CONTENTS

SMART CITY ACTION PLAN ........................................ 2
- Project in Focus
  Coastal Road Ulwe – Connecting MTHL & Proposed Navi Mumbai International Airport

FEATURED COURSES ON UIJWAL ............................. 2

UIJWAL@SMART CITY LAB ................................ 3
- Interviews And Feedback
  Interviews of Training Attendees

INTRODUCTION ....................................................... 4

NEWS UPDATES ..................................................... 5

DATA SHEET .......................................................... 6
  Issues And Challenges Faced by The Bus Systems

SMART CITY CORNER .............................................. 8
- Emerging Ideas
  Social Equity in Accessing Public Transportation: Case Study of Job Access and Reverse Commute (JARC), USA
  Marketing the Public Bus: Case-Study of LA Metro’s Orange Line
  New Generation of Multi-Modal Nodes: Case-Study of Mobi-Pole In Rueil-Malmasion, France
- Innovation
  Reimagining The Humble Bus: Case Study of Select Bus Service (SBS), New York
  Modernisation of Operations Management: Role of ITS In Bus Operations at NMMT (Navi Mumbai) and The Netherlands
- Best practices
  Low Carbon Emission Bus Fleets: Case Study of Shenzhen, China
  Preventive Maintenance Practises for Bus Fleets: Case-Study of WMATA, Washington, USA and APSRTC, India.

ANNEXURES ............................................................ 24

BIBLIOGRAPHY ....................................................... 26

CIDCO SMART CITY LAB @ NIUA

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Coastal Road Ulwe

Connecting MTHL & Proposed Navi Mumbai International Airport

Background

Jawaharlal Nehru Port Trust (JNPT) established in 1989 is the largest container port in India. JNPT is currently handling almost 4.4 Million TEU. The port is expanding and is expected to handle 10 million TEUs by 2020-21. Presently, traffic from and to JNPT flows mainly two routes, i.e. through Nh3 and Nh5A. Aamra Marg, for distribution of cargo in Mumbai and other regions. Both the routes have port as the single point. Thus the port accessibility is currently from single point where traffic gets routed to Nh3 or Nh5A. This single point access creates a threat of limited capacity of the existing route and a grade junction just outside boundary of port which would be unable to meet the expected increase in traffic.

It is a serious threat that any blockage on Nh3 and Nh5A will disrupt the activities of port. With the upcoming Nh4B, a strong need is felt to provide a link that connects with the Mumbai Trans-Harbor Link (MTHL).

Toilet technologies, water management and solid and liquid waste management in rural areas

Leadership skills for top Management

24th to 28th September 2018

Effective Land acquisitions, resettlement and rehabilitation

24th to 28th September 2018

Conflict Management and negotiation skills

26th to 28th September 2018

UJWAL@SMART CITY LAB – INTERVIEWS AND FEEDBACK

Mr. Umesh Pote, Development Officer – Estate, Mts II
Managing self and others for higher performance – Management Development Institute, Gurgaon – 11th – 13th December 2017

How was your experience attending “Managing self and others for higher performance” from Management Development Institute? Can you please detail out few topics that made it more interesting?

This was my first visit to Gurugram, I am thankful to CIDCO and UJWAL for giving me an opportunity to undergo this excellent training. The structure of the training was nice; it was very interactive and not theoretical. The accommodation and the clarity of the training was good. The faculties were well qualified and thorough with their subjects. Contributing to self-development and management effectiveness, the basic motive of the training was to enhance the understanding of others and ourselves at workplace. They had included case studies, interactive sessions and psychometric assessments for our self-assessment and understanding. The session on communication carried a one-on-one basis and had direct interaction with other participants.

Do you think this course helped you in your current role and how do you relate this course to your daily life personally as well as professionally?

I joined CIDCO course all year back so I am still new to this organization. Coming from a private sector job, for me CIDCO was a different world altogether. Initially, I faced a few hurdles in adjusting to this environment. There were a few hindrances between my subordinates and me. Therefore, after coming back from the training, I started emphasising on trying to understand others’ perspective by conducting regular meetings and by identifying the hurdles we face in our daily routine. One of the module on interpersonal effectiveness was also beneficial. Although I am still assessing my efficiency after the training, but I can already see some improvements in my working style.

Who were the participants and how was your interaction with other participants?

The participants were from different organisations, it was mix of Public and Private sectors. They were participants from Ministry of Defence, Barco Electronics, Indiabulls, Bosch Ltd., O. P. Jindal Global University and a few participants from Nepal as well. The participants from Nepal belonged to different departments of the banking sector. Different people from different backgrounds sharing experiences was a good opportunity to learn from them and learn from their experiences. We shared many ideas and our knowledge as well.

What was the best part of this training? If you want to highlight anything in particular, understand your personality, how personality affects your behaviour and working as a leader: how to deal with persons of a different personality types. JHORI window concept gave us clarity on how to enhance interpersonal effectiveness. It was very interesting and informative session.

Do you think a similar course will benefit CIDCO employees? If yes, how?

I would definitely recommend this kind of training to all middle and senior level management employees of CIDCO. Managing Self and others for higher performance will certainly help in motivating self & others through effective leadership styles. People from middle level job, for me CIDCO was a different world altogether. Initially, I faced a few hurdles in adjusting to this environment. There were a few hindrances between my subordinates and me. Therefore, after coming back from the training, I started emphasising on trying to understand others’ perspective by conducting regular meetings and by identifying the hurdles we face in our daily routine. One of the module on interpersonal effectiveness was also beneficial. Although I am still assessing my efficiency after the training, but I can already see some improvements in my working style.

Who were the participants and how was your interaction with other participants?

There were 12 participants from all over India. In addition to CIDCO participants, some were from Military Engineering Services, Ordinance factory, Private sector, and State PWDs. It was mix of public and private sector. We interacted well within the course. We collaborated during discussion sessions and worked together to come up with solutions for various issues.

Do you think a similar course will benefit CIDCO employees? If yes, how?

Definitely, a similar programme will be helpful. Therefore, after coming back from the training, I started emphasising on trying to understand others’ perspective by conducting regular meetings and by identifying the hurdles we face in our daily routine. One of the module on interpersonal effectiveness was also beneficial. Although I am still assessing my efficiency after the training, but I can already see some improvements in my working style.

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The Purpose of Public Transportation

The purpose of transportation and mobility is to gain access to destinations, activities, services and goods. Accessing the spatially and temporally disjointed resources is the ultimate objective of all transportation modes (Bertolini & le Ciercq, 2003). Three assumptions about human behavior is considered while defining ‘accessibility’ (Bertolini & le Ciercq, 2003):

- People travel only to participate in spatially disjointed activities (like, work, recreation, home, etc.)
- People always require access to a large and diverse choice of activities around them.
- Travel cost and travel time, rather than distances, sets the limit to these possibilities.

From which, two development models can be derived:

- To connect the spatially disjointed resources – Have better infrastructure
- Provide the resources in closest proximity – Design multi-functional spaces

Currently, private motorized vehicles are the preferred means of mobility and the ‘bus’ while developing a transportation model. However, the focus from a ‘transport bias’ in urban mobility should move to a focus on the human right to equitable access to opportunities (UN-Habitat, 2013).

### Table: Public transport share in total trips across select countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Estimated</th>
<th>India</th>
<th>Australia</th>
<th>Brazil</th>
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<td></td>
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<td>24</td>
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### Source: KPMG, 2017

The Role of Buses In Urban Transportation

Having access to multiple modes of transportation is one of the most important elements of last-mile connectivity. While shared mobility remains at the heart of last-mile connectivity (Manning, 2017), bus transit systems also play an important role in any city’s urban transport network. Currently, the current transportation network in India faces many challenges like, increasing congestion, deteriorating air quality, increasing travel time, poor infrastructure, lack of data, etc. Much of it can be resolved by establishing a public transport network that is flexible and cost-effective. Bus transit over the years have come up as a cost-effective, flexible and an environment-friendly public transport (EMBARQ, 2010). They are healthier, safer than individual vehicles, improves access and creates community cohesion (Hanley, 2016). A bus network can play an important role in connecting a commuter from a local node to a regional node or a rapid transit station. A bus network of any city is highly specific to the demands and the context of the city. Therefore, to define a ‘good’ bus system can be rather difficult. However, it can be derived that a good system provides a reliable, safe, comfortable, fast and affordable means of transport. Some key factors for a successful bus system can be (EMBARQ, 2010):

- Strong political leadership for the decision making process
- Local institutions leading the technical planning for route reorganization
- Implementing bus priority
- Use of ICT for system performance monitoring and user feedback
- Managing subsidies to improve the quality of service

Although there are many policies and financing schemes (JNNURM, NITI etc.) dedicated for bus transportation, however, with limited resources it still struggles to sustain. Many cities have not been able to maintain the size of its bus fleet with the growth of its population (Shah foundation, 2016).

