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Ropeway - As urban transport

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Abstract

The main purpose of conventional transit systems is to serve concentrated travel patterns in urban areas. Unconventional transit modes have also found success in specific conditions that handle different demand levels, urban environment patterns, and even natural constraints and barriers. In many urban contexts, in a country like Bangladesh the implementation of conventional public transportation systems may not permit the huge traffic alone. In such cases, transit agencies may look to unconventional modes of travel to serve the needs of the residents of Dhaka, Chittagong etc. metropolitan cities. Aerial ropeway transit (ART), a type of aerial transportation in which passengers are transported in cabins that are suspended and pulled by cables, is one of the options that has shown its implementation rise in the past decade in many countries of the world. This paper attempts to shed some light on implementation of ART technology in urban area of Chittagong, by presenting experiences with this technology from Bangladesh as well as other parts of the world including the reasons for building these systems and their service and operational characteristics as well as other case-specific information. The paper presents an assessment of experiences with these systems including their benefits and limitations as well as a discussion of the advancements needed for ART technologies to be a fully recognized transit mode. Till now ropeway has been being used for recreational purpose in only two places of Bangladesh. From this study it has been found that Ropeway can efficiently be used to reduce traffic congestion in urban areas and to create a recreational event in the monotonous life of a city. This paper also defines Ropeway as an environment-friendly transportation system.

Keywords: Ropeway Transportation, Environment-friendly, Traffic Congestion, Recreation, Flyovers.

1. Introduction

Transportation plays an important role in globalization but most types of transportation cause air pollution and use large amount of land. While it is heavily subsidized by government, good planning of transport is essential to make traffic flow and restrain urban sprawl. Transport in Bangladesh is an important part of the national economy. With continued economic growth and development, Dhaka, the capital of Bangladesh has begun to experience massive traffic congestion. Today, this is causing extreme frustration to the inhabitants of the

metropolitan which is the largest and most crowded city of the nation. Transport in Chittagong is similar to that of the capital, Dhaka. Chittagong is often called Bangladesh's commercial capital due to its diversified industrial base and seaport.

Fig. 1(a). Huge traffic causing delay.

Fig. 1(b). Gas emission.

Fig. 1(c). Risky road crossing.

Fig. 1(d). Water logging.

Fig. 1. Various problems related to traffic congestion.

The Chittagong City Corporation (CCC) is responsible for governing municipal areas in the Chittagong Metropolitan Area. The Chittagong Development Authority (CDA) is responsible for implementing the city's urban planning. As the population of the city has begun to grow extensively, the CDA has undertaken some transportation initiatives aimed at reducing the traffic congestion in Chittagong. Under this plan, the CDA has constructed some flyovers and expanded the existing roads within the city. In Bangladesh, there are more than 2,50,000 vehicle and Bangladesh's huge population and current infrastructure, frequent traffic jams waste valuable fuel and time and makes travel very unpleasant and difficult. Furthermore, it makes the existing public transport very inefficient and most importantly adds unbearable and unsafe levels of noise and hazardous air pollution to an already unregulated country. Traffic congestion changes during the day, and planning for trips is becoming impossible. It is a condition on transport networks that occurs as use increases, and is characterized by slower speeds, longer trip times, and increased vehicular queuing. Traffic congestion is no fun for anyone, but it's deadly for public transport. In a word, country loses its huge amount of

working hours and investors. Hence it hampers economic growth & national development of the country. Some problems have been identified in the congested areas.

Fig. 2(a). Complexo do Alemao, Brazil.

Fig. 2(b). Teleferico Bicentenario CPT project.

Fig. 2. Ropeway transport (Gondola Lifts).

