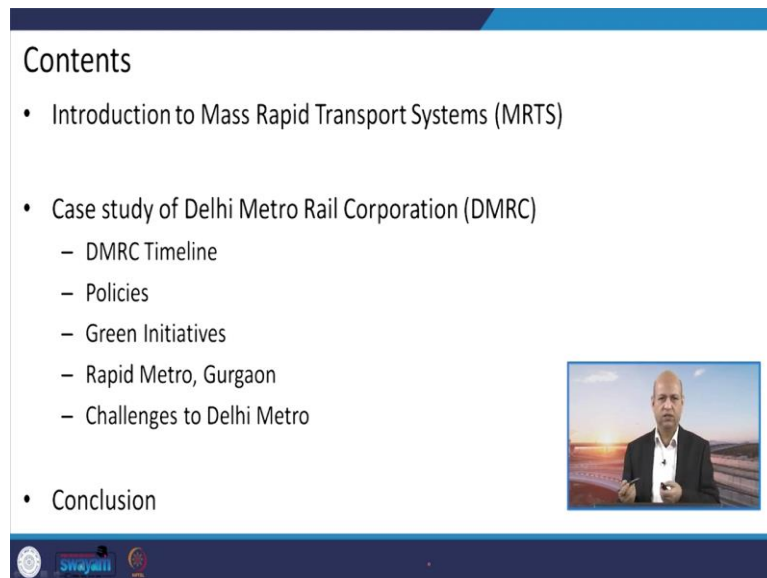


**Sustainable Transport System**  
**Professor Bhola Ram Gurjar**  
**Department of Civil Engineering**  
**Indian Institute of Technology, Roorkee**  
**Lecture 51**

**Case Study-II: Mass Rapid Transit (MRT) Systems**

Hello friends, you may recall our last interaction on a BRTS, Bus Rapid Transit System in that we studied the success story of Bogota, BRTS system and then some limitations and failures of Delhi BRTS and the success story of Ahmedabad BRTS, today we will discuss about Mass Rapid Transit systems and for that, we will study the success story of Delhi Metro as a case study.

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So, means the introduction will be there little bit about Mass Rapid Transportation system and then case studies will be focused only on Delhi Metro, but various aspects will be considered like, what were the timeline, how it was implemented and planned, then various policies which has affected or influenced the growth of Delhi Metro and then very good initiatives or green initiatives, which has made this Delhi Metro as a wonderful case study all over the world and then the integration with the rapid Metro of Gurgaon which is small town, now a big town in the earlier it was a very small town, but now a lot of MNCs offices are there, so it is in NCR that is National Capital Region and this is the town of Haryana, but just at the border of Delhi.


So, the rapid Metro Gurgaon how it was integrated with Delhi Metro and then some challenges means, not all things are very good, but there are certain limitations or challenges or lessons to learn, so those things will be there and ultimately, we will conclude this lecture.

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### Introduction to Mass Rapid Transport Systems (MRTS)

- Metro Systems are one of the **most Energy efficient Transportation systems**.
- The **benefits of metro systems** includes:
  - Potential to remove private automobiles off roads
  - Fuel savings
  - Pollutant emission savings
  - Reduced travel time
  - Reduced congestion on streets
  - Reliability
  - Reduced accidents on streets

Mode	Per km Unit Energy Consumed
Metro	1
Bus	3
Two wheeler	5
AC Bus	6
Petrol Car	21
Diesel Car	22



So, when we talk about this brief introduction of Metro system, basically we will focus upon energy consumption and then the emissions means, exhaust emissions which are avoided by metro system, now very small indicator which is very good indicator you can see like per kilometre unit energy consumption.