A bus transport network, over other modes, incurs lesser development costs for many reasons. Majorly, it works on the existing road infrastructure. This also gives them the capability to penetrate through the neighbourhoods. Unlike trams and metros, the setup and maintenance cost is lesser. Depending on the dynamics of user’s demand over the years, the routes of a single bus line can be changed multiple times without having much impact on the existing infrastructure. However, it is important that any transport network is setup in such a way that it fulfills the basic needs of mobility and optimizes the synergy between sustainability and accessibility (Bertolini & le Ciercq, 2003). To develop a transportation model that has the maximum impact on the current issues, it is important to:

- Develop a system that optimizes the value of the dispersed resources by identifying the locations and making them accessible).
- Develop a system that forecasts the traffic and demand patterns.

The design consideration for an effective bus transportation should cater to a variety of issues (EMBARQ, 2012):

- Bus priority system
- Social equity and access for disabled people
- Safety and personal security
- Coordination among the local stakeholders
- Effective data management
- Module-based design
- Change in transit needs over time
- Efficient maintenance and operations
- Funding

While developing a transit system, a location-based model is used for the development of a bus network. The approach can be traditional or simulation-based, depending on the available database and the pre-requisites of the agency. These models provide many crucial information for the probable lines, the location of the bus stops and the dynamics of the demand. Once established, the quality of the bus service depends on its capability of providing comfort, meeting the safety requirements and the deliverability of the available fleet (Glimury, 2014).

This special issue, dedicated for buses, looks into different good practices in India and around the world. Through different case studies, we look into various models in practice that helps in establishing and optimizing a bus transportation network.
**Issues And Challenges Faced By The Bus Systems**

**Current Statistics**
As per 2015-16 data from 47 State Road Transport Undertakings (SRTUs):

- Number of public buses: Approximately 140,000 buses
- Fleet utilization rate: 90.4%
- Occupancy ratio: 69.65%
- Staff to bus ratio: 5.17
- Passenger-kms per day: 1.48 billion
- Passengers per day: 68 million

*Source: Ministry of Road Transport and Highway, 2017*

**Increasing private vehicle ownership**
In India, as of March 2015, public buses constitute only 0.07% of the 210 million registered vehicles.

*Source: UITP, 2018*

**Inequity in access to public transportation**
People living in informal settlements have difficulty accessing bus stops and have longer commute time.

*Source: Wilbur Smith Associates, 2008*

**Increasing traffic congestion**
Private cars and two wheelers make up to 29% of the total trips yet they occupy 80% of the total space available, amounting to a congestion index of about 0.33.

*Source: Wilbur Smith Associates, 2008*

**Absentee of policies that commit budgets to bus transport**
Apart from Jawaharlal Nehru National Urban Renewal Mission (JnNURM) and National Urban Transport Policies (NUTP), there are very limited policies that fiscal support bus transportation.

*Source: Ministry of Road Transport and Highway, 2017; Wilbur Smith Associates, 2008*

**Low maintenance and inadequate bus fleets**
Buses carry 3 times more passengers per day than the Indian railways. Despite heavy reliance on the buses to commute, the bus fleet has significantly reduced over the years.

*Source: Ministry of Road Transport and Highway, 2017; Wilbur Smith Associates, 2008*

**Fragmented institutional framework leading to gaps in multi-modal integration**
Co-ordination among different authorities in planning and implementation of multi-modal integration is missing.

**Huge tax burden on public buses**
The total tax burden for public transport vehicles per vehicles-km is 2.6 times higher than that for private vehicles.

*Source: Sanjay Kumar Singh, 2012*

**Unsafe road infrastructure**
Increasing accidents and fatalities. Accidents took place in 2017 amongst which approximately 1,50,000 were fatalities.

*Source: Ministry of Road Transport, 2017*

**Increasing air pollution**
15 out of 30 cities in the world having the worst ambient PM2.5 pollution levels are in India.

*Source: NIUA, 2016*

**Lack of transportation data**
Complete lack of real-time transportation data on infrastructure, services, users and usage patterns through fare collection data.

*Source: Association of State Road Transport Undertaking, 2014*

**Financial Constraints**
On average, cost/km is more than the revenue/km.

*Source: Association of State Road Transport Undertaking, 2014*

**Gaps in last mile connectivity**
The reliance on NMT for short trips decreases with the lack of proper infrastructure like proper sidewalks, pedestrian crossways, bicycle pathways, proper lighting of the streets, etc.

**Increasing traffic congestion**
Private cars and two wheelers make up to 29% of the total trips yet they occupy 80% of the total space available, amounting to a congestion index of about 0.33.

*Source: Wilbur Smith Associates, 2008*
Social Equity in Accessing Public Transportation:

- **Case Study of Job Access And Reverse Commute (JARC), USA**

**Introduction**
Transportation planning has always focused on urban mobility, reducing traffic congestion in cities and providing access to major locations (Karan, 2014). However, often ignored is the social equity in access to public transportation. With route planning focused on demand forecasting, low-income neighborhoods and other vulnerable populations are often neglected due to budget constraints (Transport for America, 2018). These vulnerable communities rely mostly on public transportation.

In the realm of transportation, social equity refers to providing affordable and equitable access to public transport. The vulnerable population here includes children, students, elderly, handicapped and low-income individuals. Social equity refers to an equitable distribution of impacts; both benefits and cost (Lambert, 2018). Equity is more than an equitable distribution of impacts; both benefits and low-income individuals. Social equity refers to an equitable distribution of impacts; both benefits and cost (Litman, 2018). Social equity refers to an equitable distribution of impacts; both benefits and cost (Litman, 2018). Equity is more than an equitable distribution of impacts; both benefits and cost (Litman, 2018). Social equity refers to an equitable distribution of impacts; both benefits and cost (Litman, 2018). Equity is more than an equitable distribution of impacts; both benefits and low-income individuals.

To address transportation equity, the vulnerable community should be involved in the planning process and projects prioritised based on their needs. It is equally important to collect the relevant data and measure progress to ensure program effectiveness in reaching beneficiaries and achieving the target goals. This article looks into the case study of JARC to understand the steps taken by FTA to implement social equity through transportation planning.

**Case study: Job Access and Reverse Commute (JARC) in the USA**

The main aim of Job Access and Reverse Commute (JARC) program, administered by the Federal Transit Administration (FTA) (1998-2012), was to assist low-income individuals in accessing employment, job training and childcare services. Low-income individuals often find the inner-city urban environments difficult to access. The major tasks undertaken were: to fill gaps in transportation services for welfare recipients and other low-income individuals (FTA, 2016). Made available for three years, it administered project funding on a cost-sharing basis. Federal funds covered up to 80 percent of the capital and planning activity and up to 50 percent of operating costs.

Some of the programs implemented under JARC were about expanding fixed-route public transit routes, late-night and weekend service, shuttle service, guaranteed ride home service, ride-sharing, carpooling and so on (FTA, 2007). The policy incentive while designing the transportation policy encouraged the local, regional and state agencies to collaborate with each other (Sandouvel, Peterson, and Hunt, 2009). Apart from organizing trips, JARC also utilized its funds for information-based and capital investment programs (Figure 1).

For example: Camden, New Jersey provides shuttle service that operates three times a day matching the three work shifts at the industrial park. Phoenix, Arizona runs service through western suburban connecting community college with residential area and retail stores. Sanford, Maine provides demand-based van service for getting to work from early morning until late night.

**Response to the Program**

For the financial year 2009, 910 projects were funded under the JARC program. Out of these, 44% served in large urban areas, 31% in non-urbanized or rural communities and 25% in small-urbanized areas. JARC supported projects provided 27.3 million one-way trips, made $3.8 million jobs accessible, which included 35.3 million low-wage jobs and 7.7 million jobs were likely reached (Commonwealth Environmental Systems, Inc, 2011).