- When buses and trams are stuck in traffic jams they fall behind schedule and this means that more people will be waiting at the next stops, they fall even further behind schedule leading to bunching and compounding delays. A common scene of huge traffic jam in GEC Circle, Chittagong has been shown in Figure 1a.
- Wasted fuel increases air pollution by emitting Carbon-di-oxide and other poisonous gases. The noise levels and pollution cause stress in most people and lead to many life-threatening medical conditions such as cardiovascular diseases and blood pressure related ailments. Emission from a public bus has been shown in Figure 1b.
- There has been an alarming rise in road accidents, significantly highway accidents in Bangladesh over the past few years. Sometimes people ignore traffic movement and cross the roads unconsciously thus creating collisions. This type of ignorance has been shown in Figure 1c.
- Disruption of traffic movement arises due to traditional water logging problem caused by tidal flow or heavy rainfall. Normal traffic movement is hampered creating traffic jam in Hat-Bazar area and people lose their valuable time that can be easily understood by Figure 1d.
- In Bangladesh most of the times, construction materials such as- stone chips, bricks, brick bats, cement bags, reinforcing steels etc. are seen to be kept beside the construction place, which block the roads partially. Due to this behavior of unconscious people roads become narrower which hampers traffic movement.
- Traffic congestion imposes large costs, primarily in terms of lost time. Bunched buses and delays make public transport unattractive for customers and increase operational costs. As a non-productive activity for most people, congestion reduces regional economic health.
- Traffic impacts almost the entire body. Effects on mental health, annoyance and somnipathy (sleep disturbance), chronically high levels of cortisol and adrenaline (epinephrine) hormones, stress, fatigue and headaches are symptoms of severe disorders.

In recent years Bangladesh is badly in need of new modes of transport which will reduce the distress of our travels. The researchers and designers are always looking for new and

improved ways to sort out these problems in the most effective ways possible. One such emerging technology is the 'Ropeway Transportation'. Almost 45 countries of 6 continents use different types of ropeway for transporting men and goods both in hilly and urban areas (Transportation Research Board 89th Annual Meeting 2010).

Fig. 3(a). Sheikh Russel Eco-Park.

Fig. 3(b). Meghla Parjatan Complex.

Fig. 3. Ropeways of Bangladesh.

1.1 Ropeway transportation

Ropeway is a means of transport that can transport people and goods. It can be operated in the places where road construction is impractical and costly. Certain limit of goods or people can be transported with the help of electricity. In the hilly remote countries, rope-way transport system may be suitable means.

Table 1
Passenger Ropeway Project**,** California State Polytechnic University

Location	From central campus to an upper terminal	Type of Ropeway	Fixed-grip, 2-person "open-air" gondola
Length	500 m	Operating Speed	1.5 m/sec
Elevation Change	50 m	Location of Proposed Ropeway	Seismic risk zone 4
Daily Demand of Passenger	5,820 persons	The Ropeway Cost	About $5.6 million
Numbers of Carrier Needed	56	Annual Operating Cost	About $547,500
Intermediate Towers (nos)	3	Funding	From transportation enhancement programs, student fees

The underlying technology of cable cars has been around for almost a century, where it has been applied mostly in terrain-challenged recreational contexts (i.e. in ski resorts) to transport skiers and tourists from the bottom to the top of the mountains and vice versa. In more recent times, the cost-effectiveness and flexibility of aerial lifts has seen increases of gondola lift being integrated into urban public transport systems. There are several types of ropeways. Two of them has been shown in Figure 2. In our country, ropeways are installed and used only in two places. One is located in the "Meghla Parjatan Complex", Bandarban and the other is in the "Sheikh Russel Aviary and Eco-Park", Rangunia, Chittagong under the supervision of Bangladesh Forest Department. Both of these are constructed in hilly areas to

ease out travelling of tourists and to amuse them. In "Meghla Parjatan Complex" they have the first ever cable car system in Bangladesh. The Cable Car Way of the "Sheikh Russel Eco-Park" is the longest and the 2nd cable car system in Bangladesh. It is one type of aerial gondola lift and installed by an Indian company "Conveyor and Ropeway Service". These two systems have been shown in Figure 3.

Fig. 4. Passenger Ropeway Project, California.

A gondola lift built by the Leitner-Poma Group now spans the Complexo do Alemao allowing residents a faster commute. It is popularly called "Bondinho do Alemao". It is a group of favelas (low-income historically informal neighborhoods) in the North Zone of Rio de Janeiro, Brazil. On July 8, 2011, Super Via began operating the cable car, the first mass transit aerial lift passenger system in Brazil. The system consists of 152 gondolas, each of which can carry 10 passengers, eight seated and two standing, and is 3.5 km in length. The system has been shown in Figure 2a.