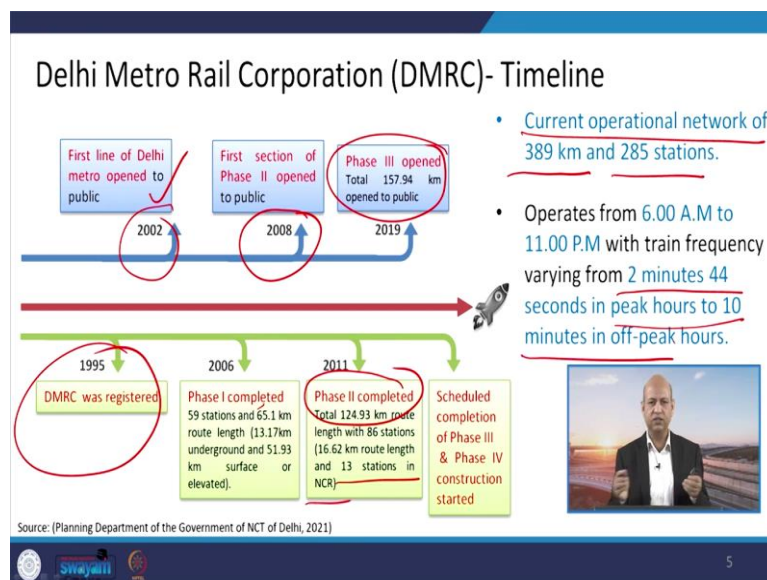
So, in moving one kilometre how much energy is consumed by a system like, Metro consumes if 1 unit and bus consumes 3 units, thrice, 2 wheelers 5 units, AC bus 6 units petrol car 21 times and diesel car 22 times, so that means metro is the most energy efficient transportation system in comparison of these other vehicular transportation systems, so there are various benefits in the sense because, it removes the need of privately owned vehicles when we shift from that sector to Delhi this metro system or MRTS and then emission saving in the sense means, those emissions are avoided which were otherwise when we ride the bus or car, fuel saving is a lot and then reliability because the complete system is dedicated corridor there is no other chances of delaying except some in a very rare case, but that is again means from the reliability aspect this is one of the wonderful system and accidents which you can see on the roads and streets there are no chances of such accidents in the metro system.

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So, you can see this one pictorial representation of Delhi Metro, which is the case study for today, so at various places it is elevated at some places it is underground, so this is a mixed kind of in different phases this Delhi Metro was built.

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In 1995 this was registered DNRC that is Delhi Metro Rail Corporation the timeline is represented here, in 2002 this first line of Delhi Metro was open for public, in 2006 the phase one was completed and around 59 stations were covered and 65 kilometre route length was achieved by this phase 1, in 2008 first section of phase 2 was opened, in 2011 phase towards completed and it could cover around 125 kilometre metres stretch or the route and 13 stations

were in the NCR means outside Delhi, but in National Capital Region and then in 2019 this phase 3 was opened total around 158 kilometre and this was open for public.

So, now this phase 4 is going on and you can see the total network current operational network is around 389 kilometre means approximately 400 kilometre with 285 stations and it runs from 6 am in the morning to 11pm in the night and during peak hours when a lot of people are travelling then the frequency is quite high every 2 minutes and 44 second 1 train is there 1 and in non peak hours around 10 minutes is the gap of these Metro trains. But, that is not a huge gap you can have your next train, if you just miss the first one.

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**Delhi Metro, India**

- Government owned Rail Transit system with **daily ridership of over 2.6 million**
- Equipped with **Modern technology, safety and security systems**
- Estimated to have **saved 16 million tonnes of emissions annually by modal shift of 0.4 million private vehicle users.**
- **Targets a cumulative CO<sub>2</sub> emission reduction of ~4.8 million tonnes in its 70 year designed lifetime.**
- Energy reduction targets by **Switching to solar power**

Source: (Rohit Sharma and Peter Newman, 2017)

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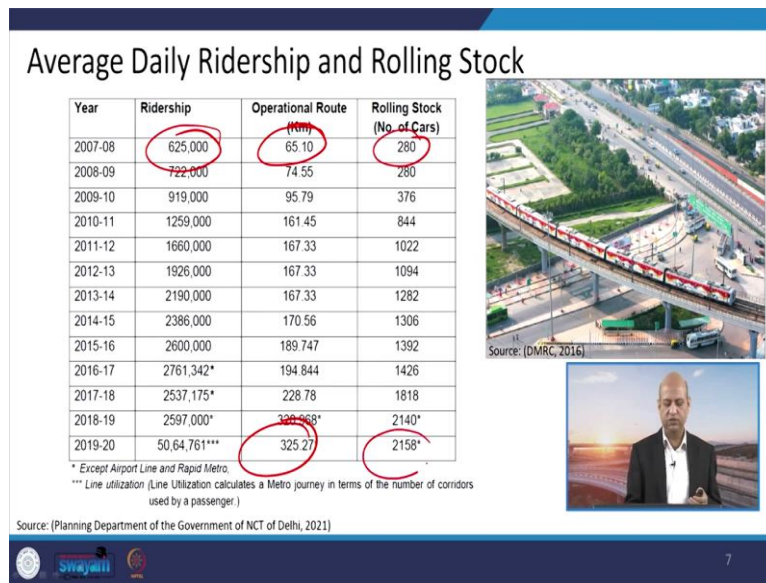
Source: (DMRC, 2016)