The two performance measures used by FTA to evaluate JARC-funded projects are: Number of jobs accessed and Number of rides provided (one-way trips).

**Figure 1: JARC Services by Type, 2006 – 2009**

The services under JARC were in response to critical issues highlighted and put forth by the community. Upon implementation, there were positive and significant effects on the mobility, employment and economic outcome of the low-income individuals. A majority of the beneficiaries were less educated and low-income groups. Thus, the benefits of the program was reaching the disadvantaged positively.

Key policy implication of JARC program is to improve public transportation in order to address the social needs. Economic outcomes of the low-income population is positively impacted through accessible and affordable public transportation. During its run, JARC focused on operating rides, in improving the information and infrastructural capacity of the service region. This combination of capacity building helped many of these JARC funded programs to sustain by themselves, even after the end of its tenure in 2009. However, depending on the availability of institutional and grassroots support, different cities responded to JARC in different ways (Sandouvel, Peterson and Hunt, 2009). If the program had an experimental setup for evaluation, the lasting impact of JARC funding was not entirely clear (Sandouvel, Peterson and Hunt, 2009). JARC is one of the multiple possible and creative solutions that agencies can implement to support disadvantaged communities and promote equity in public transportation.

As of 2012, combining JARC with the existing Urbanized Area Formula Program and the Formula Grants for Rural Areas Program enabled JARC programs to apply for funding through the urban area transportation program (GAO, 2017). This was mainly due to changes in JARC’s formula program status where separate funding was not available anymore. However, when GAO interviewed few JARC services, two-thirds of them reported to continue the program in some form of service.

**Conclusion**

"Every program’s stance on equity should be assessed by asking the following questions: Do its monetary efforts need to be identified by a disadvantaged community? Are the benefits associated with the significant, rather than incidental? Are benefits targeting the low-income residents? Does it avoid substantial harms to the community?"

(Marcantoni and Kermer, 2016)

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(Marcantoni and Kermer, 2016)
Marketing the Public Bus:

Case-Study Of La Metro's Orange Line

A shift towards public transportation is pivotal in dealing with issues such as traffic congestion and poor air quality. Although, one of the reasons for commuters to not shift to public transport is due to the highly competitive marketplace alongside private automobile companies. Private automobile companies invest billions of dollars every year to (Carrigan, Arpi & Weber, 2011):

- Maintain their image,
- Cultivate customer’s mind-set,
- and, push their products into the market by creating demand

In the year 2009 alone, major automobile companies spent over US$ 23 billion globally on advertisements (Advertising Age Group, 2010). Such intensive marketing from the private sector highlights the need for public bus corporations to engage in cost-effective marketing campaigns to increase their ridership.

Public bus corporations can use various marketing strategies to (EMBARQ India, 2010):
- Attract new riders
- Retain existing riders
- Improve public and political support
- Educate and inform users about the facilities, and manage the public narrative through communication

When combined with a good service, branding and marketing encourages people to use the public bus network and thereby reduces the reliance on private vehicles. In this article, the case study of the Orange Line in Los Angeles Meto focuses on their branding, marketing campaigns and user education activities. Few other examples highlight similar aspects of marketing the public transit.

Metro's Orange Line BRTs in Los Angeles, California

The Orange Line, a Bus Rapid Transit System (BRTS) started its service in 2005 in the San Fernando Valley area, as a part of the Los Angeles Metro. It is 29 kilometres long, has dedicated bus lanes and exclusive right-of-way. Metro (also the name of the operating agency) took many public outreach and engagement initiatives to disseminate the benefits of the public transportation and encouraged the commuters to make a shift. Following are some of the strategies:

Branding

The brand of the Orange Line is incorporated into the system in numerous ways. The Orange Line is designed to be a part of the Metro's vast rail network and provides equivalent quality of service. Similarly, it is marketed as part of the Metro and not as a separate entity. This idea is conveyed by keeping the Orange Line brand consistent with the familiar Metro's colour code instead of typical numbers for bus routes. (Figure 1). The colour scheme is carried over and incorporated into multiple components of the service, such as vehicles, bus stations, signs, maps, seating, etc. (Carrigan, Arpi & Weber, 2011).

Marketing campaigns

During the construction of Orange Line, the management regularly posted construction updates and other information through regional newspapers, the acoustic barriers of their construction site, town hall meetings, flyers, etc. In a pre-launch survey, it was found that people were confused if the Orange line was a bus or a train service. Through "It's…" promotional campaign, the management answered the questions raised by the people and highlighted the various advantages of the new line (Carrigan, Arpi & Weber, 2011).

The campaign, passed through public approval, helped in securing funding of over $40 billion over 30 years for major transit and highway projects. The discretionary ridership of those who have a car but still use the public transit, also increased from 24% to 36%. Metro's "unfavorable" ratings dropped from 27 percent to 12 percent and "strongly favorable" ratings increased by 17 percent. Public awareness of the Metro is now at 95 percent. (Lejeune, 2013)

User Education

User education is an essential aspect of launching and promoting the public transit. Free rides, study tours and safety instructions are some ways to encourage the community and acclimatize them to the transit system. During the launch of the Orange Line, the Metro provided free rides on the opening weekend of operations to familiarize the public with the BRTS service and eliminate any uncertainties that existed before. Also, the 

Conclusion

From the Los Angeles case study, through many interventions LA Metro built a strong brand image. Building up a strong brand image is important to communicate the core value of an organization, inform the people about the services and encourage them to use it often. Marketing strategies can help transit organizations reach their organizational target of increased public awareness, increased use of services and other specific goals. They can be cost-effectively utilized by the public transit organization. However, marketing campaigns should only promote services that already exist, and the transit corporations must be prepared to handle the generated demand.

Janmarg, Ahmedabad

In Ahmedabad, to acclimate the public with BRTS, the agency built a prototype of the BRTS station one year before Janmarg became operational. The prototype showcased the station designs and educated people on how to use the facilities. This user education policy also provided an opportunity to gather feedback from the public and make necessary design changes before starting the operations. Janmarg also offered free rides to the public for the first 100 days of operations (Carrigan, Arpi & Weber, 2011).

Other Examples

Metrobus, Mexico City

In Mexico City, Collectivo drivers often behaved in a manner that was unprofessional, such as inattentive driving, speeding, and not respecting public order. This led to the implementation of a new program called the "Metrobus Movement," which included training programs for drivers, improving the infrastructure, and enforcing stricter traffic rules. This resulted in a decrease in accidents and an increase in public satisfaction with the service.

Source: EMBARQ India, 2010

Go Metro

In 2005, Metro expanded its service to include the Orange Line, a BRTS network. The Orange Line was designed to be a part of the Metro's vast rail network and provides equivalent quality of service. The brand of the Orange Line is incorporated into the system, and the management regularly posted construction updates and other information through regional newspapers, the acoustic barriers of their construction site, town hall meetings, flyers, etc. In a pre-launch survey, it was found that people were confused if the Orange line was a bus or a train service. Through the "It's…" promotional campaign, the management answered the questions raised by the people and highlighted the various advantages of the new line.
New Generation of Multi-Modal Nodes:

- Case-Study of Mobi-Pole In Rueil-Malmaison, France

Introduction

The Greater Paris is an ambitious urban project that aims at reinforcing the development of the French capital region (Île-de-France). This project is being made possible through a massive reorganization of the transport system (Art.1 Law of the Greater Paris). As part of this initiative, Île-de-France Mobility (IDFM), the transport authority of the ÎDF Region in charge of the mobility master plan, launched a series of public consultations to understand the expectation of the citizen regarding bus transportation and to adapt infrastructures accordingly.

Among other topics, the results of these consultations converge to the question of multimodal nodes. In Paris bus transportation, this multimodal connection appears more important as buses are often complementary to a heavier transport mode (to connect with metro) (Avril et al., 2002). By adapting multimodal infrastructure, from an architectural or urban perspective,ULBs can enhance the quality of the services, ensure security and reliability of the bus transport system.