Table 2
Teleferico Bicentenario CPT Project

Location	Located in the communes of Providencia and Huechuraba	Numbers of Intermediate Nodes	Three (Costanera Center, Cerro San Cristobal and Ciudad Empresarial)
Length	3.2km	Daily Service Time	17 hours
Demand of Passenger	3,000 passengers per hour per direction	Travel Time Reduction	By nearly 70% to 13 minutes.
Type of Ropeway	147;10-person urban gondola	The Ropeway Cost	US$80 million
Intermediate Towers	26	Max. Ticket Cost	US$0.90

A passenger ropeway was planned and designed for the California State Polytechnic University, Pomona campus. The project fulfilled the requirements of a capstone senior design course in civil engineering for 10 supervised undergraduate students. The system has been shown in Figure 4. The details of the passenger ropeway are tabulated in Table 1.
Chilean Public Works Minister Alberto Undurraga released tender details for an urban gondola in the Chilean capital of Santiago. The system will be known as the Teleferico Bicentenario. The gondola will be launched in 2022. The system has been shown in Figure

2b. The details of the urban gondola are tabulated in Table 2. Traffic congestion is the curse of unplanned urbanization. The causes of severe traffic congestion are to be investigated. For the reduction of traffic jam on urban roadway, a suitable solution is to be found out. Various modes of transport which are causing environment pollution should be replaced by a better and economic technique. From the above discussions, the following objectives have been chosen for the present investigation.

- To suggest for introduceing a new mode of environment-friendly transport system.
- To reduce traffic congestion by providing this new transport system in urban road of Chittagong city.
- To introduce a recreational transport system in the monotonous urban life.

2. Methodology

Road transports are being hampered due to enormous problems created by traffic congestion. To overcome this situation, a sustainable and effective solution has to be implemented. Regular transportation systems can be aided by introducing ropeway transport beneath flyovers. The total investigation has been done by the following ways which are given in Figure 5.

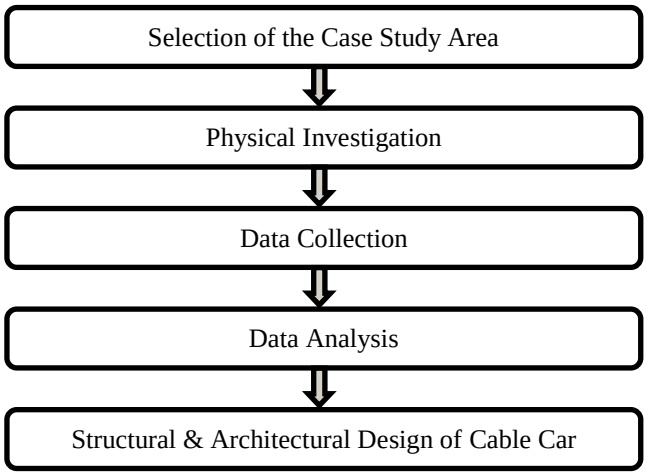

Fig. 5. Work Flow Diagram of the Present Study.

2.1 Selection of study area

Construction work of a 5.2 km flyover from Muradpur to Lalkhan Bazar has been going on. Due to the flyover construction in Muradpur area, huge traffic congestion is being created every day at Bahaddarhat, Muradpur and Gate No. 2. The CDA is responsible for the development of the area under consideration. Commuters in Chittagong city are experiencing acute sufferings for gridlock every day as under-construction flyovers have shrunk space for traffic. The size of the roads along the projects site has turned narrower due to the construction work forcing the vehicles to move slowly. Traffic police sources said that traffic congestion witnesses an increase in every month. Slow vehicular movement due to dilapidated roads and narrow roads in flyover construction areas causes severe traffic sandals.

Moreover numerous wire-houses of several renowned industries are situated near Muradpur and Gate No. 2 junction. Huge volume of heavily loaded Lorries travels this path every day. Various important government and non-government official buildings are also located there. For these reasons, traffic gathers to this area more. That's why this area has been selected as the case study area for the present study.

