expects conversion of at least 10% of the vehicles to use bicycles as their prime medium of travel to work for 5 days a week. This conversion of 10% of the private transport will create 79,845 cyclists travel to the city, daily. The proposal addresses the quantification and cost-benefit analysis of practical modeling. According to the analysis, it proposes an infrastructure of 120 Kms of cycling paths along 6 corridors at a cost of LKR 75,840,000. The analysis showed that this proposal generates a cost-benefit of LKR 542,914,062. (Premaratne, 2019)

The elevated railway structures and creation of cycling lanes below that is new to Sri Lanka. Thus, there is an uncertainty about the nature of required infrastructures and challenges faced in adopting those. A proper research can help to understand and mitigate problems in designing bicycle lane for space under the elevated transportation infrastructures.

5. REMARKS AND RECOMMENDATIONS

This research focused on identifying relevant literatures for cycling needs and availability of overhead infrastructures space for cycling. Analysis of conflicts for implementing bicycle lanes in space under the elevated highways/railways has been reviewed. Only few studies were focused on utilizing the space beneath elevated structures.

Key findings are tabulated along with the areas of cycling challenges, design strategies, user groups for cycling, renting systems, and innovative technologies.

Table 1. Key findings of the study

Cycling Challenges (Stromberg and Karlsson, 2016; Karanikola et al., 2018; Bandara *et al*., 2016)		
Physical barriers	**Environmental barriers**	**Personal barriers**
Poor road condition	Bad weather and unpredictable precipitation events	Lacking sufficient fitness
Lack of facilities for cyclists	Lack of daylight	Being tired
The existence of bends		Too much effort

Absence of significant buffer width to safe guard cyclist from tress passing vehicles except white lane marking			Difficulty in shopping and picking up children with bicycles
Absence of safe parking			Social stigma as a poor man's vehicle
Long distances and lack of time			
Absence of connectivity in bicycle lane therefore cyclist have to share the motorways for the remaining part of their journey			
Using bicycle lane space to park vehicles and as well as using bicycle lane to bypass the traffic			
Poor driver discipline of different transport modes			
Heavy congestion and too dangerous on road			
Intersections, underpasses and overpasses			
Design Strategies (Pucher and Buehler, 2007; Dahanayaka and Kankanmge, 2018; Bandara *et al.,* 2016; Viljoen, 2018; Finger, 2017; Eva Kido, 2018; Qamaruz-Zaman *et al*., 2012)			
Institutional support required	**Infrastructure facilities required**	**Elevated type strategies**	**Intersection treatments**
Funding and leadership to promote cycling	Physically separated bicycle facility network	Investment in transport infrastructures to attract people	Accidents occurred closest to an intersection would be more

			likely to end in injury or fatality
Policy development to increase cycling safety	Raised bicycle lanes separated from the motorized way, bicycle lane width between 1.5 m and 2.0 m	Combine multiple development scenarios together. The elevated structures should be designed simultaneously to have a bicycle lane underneath it.	Intersections were facilitated with push button activated bike traffic lights.
Proving bicycles to school children and university students	Safe crossing zones in the form of fully marked intersections.	Utilizing the space beneath the elevated highways/railways as a cycle lane can minimize the effect of the bad weather patterns and some other negative points.	The replacement of traffic light systems with the standard right of way for cycling.
	Green shelter for the bicycle lanes to minimize sweating.	Piers of the elevated highways/railways can make to a green wall by using new technology and methods.	
	Minimum number of parking slots in each section of the track.	Trees can be planted along and besides the cycle track.	
	Parking facilities at bus and train stations	Suitable paving materials can be used to reduce the heat generation and base of the elevated highway/railway provide shelter for the cycle track.	
	An additional number of supervised or lockable bicycle parking spaces		
	Provide points of attraction.		

Potential User Group for Cycling (Weerasinghe, 2010)	
The group of the people who travel daily to stations to catch the public transportation can consider as a target group. Most of the	At least 4km bicycle lane surrounding the institutions like universities where a potential bicycle usage is anticipated

time this group of people use uber or Three-wheelers to reach to the station.		
Changes to the Bike and Bike Renting System (Pucher and Buehler, 2007)		
Electrical bicycles, Freight bicycles, folding bicycles, Three-wheeler's bicycle are some modifies bicycles which use for different purposes. Simply a bicycle with an attached trailer can be used to carry more goods when cycling.	By the rent-a-bike systems it will be easy to enhance the use of bicycle for travelling.	Free bicycling safety instruction materials are distributed and free bikes and bike helmets for winners of various cycling safety competitions are offered.
Innovative Technologies (Iyer, 2018; Union Cycliste Internationale, 2020)		
Integrate an energy harvesting technology that generates electricity when bicycle's role over the pavement		
In pandemic situation cycling seems to be a better option for respecting social distancing guidelines while traveling safely		

6. CONCLUSIONS

Cycling requires a specific way of looking in terms of infrastructure facilities. Space under the elevated highways/railways has the potential to be developed into a cycling lane. This review paper focused on the potential usage of elevated structures for cycling and methods to improve such cycling usage. The effect of the bad weather patterns and absence of separated bicycles, heavy congestion, and feel of insecurity on road can be mitigated by utilizing the space beneath the elevated highways/railways as a cycle lane. The elevated transport structures should be designed simultaneously to have a bicycle lane underneath them. Lockable bicycle parking spaces can be arranged at bus and train stations. The group of the people who travel daily to stations in towns from their village can be motivated to use a bicycle for their daily journey to the station. The public transportation system can link with cycling as a transport mode for a shorter distance. To attract the younger generation in daily cycling, implementing bicycle lanes near universities and schools can be started. The development of policies on cycling safety can increase the number of users of cycling. In the course of implementing the cycling strategy for elevated highways/railways, a more focused study should be carried on in terms of safe linking. The intervention of the government institute for policy marking and implementation of cycling infrastructures can increase the use of this sustainable transport mode. Utilization of underneath space for other effective uses such as for shops and recreational activities is active in the present and can be upgraded with new transport infrastructure developments.

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