These new infrastructures help in:
- Balancing the territory structure of the Parisian region
- Optimizing the existing transport

Improving the bus system in the Parisian region (and later in the Greater Paris) is necessary to integrate it in a larger multimodal and comprehensive network. To improve the efficiency and the quality of the bus system, new features are developed to efficiently connect the bus system to the rest of the transport system (RET, train, tram), and to ensure a better user experience. Both territorial dynamics and the end users expectations seems to converge toward the crucial aspect of multimodal nodes. This type of infrastructure addresses both the technical challenge of the network management (balancing the traffic, covering the entire territory and ensuring efficient connection with other transport modes) and the end user demands regarding the quality of the service. The French capital is already strongly structured by multimodal nodes and is now in the process of developing the next generation of infrastructure.

This article will present an overview of the challenges faced by the bus system in the Parisian region, and the evolutions of the multimodal nodes (from an urban or an architectural perspective) to address the challenges.

Main features of bus mobility in IDF

The main features of bus mobility in IDF can be understood through two perspectives:

1. **Territorial approach**
   - Implemented nearly 70 years ago, the Parisian bus network is consciously divided into two parts:
     - **Inner ring network (Inter-Métropole)**: The vehicular traffic is extremely dense and the streets are currently facing a situation of overcapacity. To get a picture, 100 bus/hours are passing every morning on the famous Rivoli road, but the occupancy in the buses is only 20% (ECOM, 2016). The Parisian network is punctuated with numerous connectivity nodes.
   - **Outer ring network (Inter-Île-de-France)**: Bus routes converging to a single station at the centre of the city.

2. **Systematic approach**
   - The main network of nodes are specified through two perspectives:
     - **Inner ring network (Inter-Métropole)**: 10 bus lines out of 50 do not pass through these nodes. (Source: STIF, 2016)
     - **Outer ring network (Inter-Île-de-France)**: To reach proximity infrastructures/services (school, sport facilities, cultural etc.

Current scenario of Multi-pole

Through the recent consultations launched by the STIF, Parisians expressed their needs regarding bus transportation. According to the final report (Figure 5), they mainly asked for STIF (Grand Paris bus des 2020):
- Better multimodal connections
- Integrating every bus station with different modes of transport (bikes, car, pedestrian, buses and so on)
- Better waiting conditions
- Improving standard of bus terminal to ‘ensure the visibility of the bus network and ease the connection between the two modes. It is crucial. However, the train station is located in the northern extremity of Rueil. Thus, the inhabitants have two options to reach the centre of Paris: the RER station in Rueil or the tram/train station in Suresnes, one of the north beaching city of Rueil.

The Greater Paris is being reinforced through a massive reorganization of the transport system. This new type of node aims at implementing better traveling and connection conditions for the 50,000 daily users of the station, at the same time also creating a vibrant and dynamic public space. In Rueil-Malmaison, being the broader municipality in the region “Haut de Seine” (2454 hectares) (Figure 5), buses are the main public transport mean for the approximately 79,000 residents. It takes almost 20 minutes to reach La Defense by RER. As Ruel is strongly polarized due its proximity with Paris, joining the RER station is crucial. This, and the train station is located in the northern extremity of Rueil. Thus, the inhabitants have two options to reach the centre of Paris: the RER station in Rueil or the tram/train station in Suresnes, one of the north beaching city of Rueil. The Ruel-Malmaison infrastructure articulates the 50,000 daily users commuting through the RER station and 20,000 daily users from the bus services. Out of these, three-fourths of daily bus users make a transit exchange to RER (Suresnes). Therefore ensuring an efficient connection between the two modes is crucial.

User Point of View

The bus network in Paris is often considered complementary to other transport means, especially the metro and RER network (high-speed inter-city). Commuters use the bus for short distances (2.5-3 km in average). In 41% of the cases, the user declare taking the bus to join a metro or a train station (STIF, july 2016). Survey results (figure 4) confirm that this tendency is very likely to increase in the future (STIF, November 2016).

Figure 4: Abstract of the "Grand Paris des Bus" (The Greater Paris Buses) public consultation

User’s need for using public transport

<table>
<thead>
<tr>
<th>User’s need for using public transport</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>To reach proximity infrastructures/services</td>
<td>47%</td>
</tr>
<tr>
<td>To reach transport mode</td>
<td>36%</td>
</tr>
<tr>
<td>To reach at workplace</td>
<td>23%</td>
</tr>
</tbody>
</table>

Figure 5: Map of the western suburbs of Paris

User's need for using public transport for people to coordinate between bus and RER.

To encourage interactions and diversity among the commuters, 316 car parking spots, 20 motorbikes places for people to coordinate between bus and RER.

To reach proximity infrastructures/services (school, sport facilities, cultural etc.

To reach transport mode

To reach at workplace

Similar Examples

Other multimodal nodes in downtown Paris are also working with similar principals. The station “Châtelet les Halles” was completely renewed in 2016. In this project, the architecture of the building (the Canopy) has been re-thought according to end-user’s perspective, to link the bus network to the underground metro and RER station. Within 75,000 daily users, 5 metro lines, 3 RER lines and 14 bus lines, this station is the centre of the Parisian transport network.
Reimagining The Humble Bus:

- Case Study of Select Bus Service (SBS), New York

**Introduction**

Traditionally, buses transported people, sharing the same road and governed by the same rules as other vehicles. In heavily congested areas, the average speed of the bus has drastically reduced to a crawl. To address this problem of congestion, some cities have taken an innovative approach in the interaction a bus has with its environment. Bus rapid transit (BRT) is a bus route mostly segregated from traffic, has traffic lights that prioritizes its movement, and has high platforms that provide a safe and expedited process in boarding. BRT has become a popular alternative to rail mode of transit; however, it still faces similar hurdles such as land use constraints (eg. to designate lanes and build platforms) and a higher than average expenditure when compared to launching a regular bus route.

**Select Bus Service**

New York City has taken a unique approach in enhancing the bus while opting for a cheaper and quicker implementation option. Select Bus Service (SBS) is a hybrid of BRT and a regular bus. It is not as physically intrusive as a BRT but still has many beneficial characteristics. The uniqueness of SBS can be seen through its three characteristics:

- **Off-board ticketing**
- **Bus Lanes**
- **Traffic prioritization**

**Off-board Ticketing**

Regular bus stops every few blocks, where boarding is completed through the front door, an elongated process that takes several minutes at busier stops. Currently, people enter the bus through the front door only and insert their MetroCard into a fare machine, which can take three to four seconds to process its validity. In busier stops, this drastically increases the dwell time (time the bus sits at a stop) and the overall commute time. With bus stops spaced every few blocks, this slow boarding process repeats multiple times.

SBS improves this situation by optimizing bus stop spacing and having off-board ticketing. Machines installed at each stop that enables passengers to purchase tickets before boarding. As pictured above, passengers place their MetroCard into the yellow slip of the machine and in turn, receive a payment confirmation receipt. This permits seamless boarding through all three doors (as all SBS buses are articulated), decreasing dwell time at each stop. Ticket inspectors who randomly enter SBS buses to verify the receipts deter free riders. SBS buses are equipped with dark red cotta paint to enhance the visibility of the lane, it helps the motorists to avoid parking and driving in the bus lanes during the restricted hours. Dedicated bus lanes are implemented along the bus corridor in areas with higher congestion, they come in different configurations:

1. **Curbside bus lanes** – The bus lanes alongside the curbs of the side. The bus bullet aligns the bus stops with the bus lanes. The lanes are restricted for buses for certain hours of the day and can be used by the regular traffic during other hours.
2. **Offset bus lanes** – Travel lanes for buses one lane away from the curb. These lanes are also used by emergency vehicles and vehicles turning right at an intersection.

**Traffic Prioritization**

Additionally, some streets are altered in a way that decrease the amount of turns that cars can make. Priority traffic lights permit buses to be precise in movement, minimizing stops at intersections. According to the New York City Department of Transportation, 21% of runtime for buses is spent at traffic lights. With priority traffic lights, a bus can communicate with the light as it approaches the intersection, shortening a red light or extending a green light (Image 3). To ensure that the alteration of traffic lights does not compromise road safety, vehicle volumes, width of the streets, and pedestrian crossings need to be taken into account when introducing this technology at an intersection.