Table 3
Details of Cable Car System of Sheikh Russel Eco-Park

Type of Cable Car	Aerial Gondola Lift.
Type of Anchorage	Double Grip System.
Bucket	Height- 6.5 ft , Length/Width- 5 ft, Weight- 350 kg, Material- Fibre.
Hanger	Height- 4.26 ft, Type- Curved Hollow Square Steel.
Type of Cable / Wire	Diameter- 34mm, Length- 2400 m (Full Rotation) Own Weight- More than 10 tonn. Weight Carrying Capacity- More than 1 tonn (Including Factor of Safety).
Speed of Cable Car	Three Types of speed- Low, Medium and High. Medium speed is maintained nearly 9.72 kmph.
Properties of Motor	Main Motor- 100 HP, Other Motors- 5.5 HP. Shaft joint with main motor @ gear ratio 1:10.
Source and Usage of Power	Electricity powered by Power Development Board (PDB), Usage- 120 kB/hr.
Alternative Source of Power	Generator in case of absence of electricity having capacity of 160 kVA for lower base station and 20 kVA for upper base station. Diesel Req.- 30 lit, 3-hase 14-40 rpm.
Braking System	Hydraulic Disk Brake.
Other Tools	2 lines of Electric cable, 4 lines of Sensor cable. A seperate rail track and pulling techniques are installed in both base stations to derail the buckets. It is a manually operated and economic method.
Cost of the Project	BDT 200 million.
Name and Address of the Company	Conveyor & Ropeway Services Private Ltd. No. 75C, Park Street, Kolkata-700016, West Bengal, India Sandeepan Vishwas (Marketing Manager), Phone: +91-8043042507.

2.2 Physical investigation

A detail reconnaissance survey has been conducted to assess the present condition of the study area which has provided a guideline for necessary surveys required for this research. Another visit has been paid to Sheikh Russel Eco-Park situated at Rangunia, Chittagong. This park facilitates its visitors with a cable car system which is a great source of amusement and adventure. Refreshing and magnificent views are seen from Cable Trolley Car.The detailed information are colleced from the Managerial Engineer of the park's cable car system. The configurations of the systems are given in Table 3.

2.3 Data collection

- In order to conduct the installation of a ropeway system, some vital information is needed to be acquired. The main component responsible for creating traffic jam is the numbers of vehicle travelled along the road. This information can be gathered by conducting traffic volume study on the route Muradpur to Gate No. 2. Here the traffic volume data has been collected from a previous researchwhich is shown in Table 4.
- Each ropeway system has to be supported via two base stations and a number of intermediate towers . Construction of these towers within the busy urban road of Chittagong city is difficult because a large portion of road width is acquired by government for construction of flyovers. A number of flyovers are being constructed by CDA to ease out traffic problems.Such a flyover is the Muradpur-Lalkhan Bazar Flyover which is almost complete. The height of the flyover can be utilized by

suspending cable cars through cables, from the bottom of the girders, connected successively from pier to pier.For all of these, the Reduced Level (R.L) of the piers have to be known. The required R.L data (From Gate No. 2 Intersection to Muradpur intersection) have been collected which are given in Table 5.

– Along with these numerical data, other pictorial data of the piers are collected with dimension drawn by AutoC AD Software, which will help us to decide the installation process of ropeway system.

3. Structural and architectural design of ropeway

Design is the most important part of any civil engineering project. Feasibility and implementation of a project depends largely on proper design. For proper design of a ropeway system, huge amounts of data are required to be collected. According to thorough literature studies and physical investigations, a preliminary design has been done.