**Challenges**

While the benefits of SBS have not been as impressive as originally projected, it has increased reliability and operating speed. New York City Transit buses have been notorious for traversing clogged streets at just over ten-kilometres per hour; however, SBS has been able to raise the average speed by five or six kilometres per hour. While this may not seem like an enormous gain, it provides a more reliable commute for passengers to reach transfer points to subway lines, as these buses are less subject to ever-changing traffic conditions.

The main problems of SBS are due to a lack of stringent enforcement. Often, commercial vehicles utilize bus-only lanes and block the buses. With the installation of additional traffic cameras, an uptick in police enforcement, and severe fines, it is possible to clear the bus lanes. Additionally, traffic planners could reconfigure roads and bus lanes in a way that discourage unauthorized vehicles from blocking the lanes. As with any public transit, only a strong political or administrative will to make bold decisions in prioritizing SBS will allow it to achieve its full potential. As people clamour for more efficient transit services, New York City is taking strides in attaining it by pushing for more SBS routes (Image 3) and taking appropriate steps in optimizing it.

**Conclusion**

The characteristics of SBS give planners the ability to designate bus-only lanes in avenues, while leaving others untouched, optimizing the traffic flow. While a BRT is quicker, it is initially spatially intrusive to traffic flows and is a more permanent feature. SBS lanes can be introduced quicker, as only the current stops need to be altered and existing lanes need to be modified. With minimal construction needed, SBS can be deployed swiftly compared to a BRT. By increasing the number available in enhancing the bus-only lanes, SBS is increasing its reliability over a traditional bus and giving commuters a quicker alternative for public mobility.

**Image 1** – For regular buses at New York, queues form, as each customer needs to slip their MetroCards

**Image 2** – Machines present at SBS stops expedite the boarding process. (Source: MTA-NY)

**Image 3** – Signal timing diagrams showing the prioritization as per the location of the buses. Source: mta.gov

**Image 4** – Proposed 22 SBS connections to be implemented by 2027. Source: NYC Mayor’s office/DOT

The content of this article does not reflect the opinion of NOKIA. Responsibility for the information and views expressed lies entirely with the contributing author.
Modernisation of Operations Management:

- Role of ITS In Bus Operations at NMMT (Navi Mumbai) and The Netherlands

Introduction

Management and operations in transportation systems is defined as an “integrated approach to optimize the performance of the existing infrastructure through implementation of multi-modal, cross-jurisdictional systems, services and projects” (FHWA, 2013). It focuses on the transit vehicle operations directly and how they interact with the transit users. Increasing the performance of an existing infrastructure can improve operational performance, reduce long-term costs and save time (Abou-Senna, Rashed, Navarro & Abdelke folks, 2018). The components under operational systems are (ADB and MoUD, 2008; CDO, 2012): Route planning, Capacity augmentation, Ticketing, fare collection and revenue management, Operations management (Schedule span, type of services, driving rules, etc.), Customer’s orientation, Passenger information, Operator’s efficiency, Human resource development, Quality Management (including safety, security, operator’s training, etc.)

It is important that the transport infrastructure always adapt to the constant growth of the city and its never-ending demand. Information Technology Services (ITS) provides many solutions and models that can help in data collection, forecasting the demand, tracking the vehicles and the passenger movement. All major cities, like Amsterdam, Sydney, Sao Paolo, London, etc. make extensive use of technology in their bus operations and maintenance. Their centralised command centre and they track the buses through GPS (EMBARQ, 2010).

The benefits of management and operations strategies like these brings forth safer travel, reduced delay in commute, improved reliability, lesser wasted fuel, cleaner air, etc. (FHWA, 2017). Earlier, we have identified that Indian cities have started implementing ITS to help improve its transportation planning and management. In this article, we will see how through implementation of ITS bus authorities have modernised the operations management system. This article looks into the case study of NMMT, Navi Mumbai and The Netherlands.

Case Study 1 - Real-Time Data Management At Nmmt, Navi Mumbai

Currently, NMMT has a bus fleet of 467 buses running on 75 routes. It experiences a daily ridership of approximately 3 lac passengers and generates an approximate daily income of Rs. 37-40 lacs. All the bus lines add up to a total route length of 1895 kms. and have an average length of 26 kms. The average headway is about 15 minutes, the maximum being 65 minutes and a minimum of 1-20 minutes (“NMMT City Bus System”, 2017). NMMT has allocated the buses among 3 depots (Turbhe, Asudgaon and Ghansoli) and 13 bus terminals.

On similar grounds of other major cities mentioned earlier, NMMT has also established a centralised command centre. It tracks the daily movement in the buses to make its operations and maintenance more efficient. They have implemented the real-time data management system through these eight modules:

1. Automatic Vehicle Locator System (AVLS)

   AVLS captures the real-time on-board location and helps create a substantial database where the progress of the bus is stored on a second-to-second basis (Hounsell, Shrestha and Wong, 2012). It receives and stores the bus location and also the bus event information through an on-board GPS. Through this system, the location speed and the route of the buses can be tracked. From the current location of the buses being tracked and comparing it with an average gives the estimated time to reach a destination. Through the same module, the estimated time for the bus to reach a bus-stop is also calculated.

Over 90% of the buses have a GPS installed in them. GPS boxes in the older buses are being installed externally, while the newer buses come with an inbuilt GPS. Based on the movement of the bus, its status (Running, idle, on-trip standby, off-trip standby) gets constantly updated at the control centre, which is useful during the peak hours.

Fig 1 - The total number of GPS enabled buses distributed among the three depots

2. Passenger Information System (PIS)

   Deriving the information from AVLS, the control centre constantly tracks the real-time information of the buses. It calculates the estimated arrival and travel time of the buses based on the historical travel data across different road segments and the time of the day. The commuters can receive this information (estimated arrival and travel time) through the mobile application. The passengers can also get information about the bus drivers and report for incidents.

   The passenger movement is counted from the tickets count, through which the peak and off-peak hours are estimated. NMMT uses this information to dispatch the buses and at the same time maintain a reserve stock of them. The reserve stock is useful in case of unpremeditated demand or breakdown of a bus.

   The control centre constantly records and analyses the real-time information of the buses and passenger’s commute. AVLS and PIS provides a substantial database, which is useful in the maintenance and operations of the buses. Based on the data provided, the control centre is able to:

   - Forecast demand
   - Avoid bus-bunching

3. Control command centre

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Check for incident reports
Interact with the staff and the commuters
Maintain the database

4. Incident Management
The control centre keeps a track of the bus operators and if their buses are following the route or not. They also maintain the incident reports submitted by the commuters. In cases of any issue noticed by the centre or submitted by the commuter, the control centre resolves it immediately. Operational faults and break-downs are resolved by the respective depots, thus:
- Releases the work load on a single depot
- Allows depots to deploy reserve buses effectively

5. Mobile application
Information like the schedule of the buses, its operators, etc. are available on the mobile application. Through the mobile application, the commuters are capable of:
- Checking the nearest bus stops and routes
- Checking the available buses and the waiting time
- Setting a time for notification to leave their place of origin and reach the bus stops
- Checking the details of the bus and the bus operators
- Reporting an incident

6. Business Intelligence, Financial management system and Enterprise management system
The control centre creates different real-time reports for the general manager, the accounts department and the employees of NMMT. These reports help them to monitor and analyse the performance of the buses and the operating staff.

7. Scheduling and planning
The scheduling of the buses at the initial stages follows the traditional approach by overlapping On-site surveys. Activities according to the land-use maps and The number of buses available.

The number of buses on a particular route are increased or reduced according to the demand of the commuters. This demand is tracked online through the count of the tickets.

8. Automatic Fare Collection System
There are many ways to register a trips made by the commuters, through on-board ticketing, monthly passes and through a mobile application.

All of these are recorded and maintained to analyse the daily ridership in the buses. Through which, the peak and off-peak hours are estimated. The same online system is also used to create stock correction reports.

Case Study 2 – Network Of Bus Corridors In The Netherlands
Any transportation system is based on potential user’s demand. This demand forms the technical foundations for designing the system, planning operations and the financial feasibility (EMBARQ, 2012). Route planning of any public transport should always be in response to the needs of the local neighborhood and in consultation with the local stakeholders. It should be laid out to serve the maximum commuters in the most efficient way.

Following a similar ideology, the development or improvement of the public transport in the Netherlands is done gradually (from a regular bus to a dedicated infrastructure) on the basis of the integral vision of the change in transport requirements (number of passengers) and the development of the locations (with the increase in number of residents and jobs) (Public transport in the Netherlands, 2016).

This data to document the necessity to develop a route is collected through many ITS models. An estimated amount of €120 million is budgeted for 75 projects in total, for data collection models such as cluster travel information, MultiModal information, dynamic traffic management, etc. (Ministry of Infrastructure and Environment, The Netherlands, 2012).

The data is processed into travel information, for both unimodal and multimodal modes, through apps such as 9392 (public transportation) and ANWB (Dutch Automobile Club). The travel information is useful for improved accessibility and traffic flows. The appropriate use of ITS architecture leads to co-ordinated and standardised development of a cohesive framework of technical and information structures (Ministry of Infrastructure and Environment, The Netherlands, 2012).

The integration of different services is also one of the key features of Dutch public transport. It follows a hierarchy of fast (peak hour), local and community, and demand responsive services. The bus operators setup their time-tables around a ‘transfer-scheme’ to be able to find a convenient way to connect to a metro/rail. The ticketing and fare system is also integrated. Use of Strippenkaart, steqabonnement or ov-chipkaart (tickets and pre-paid cards) are capable to allow the commuters to travel using the same fare and tickets.

Take-Aways
The real-time data management system implemented in NMMT is still young and constantly upgrading. However, a positive impact in the operations can be seen. Since the implementation of this system, there has been a significant reduction in the incident reports (Fig. 2). The statistics suggest that cases of over-speeding of buses is almost negligible now.

Through constant tracking of the buses and implementation of this system, NMMT is now capable of:
- Monitoring the services of the buses
- Managing operational maintenance and reports
- Real-time incident reporting and resolving
- Relieving performance data for post process applications
- Reducing the manual data collection

Efficient data collection, availability of travel information and integration among different operators are key for developing an efficient operational model. A coherent and integrated route plan ensures user-friendliness and higher usage of the bus services. It has a direct influence on the passenger demand, reduced travel time and the operating costs; hence, also on the revenues (ADB and NLD, 2008). Indian ULBs have also started developing similar models, however, the process of implementation is rather slower and complex. With an increasing use of ITS in bus operations, open data collection and disseminating travel information is getting easier and more efficient.
Low Carbon Emission Bus Fleets:

Case Study of Shenzhen, China

Introduction

In the recent years, climate change and increasing pollution levels in urban areas have brought our attention to the detrimental impact of the fossil fuel-based transportation sector on the environment. In 2010, the transportation sector alone contributed to 14% of 2010 global greenhouse gas (GHG) emissions. 95% of the global transportation energy in 2010 came from fossil fuels that are highly polluting (EPA, 2018). Considerable reduction in the GHG emissions can be achieved and urban air quality improved by shifting to low-emission vehicles that run on clean fuel. Low emission vehicles use alternative fuels such as biodiesel, natural gas, hydrogen (fuel cells), ethanol, propane, compressed biogas, biomethane, electricity and so on. Electric vehicles are the cleanest amongst these, with zero tailpipe emissions during operations. Every zero-emission pure electric bus eliminates about 1.86 tons of CO₂ per year over its lifespan of 12 years, which is similar to removing 27 cars off the road (US Department of Transportation, 2016). This article takes the case study of Shenzhen, China to understand the initiatives taken by their authorities to develop the largest electric bus fleet in the world.

Case Study of Shenzhen: World's Largest Electric Bus Fleets

Located in the Pearl Delta region, the city of Shenzhen is a major financial, industrial and technological center in Guangdong Province, China. It has developed rapidly due to its special economic zone (SEZ) status and its proximity to Hong Kong. As of 2015, Shenzhen is home to about 12.6 million residents and covers an area of 1,995 square kilometers (Shenzhen Bureau of Statistics, 2016).

In Shenzhen, 0.5 percent of the city's total vehicle fleet is diesel buses, but they accounted for 20 percent of the city's transport emissions (Ying, 2017). Switching to electric vehicles was one of the solutions to improve air quality substantially in the industrial hubs. The city of Shenzhen began introducing electric buses (e-buses) in 2009 and since then they have pushed for 100% electrification of its bus fleets. As of 2018, Shenzhen has electrified its entire fleet of 16,359 buses (Lu, Xue & Zhou, 2018).

Cost Management

Even with the current advancements in technology, the upfront cost of an e-bus is still higher than that of a diesel bus, and public transportation organizations had to find ways to deal with the massive investment deficit. The authorities in Shenzhen took initiatives at many levels to be able to implement 100% electrification of their buses. It was made possible through:

- Subsidies: Capital investment in the form of national and local subsidies made it possible to electrify 16,359 buses in Shenzhen. For example, a 12-meter e-bus in Shenzhen received $150,000 in government subsidy covering more than half of the vehicle's price (Shenzhen Municipal Development and Reform Commission, 2016). Apart from the e-buses, the government has also provided clean energy vehicles by providing financial subsidies for using charging facilities for other private electric vehicles.
- Cost of the Batteries: According to the bus operators, the high upfront cost of e-buses (2 to 4 times of a traditional diesel bus) is one of the major hindrances in adapting to this technology (Shenzhen Urban Transport Planning & Design Institute, 2017).
- Local Support: Shenzhen has a strong local technical and industrial support in the form of home-grown high-tech companies like Build Your Dreams (BYD). Over the last three years, through technological innovation and mass production, BYD has managed to bring down their battery costs by half. These have a longer lifetime, faster charging time and better safety features. BYD, central and city government officials have worked together to achieve Shenzhen’s sustainable urban development goals through corporate innovation and government policy (Chen & Ogan, 2016).

Defining the Role of the Stakeholders

A change of battery is required once during the lifetime of the bus and costs almost half the price of the buses. Shenzhen bus operators worked out a procurement deal with the manufacturers to provide a warranty on vehicles and batteries. Manufacturers providing warranty for the vehicles and batteries reduced a significant part of the maintenance cost for the bus operators (Lu, Xue & Zhou, 2018). This distributed the financial risks among the major stakeholders. Some of the major stakeholders include:

- Central and local government
- E-bus operators (Shenzhen Bus Group Ltd)
- E-bus manufacturers (Build Your Dreams)
- Power supplier and distributor (Shenzhen Power Supply Bureau Ltd)
- Charging infrastructure operator (Potevio Ltd)

Other stakeholders also had to adapt to the new technology. For example, the charging infrastructure operator had to procure more charging stations. The Local Support in Shenzhen was possible through local technical innovation and mass production, which resulted in a reduction of battery costs by half (Ying, 2017).

Benefits Achieved

The environmental benefits of 100% electrification of the city bus fleet have been highly positive. In the year 2015, Shenzhen saved standard fuel of 84,000 tons and reduced 150,000 tons of GHG emissions (C40, 2018). The estimate shows that the total average mileages of one e-bus will be approximately 174.4 kms with reductions of (Ying, 2017):

- 48.6 tons of nitrogen oxides
- 62.1 tons of non-methane hydrocarbons

Figure 2: TCO comparison for e-buses and diesel buses with different annual distance travelled

Figure 3: Illustration of major players and their interactive role

Figure 4: Electric bus adoption in Shenzhen, China

Table 1: Lithium-ion battery's price survey – volume weighted average

| Year | Battery pack price per kWh | Battery price | TCO Diesel bus | 1.80 | 1.60 | 1.40 | Cost Management

| 2012 | 1277 | 48.6 tons of nitrogen oxides | 30,000 | 2014 | 120,000 | Leasing bus and charging infrastructure | 697 | E-bus manufacturers (Build Your Dreams) | 40,000 | 10,000 | The engine does not produce any noise | 100,000 | 62.1 tons of non-methane hydrocarbons | 250 kwh e-bus, slow depot charging | Charging infrastructure operator (Potevio Ltd) | 2016 | Central and local government | Providing financial subsidies for using charging facilities for other private electric vehicles | 500 | 350 kWh e-bus, slow depot charging | 1.2 tons of particulate matter

By implementing 100% e-buses fleet, the city saves 345,000 tons of fossil fuel per year. Apart from reducing air pollution, e-buses have other benefits (Ying, 2017):

- They are more fuel-efficient
- The cost of fuel is lower
- The engine does not produce any noise