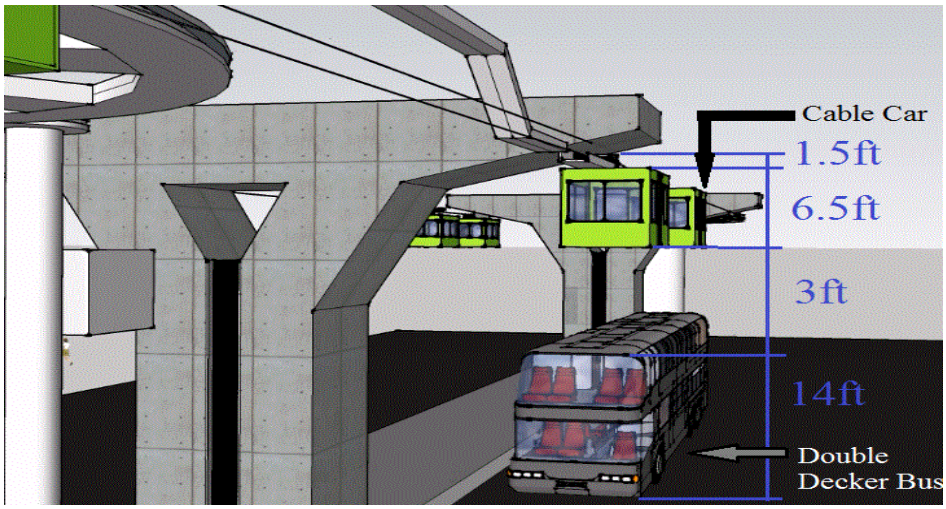

Fig. 6. Available height from the installation level up to the existing ground level.

Table 4
Volume, Capacity and Speed of the Road Sections (Field Survey 2013)

Components with Direction		Muradpur to GEC	GEC to Muradpur
Volume (PCU/hour)	Working Day	2275	2052
	Holiday	1724	1448
Capacity		1280	1278
Average Journey Speed (kmph)		19.34	17.81

3.1 Feasibility analysis

Regular vehicles of all types are using the underlying road which cannot be denied. To facilitate undisturbed traffic flow along the underlying road, the ropeway must be suspended in such a way that it will not face any collision with the highest vehicle, otherwise fatal accidents might occur. Various types of 3-Axle Truck/Lorry and Double Decker Buses are the two of the higher vehicles. So the maximum permissible height of a Double Decker Bus has been considered as 14 ft. according to international standard. The minimum available height from the installation level up to the existing ground level has been found to be 24.5 ft. So the rest 10.5 ft. can be used safely for the installation of the system with a minimum clear space of 3 ft. between the cable car and the underlying vehicles. The available height has been shown in Figure 6.

Table 5
R.L of the Piers of the Muradpur-Lalkhan Bazar Flyover (CDA)

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Pier No.	Pile Cap Top R.L (m PWD)	Pier Cap Top R.L (m PWD)	Y Top Level (m PWD)	Available Height [{(Col.3-Col.2)* 3.28}-5] (ft.)	Location
P56	10.015	21.254	19.254	31.864	Gate No. 2 Intersection
P57	10.098	21.049	19.049	30.919	Gate No. 2 Intersection
P58	9.959	20.847	18.847	30.713	Mid Section
P59	9.437	21.210	19.210	33.615	Mid Section
P60	9.044	21.050	19.050	34.380	Mid Section (Maximum)
P61	9.684	20.890	18.890	31.756	Mid Section
P62	9.460	20.730	18.730	31.966	Mid Section
P63	9.652	20.517	18.517	30.637	Mid Section
P64	9.607	20.304	18.304	30.086	Mid Section
P65	9.441	20.091	18.091	29.932	Mid Section
P66	9.463	19.878	17.878	29.161	Mid Section
P67	9.179	19.665	17.665	29.394	Mid Section
P68	9.098	19.452	17.452	28.961	Mid Section
P76	8.668	17.748	15.748	24.782	Mid Section
P77	8.558	17.731	15.731	25.087	Mid Section
P78	8.564	17.713	15.713	25.009	Mid Section
P79	8.685	17.695	15.695	24.552	Mid Section (Minimum)
P80	8.465	17.677	15.677	25.215	Mid Section
P83	8.105	17.632	15.632	26.245	Mid Section
P84	8.079	17.616	15.616	26.281	Mid Section
P85	7.911	17.616	15.616	26.832	Mid Section
P86	8.008	17.116	15.116	24.874	Mid Section
P87	8.070	17.116	15.116	24.671	Muradpur Intersection
P88	7.922	17.116	15.116	25.156	Muradpur Intersection

**3.28 is multiplied with the subtracted value to convert it from metre to feet.*
*** A value 5 is subtracted to cut up the elevation of existing ground level (EGL) from the pile cap top level (1.15 ft.), the height of the straight portion of the pier cap top (2.62 ft.), the height from the end of the straight portion upto the point of connection (1 ft.), rounding upto 5 ft.*

From above discussion it has become clearly visible that it is obviously possible to introduce a cable car system in the selected area. For supporting cables in intermediate points continuous piers are available and their heights are adequate enough. That's why a qualitative design has been done below.