Take-Aways

Major cities, like London, Amsterdam, France, etc., have started switching to electric buses in their own capacities, the case of Shenzhen is a bit different since it from this case study, major takeaways are that it is possible to convert traditional diesel bus fleets to clean fleets by:

- Encouraging electric vehicles through subsidies
- Having strong technical assistance from local manufacturing industry (like electric vehicles and batteries)
- Leasing bus and charging infrastructure
- Getting buses and battery warranty from the manufacturer
- Outsourcing maintenance and operation services

The city of Shenzhen is working to reduce pollution and improve air quality with the use of clean fuel in their transportation sector. From the current state, the city of Shenzhen has now turned its focus to electrify their taxis by 2020 (Gosin, 2018). However, this case study also shows that in the current scenario, only large cities that have the financial capacity to provide subsidies can attempt for electrification of their public buses.
Preventive Maintenance Practices for Bus Fleets

Case-Study of WMATA, Washington, USA And APSRTC, India

Introduction
Routine bus maintenance is crucial for the smooth functioning of an effective bus system. Preventive maintenance is defined as a servicing undertaken by technicians to maintain equipment in a satisfactory operating condition, to avoid failures or major defects (US Department of Defence, 2008). It helps anticipate and initiate repairs, improves safety, prevent service interruptions and critical mechanical failure on the road. Regular maintenance of bus fleets has the benefit (National Academies of Sciences, Engineering, and Medicine, 2015) of:
- Preventing mechanical failures.
- Achieving zero breakdowns during service.
- Reducing Green House Gas (GHG) emissions.
- Lowering fuel costs by improving fuel efficiency.
- Promoting passenger satisfaction and public safety.
- Improving occupancy rate and public service.
- Increasing life service of buses.

Preventive maintenance measures are usually conducted at fixed intervals. These intervals are based on legal requirements, the operating agency’s prior experience, manufacturer’s warranty requirements or merely borrowed from other agencies. The preventive maintenance interval suggested in the United States is 6,000 to 10,000 miles or about 10,000 kilometres (National Academies of Sciences, Engineering, and Medicine, 2015). In India, APSRTC (2016) reports doing the same within 9000 to 15,000 kilometres depending on the type of operation, age and model of the bus. Similarly, BMTC (2012) performs a docking preventive maintenance at a span of 20,000 kms, apart from the periodic 1,2, 3 and 10-days maintenance. Apart from Preventive Maintenance Inspections (PMI), daily service line inspections are also undertaken. Through the case studies of WMATA and APSRTC, this article looks into the measures, needs and advantages of Preventive Maintenance.

CASE STUDY 1: Washington Metropolitan Area Transit Authority (WMATA): Use of AVM to optimize preventive maintenance
Metropolitan service at Washington Metropolitan Area Transit Authority (WMATA) provides service in Washington DC. With a fleet of 1500 buses, WMATA covers an area of 1500 square miles. It serves a population of 1.9 million and logs about 134 million trips annually. As of 2010, the fleet also contains 460 CNG buses and 50 hybrid buses, with steps being taken to increase the number of low emission buses. WMATA has a preventive maintenance interval of 6000 miles (National Academies of Sciences, Engineering, and Medicine, 2015).

The benefits of preventive maintenance through AVM are as follows (National Academies of Sciences, Engineering, and Medicine, 2015):
- Senior technicians are able to conduct a trend analysis from the review of past issues.
- The trend analysis generates a work order on detecting the actions required to correct the defect. This relieves the technicians from diagnostic work.
- Fault detections are faster and more accurate.
- Using AVM has enabled the collection of system components data on a daily basis, instead of PMs of 10,000 kms. This regular check on components has helped prevent initial problems from growing into critical issues.
- Loaded with quality information and analyses, WMATA is able to request certain technical specifications and carry out maintenance.
- The agency also uses the data to check for procedural compliance of drivers.
- The agency is able to save money from warranty claims.

CASE STUDY 2: APSRTC: Maintenance practices to maximize fuel economy

Preventive maintenance measures are used to maximize fuel economy. Improvement in fuel efficiency is another major benefit that stems from regular fleet maintenance. In 2005-06, APSRTC reported an average that they spent about 25% of their operating cost on fuel (Ministry of Road Transport, 2017). Therefore, even a small improvement in fuel efficiency significantly reduces the operating cost. The cost saved can be diverted into critical service repairs and improvements.

Andhra Pradesh State Road Transport Corporation (APSRTC) covers over 4.3 million kilometres and carries about 6.5 million passengers. As of 2015, it has 12,512 buses. In an effort to maximize the fuel economy and reduce GHG emissions, Energy Sector Management Assistance Program developed bus maintenance guidelines and implemented them in the state of Andhra Pradesh in APSRTC in 2011. Some of the recommended actions include (ESMAP, 2011):
- Managing corrective work orders.
- Setting fuel economy benchmark.
- Publicly communicating fuel economy results.
- Automation of data collection and analysis.
- Using data to refine preventive maintenance intervals.
- Conducting two-tiered checks at the depot and central maintenance facility.
- Conducting periodic and random checks of repairs.
- Having an independent QA/QC team.
- Training mechanics on critical systems.
- Training for low performing drivers.
- Providing awards as incentives for technicians and drivers.

A key recommendation was to conduct two-tier preventive maintenance checks that are well documented and standardized as operating procedures. Junior to mid-level mechanics can conduct the Tier 1 (Annexe 3) maintenance while the senior mechanics are responsible for conducting Tier 2 (Annexe 3) maintenance to ensure that quality is maintained throughout. The above recommendations were implemented and tested over a period of 10 weeks in 2011. Under APSRTC, 3 bus depots were chosen to do the field testing, namely Bharkatpura (BPT) depot in Hyderabad, Governorpet (GPT1) and Governorpet2 (GPT2) in Vijayawada. In each of these depots, 10 buses and 20 drivers performing on fuel economy were identified each month. Maintenance for low performing buses and trainings on good driving practices for the drivers was conducted to maximize the fuel economy (ESMAP, 2011).

From the subset of buses that underwent maintenance, the results show that the maintenance had a positive and significant effect on the fuel economy. Average fuel economy benefits range from 6 to 10 percent. Figure 1 shows the fuel economy improvements from repairs at Bharkatpura Depot in Hyderabad, Governorpet1 (GVPT1) in Vijayawada (years) per annum along with the maintenance activities that newer buses (< 3 years) (ESMAP, 2011).

The trainings for the drivers included instructions for best practices on on-road driving and the depot’s (National Academies of Sciences, Engineering, and Medicine, 2015). Some of the recommended actions include (ESMAP, 2011):
- Training for low performing drivers.
- Providing awards as incentives for technicians and drivers.
- Conducting periodic and random checks of repairs.
- Having an independent QA/QC team.
- Training mechanics on critical systems.
- Conducting two-tiered checks at the depot.
- Conducting random and period checks of repairs.
- Promoting the use of fuel efficient driving techniques.

The performance boosted their pride and their workmanship, and the drivers were satisfied with the benefits from reduced GHG emissions.

Conclusion
In WMATA, the availability of real-time data has equipped the agency to engage in preventive maintenance measures actively, thereby ensuring smooth functioning of the bus system in Washington. Through data analysis, the agency has developed a deep understanding of their priorities and specific requirements in bus maintenance. ISSUES in APSRTC are dealt with at the earliest possibility, rather than allowing it to develop into a critical and more expensive problem to fix.