4. Proposed ropeway

A ropeway system generally constitutes of several distinct components. The stations, the drive system, the line, the vehicles etc. are the major of them. All the components are shown at a glance in Figure 7. The details of the base stations have been shown in Figure 10.

4.1 The vehicle

The proposed vehicle will be of mono-cabled detachable urban gondola type. Cabins will be suspended and pulled by the same cable (a moving loop of cable). Cables will be set at

regular interval and can be detached from the cable at the terminal for loading and unloading. The bucket size has been decided as 8 ft. x 5 ft. x 6.5 ft. There will be 11 seats for the passengers' facility. 3 sides will be fabricated with closed glass windows and there will be a manually operated door in the front side. The portions without having glass will be made of fiber. A bucket model is shown in Figure 8.

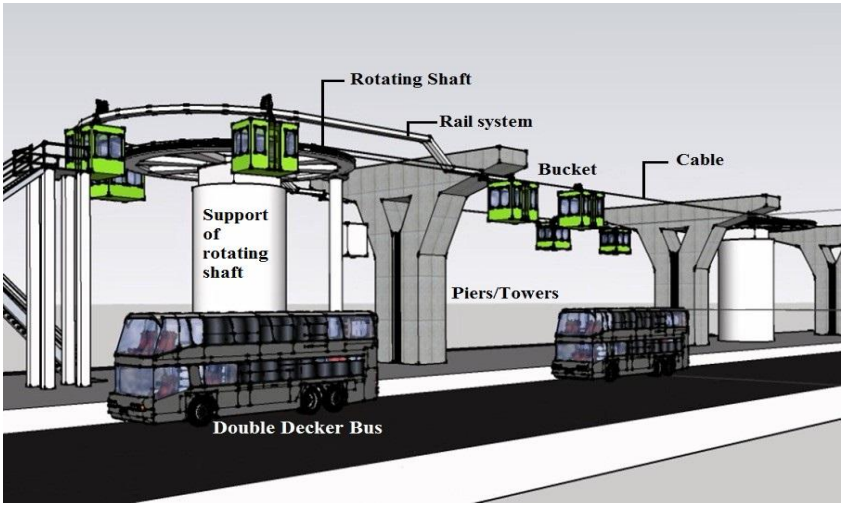

Fig. 7. Overall components of the proposed ropeway with base stations.

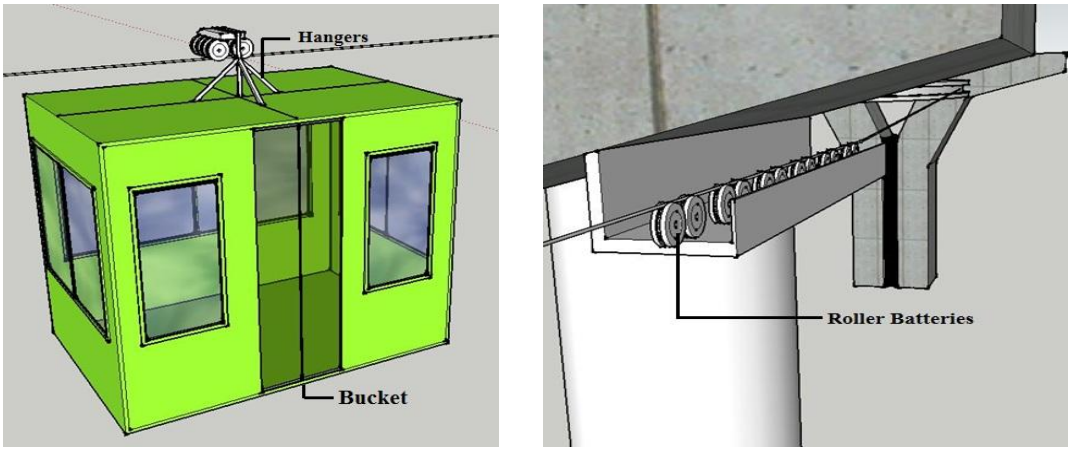

Fig. 8. The vehicle, hanger & roller batteries of the proposed ropeway.