In APSRTC’s case study, test results from Hyderabad and Vijayawada highlight the importance of preventive maintenance and on-\road training of bus drivers to maximize on the fuel economy. With cost-benefit ratios of 1.94 for new buses and 2.31 for old buses, the recommended maintenance activities prove to be cost-effective for large operators with in-house maintenance capacity. These results would be more effective on considering the benefits from reduced GHG emissions and improved safety. The APSRTC case study has demonstrated that overall efficiency and safety can be achieved by a cost-effective and comprehensive plan through maintenance activities.
### Annex 1 - An example of a daily non-critical exemptions report generated:

#### Exception Summary Report

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Component</th>
<th>Description</th>
<th>Code</th>
<th>Last Occurred</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>2616</td>
<td>Engine</td>
<td>Engine Coolant Temperature Above 212 Degrees</td>
<td>M0851F</td>
<td>07/15/09 08:11 AM</td>
<td>1</td>
</tr>
<tr>
<td>2616</td>
<td>Safety/Security</td>
<td>Brake and Throttle Interlock Exception</td>
<td>M0851F</td>
<td>07/15/09 08:11 AM</td>
<td>1</td>
</tr>
<tr>
<td>2616</td>
<td>Fuel System</td>
<td>Fuel Valve Fail Signal</td>
<td>M0851F</td>
<td>07/15/09 08:11 AM</td>
<td>1</td>
</tr>
<tr>
<td>2616</td>
<td>Brake</td>
<td>Tractor Brake Stroke - Axle 1 Left - Brake oversstruck: the brake rod has not activated during a braking operation.</td>
<td>M0851F</td>
<td>07/15/09 08:11 AM</td>
<td>1</td>
</tr>
</tbody>
</table>

### ANNEXURES

#### Annex 2: Tier 1 Checks At The Local Bus Depot To Improve Fuel Economy

<table>
<thead>
<tr>
<th>Component</th>
<th>Check</th>
<th>Pass/Fail Criterion And Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIres/ wheels</td>
<td>1. Check tire inflation</td>
<td>1. Pressure meets specification or add air</td>
</tr>
<tr>
<td></td>
<td>2. Check for free rolling of wheels</td>
<td>2. Wheels rotated easily by hand or check brakes</td>
</tr>
<tr>
<td></td>
<td>3. Wheel bearing lubrication</td>
<td>3. No grinding noise in bearings or lubricate as required</td>
</tr>
<tr>
<td>Brakes</td>
<td>4. Check for free play of brake pedals</td>
<td>4. Excessive free play requires brake pedal linkage adjustment</td>
</tr>
<tr>
<td></td>
<td>5. Check gap between brake linings and drum/disc</td>
<td>5. Gap must be visible, or liners reinstalled</td>
</tr>
<tr>
<td></td>
<td>6. Check caliper boot and wear adjuster cap</td>
<td>6. Wear adjuster should not be at setting limit, or replace liner</td>
</tr>
<tr>
<td></td>
<td>7. Check for brake retraction after pedal release</td>
<td>7. Liners move away from rotor on brake release, or else check for brake hydraulic/airline defects</td>
</tr>
<tr>
<td>Driveshaft/ Axles</td>
<td>8. Check lubrication of driveshaft joints, axle bearings and differential</td>
<td>8. Lack of visible lubricant and/or noise in joints and bearings signify need for lubrication</td>
</tr>
<tr>
<td></td>
<td>9. Examine tightness of driveline and gearbox mounts</td>
<td>9. Visible driveline and gearbox vibration indicates need to tighten mounts</td>
</tr>
<tr>
<td>Accelerator/ Clutch pedal</td>
<td>10. Check clutch pedal linings</td>
<td>10. Excessive play requires linkage adjustment</td>
</tr>
<tr>
<td></td>
<td>11. Check Accelerator linings</td>
<td>11. Excessive play requires linkage adjustment</td>
</tr>
<tr>
<td>Engine-related</td>
<td>12. Check accelerator return spring</td>
<td>12. Accelerator snaps back on release or else replace spring</td>
</tr>
<tr>
<td></td>
<td>13. Check air cleaner for clogging</td>
<td>13. Visible dirt on air cleaner, replace</td>
</tr>
<tr>
<td></td>
<td>14. Check exhaust pipe for blockage</td>
<td>14. Check for any foreign objects or broken catalyst in pipe</td>
</tr>
<tr>
<td></td>
<td>15. Check on-board diagnostics if applicable</td>
<td>15. Electronics check for diagnostic codes indicating any failure</td>
</tr>
<tr>
<td></td>
<td>16. Check for visible smoke on snap acceleration</td>
<td>16. Smoke opacity over 20 percent indicates engine problem, send to central maintenance facility</td>
</tr>
<tr>
<td>Air conditioner-related</td>
<td>17. Check tension in compressor belt drive</td>
<td>17. Tighten belts as required or replace if worn significantly</td>
</tr>
<tr>
<td></td>
<td>18. Check for refrigerant pressure</td>
<td>18. Low pressure indicates refrigerant leaks and leaks should be identified and fixed</td>
</tr>
<tr>
<td></td>
<td>19. Check for compressor damage</td>
<td>19. Replace or repair as required</td>
</tr>
</tbody>
</table>

#### Source: ESMAP, 2011

### Annex 3: Tier 2 checks at the central bus maintenance facility to improve fuel economy

<table>
<thead>
<tr>
<th>Component</th>
<th>Check</th>
<th>Pass/Fail Criterion And Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheels</td>
<td>1. Check wheel alignment</td>
<td>1. Set to manufacturer specification</td>
</tr>
<tr>
<td></td>
<td>2. Check tire camber</td>
<td>2. Set to manufacturer specification</td>
</tr>
<tr>
<td>Clutch</td>
<td>3. Check condition of clutch facings</td>
<td>3. Replace clutch facings</td>
</tr>
<tr>
<td></td>
<td>4. Check clutch release bearing</td>
<td>4. Replace bearing if worn/failed</td>
</tr>
<tr>
<td>Fuel System (Diesel/ CNG)</td>
<td>5. Check lubrication of driveshaft joints, axle bearings and differential</td>
<td>5. Lack of visible lubricant and/or noise in joints and bearings signify need for lubrication</td>
</tr>
<tr>
<td></td>
<td>6. Examine tightness of driveline and gearbox mounts</td>
<td>6. Visible driveline and gearbox vibration indicates need to tighten mounts</td>
</tr>
<tr>
<td>Engine (Diesel)</td>
<td>7. Check Fuel Injection pump timing and maximum fuel stop</td>
<td>7. Set timing and stop to manufacturer specifications</td>
</tr>
<tr>
<td></td>
<td>8. Check F1 pump pressure</td>
<td>8. Low pressure indicates pump rebuild</td>
</tr>
<tr>
<td></td>
<td>9. Pull and check fuel injectors for leakage or clogged spray holes</td>
<td>9. Asymmetric spray indicates need for injector cleaning or replacement</td>
</tr>
<tr>
<td></td>
<td>10. Check turbocharger bearings (if turbocharged)</td>
<td>10. Turbo rotor must rotate freely or else replace bearings</td>
</tr>
<tr>
<td></td>
<td>11. Inspect cylinder head for cracks, bolt tightness</td>
<td>11. Low compression requires head gasket, ring check or engine rebuil</td>
</tr>
<tr>
<td></td>
<td>12. Check piston rings if oil consumption is high</td>
<td>12. Torque head bolts to manufacturer specification, replace cracked head</td>
</tr>
<tr>
<td></td>
<td>13. Check for engine coolant loss/overheating</td>
<td>13. Replace worn rings</td>
</tr>
<tr>
<td></td>
<td>14. Check for air cleaner for clogging</td>
<td>14. Radiator or hose leaks should be patched</td>
</tr>
<tr>
<td>Engine (CNG)</td>
<td>15. Check Fuel Injection pump timing and maximum fuel stop</td>
<td>15. Set timing and stop to manufacturer specifications</td>
</tr>
<tr>
<td></td>
<td>16. Check Fuel Injection pump timing and maximum fuel stop</td>
<td>16. Low pressure indicates pump rebuild</td>
</tr>
<tr>
<td></td>
<td>17. Asymmetric spray indicates need for injector cleaning or replacement</td>
<td>17. Asymmetric spray indicates need for injector cleaning or replacement</td>
</tr>
<tr>
<td></td>
<td>18. Inspect cylinder head for cracks, bolt tightness</td>
<td>18. Turbo rotor must rotate freely or else replace bearings</td>
</tr>
<tr>
<td></td>
<td>19. Check piston rings if oil consumption is high</td>
<td>19. Low compression requires head gasket, ring check or engine rebuild</td>
</tr>
<tr>
<td></td>
<td>20. Check for engine coolant loss/overheating</td>
<td>20. Turbo rotor must rotate freely or else replace bearings</td>
</tr>
<tr>
<td></td>
<td>21. Inspect exhaust brake valve if used</td>
<td>21. Radiator or hose leaks should be patched</td>
</tr>
</tbody>
</table>

#### Source: ESMAP, 2011