4.2 The towers

Towers are compulsory part of line of any ropeway system. All the ropeway systems are dependent on towers which are identical in types and are to be installed seperately in several locations. But in our case, no towers will be constructed seperately. Here, the piers of the Muradpur Flyover will be used as support in case of towers. From physical investigation, it has been clarified that there is enough space beneath the flyover to install cable car system without disturbing traffic. there will be a minimum clear space of 3 ft and maximum 13 ft in between the bucket and the heighest type of vehicle i.e., double decker bus. A supporting pier is shown in Figure 9.

4.3 The base stations

There will be two base stations. One will be at the Muradpur junction in between pier no. 88 and 89. The another will be at the Gate No. 2 junction in between pier no. 55 and 56. The

base station of Muradpur will provide shelter to the control pulley, the supporting cable, the braking system and other functioning structures. Both stations will be used as loading and unloading platforms. The civil structure and foundation should be stable enough to bear all the impact and operating load of the system.Both stations are shown in Figure 10.

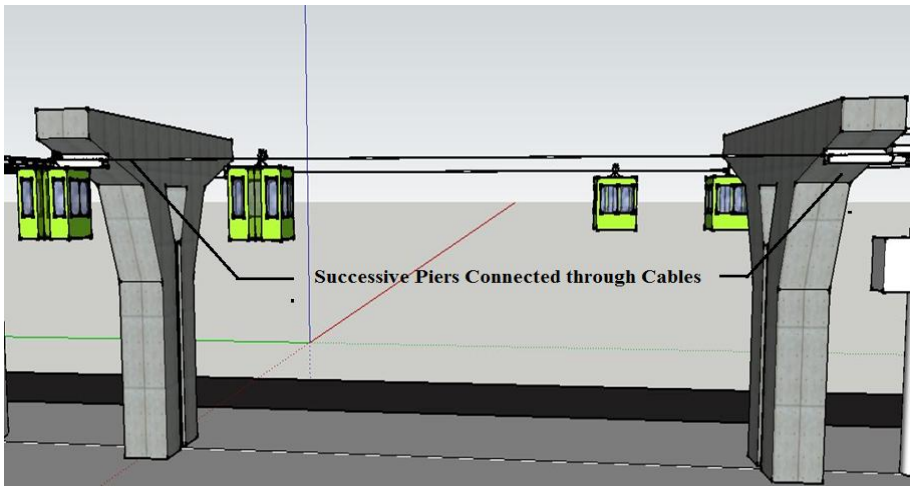

Fig. 9. Supporting pier as tower of the system.

4.4 The properties of cable

According to ANSI B77.1 (2006) suggests designing for 110% of the full carrier passenger load, at an average passenger weight of 77.1 kg. The tare weight of a two person cabriolet has been assumed to be about 100 kg. So the tare weight of the proposed cable will be 600 kg for 11 persons. The total weight have to be carried by the cable will be about 1450 kg. A detailed calculation is needed to find out the cable sag.

But that formula was not considered here because the deviation of the alignment of the cable between two successive piers is very negligible. Wind effect was also not considered. The diameter of the cable has been assumed to be 34mm, 6 strands wire. The length of the cable will be twice the cumulative distance between two base stations. The weight of the cable will vary with the length. The length has been found to be approximately 1190 m in one direction.

4.5 Mechanism of the system

The speed of rotation of the cable will be 15 kmph. The whole cable connection will be elastic. The tension in the cable can be controlled by increasing or decreasing length based on season or load. This will be done by using hydraulic jack. The main power source of the system will be electricity, provided by Bangladesh Power Development Board (BPDB) or any other non-government organization. There will be a main motor of 100 HP, which will run by electricity. There is a shaft jointed with the motor which will rotate 2 wheels in opposite direction. The gear ratio of the wheels will be 1:10. The cable will be connected with the bigger wheel and rotate accordingly in clockwise direction. Load shedding is a common problem in Bangladesh. It occurs frequently in day and night. That's why an alternate power source must be arranged. A 3-phase generator of 40 rpm will serve this purpose properly.

4.6 Official building

There will be two official buildings in both base stations. Official building includes ticket counter, control rooms, office room for the managerial personnel etc. There will also be a waiting room for the passengers.

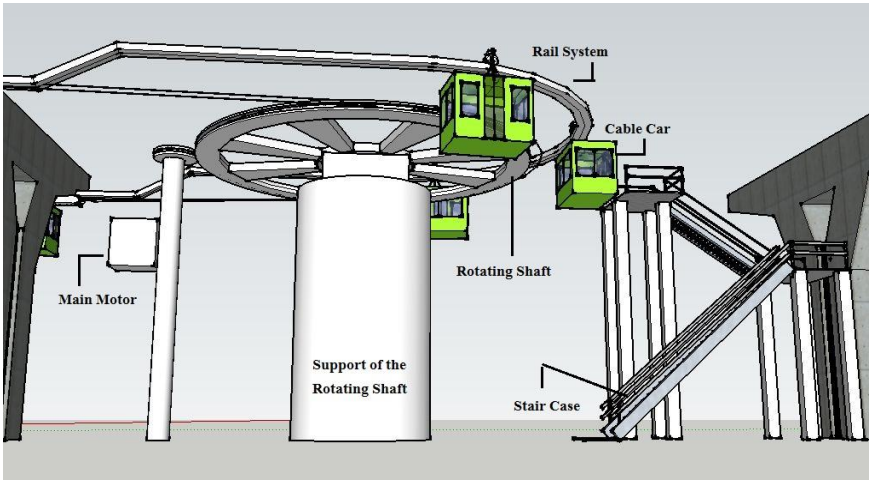

Fig. 10(a). The Muradpur base station.

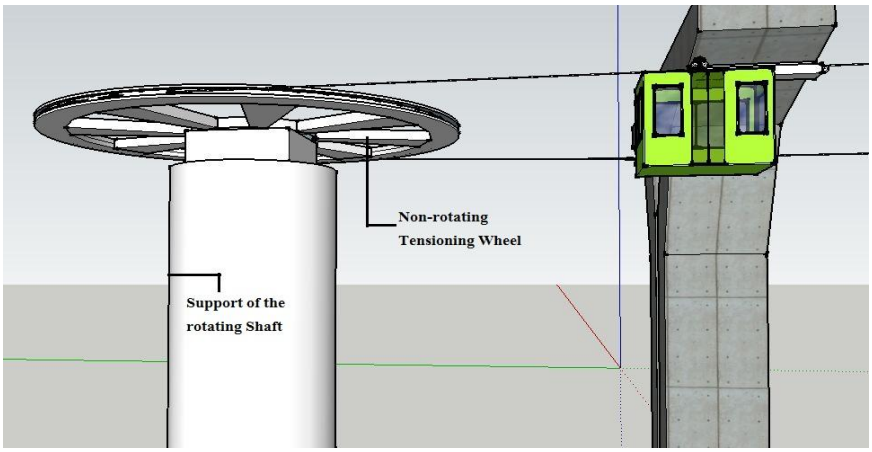

Fig. 10(b). The gate no. 2 base station.

Fig. 10. The base stations.

5. Discussion

Traffic congestion is a serious problem that needs immediate attention and sustainable solution. Traffic congestion on urban roads is the consequence of absence of proper urban planning. Traffic concerning authorities is trying to lessen this chaos by constructing flyovers and elevated expressways but things are not being fully effective. Now-a-days, in developing countries ropeway is an effective solution for urban traffic congestion. Ropeway transportation is generally used for transferring people along above the ground level. So it can be a factual solution in a region where water logging is a severe issue. The practical view of an existing ropeway situated in a nearby place is found to be useful to clear our ideas. We hope proper authorities will take appropriate measures to implement ropeway system. Though ropeway system in the proposed location is not capable of fully eradicating the traffic congestion, it can be used to carry some noticeable percentage of traffic. Moreover, the results found in this investigation are encouraging. So application of ropeway transportation can be possible in the field.

6. Conclusion

A new and efficient transportation system can reduce traffic congestion and various congestion-related problems to enhance economic and social activity. A cable car system with proper operational activities can be effective and mono-cabled detachable gondola lifts are

available in different designs. A ropeway of about 1200 m long can be expected to travel at a speed of 15 kmph which will cause 4.8min to reach from Muradpur to Gate No. 2 and vice versa. From the Flyover construction authority, it is known that these piers are only designed for pre-planned traffic load. If a ropeway system is to be introduced beneath flyover decks, the loading condition would be different though very negligible load compared to traffic load will be acted on this cable. It will be needed to check the tension and sag of cable of the proposed system before implementation in the field.

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