of corridors

7

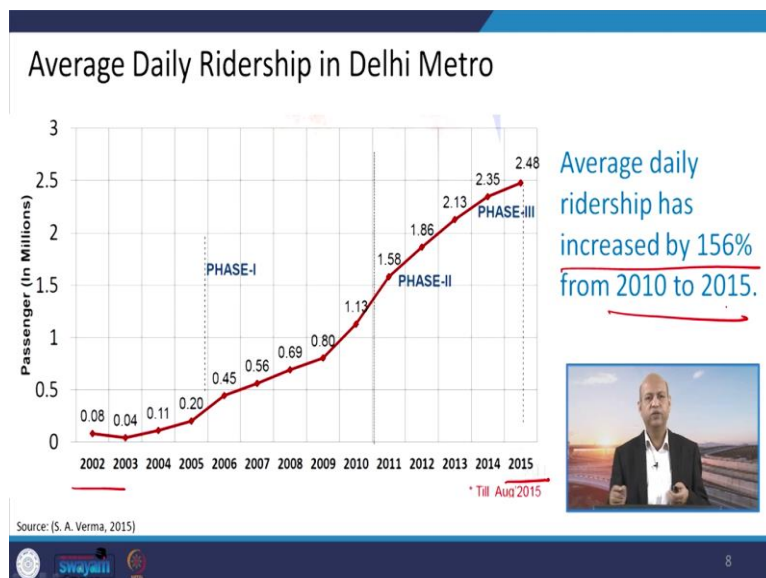
The ridership is very large like 2.6 million people daily using this Delhi Metro and it is equipped with very high reliable technology of modern days in terms of safety and security systems and then, if you see in terms of emissions 60 million tonnes of emissions annually it is reducing, because of modal shift of around 0.4 million private vehicles, so that kind of emissions saving is there or avoidance is there well target of cumulative CO2 emissions reduction around 4.8 1 million tonnes in its 70 year design lifetime, so this is estimated figure and solar power is also being inbuilt or integrated in the whole system, so that it can have the renewable resources integration and that way further reduction in emissions.

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You see the ridership increase from 2007 to 2019, so around 625,000 riders it was initially, but in 2007, but now it is 50,100,000 or 51,000 you can say operation route from 65 kilometres to around 325 kilometre stretch is covered and the coaches or cars earlier it was 280 and now it is around more than 2100, so the growth you can visualise with these numbers plus the ridership is increasing every year from 2002 to 2015.

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If you see the graph is always increasing, that means the people are feeling incentive to ride the metro, because of its comfort level because of its efficiency, because it reduces time to



travel from one point to another and its completely air conditioned and wonderfully equipped, so that way people like to use it, so it has increased around 156 % in between 2010 to 2015.

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### Mode shift from Road transport modes to Delhi metro in 2011

Vehicle Type	%	Commuters (a)	Occupancy (b)	Veh. Shift/Day (c)=(a)/(b)	Average Trip Length (Metro) (d)	Veh.x12.50 (e)=(c)x(d)	VKT/Day (f)	Total Veh. Shifted (a)+(e)/M
Bus (CNG)	55	1 100 000	39.6	27 778	12.50	347 222	111	3 128
2W	20	400 000						
2W-2S	0.30	120 000	1.5	80 000	12.50	1 000 000	51	19 608
2W-4S	0.70	280 000		186 667	12.50	2 333 333	51	45 752
4W	20	400 000						
4W-P	0.70	280 000	2.4	116 667	12.50	1 458 333	55	26 515
4W-D	0.30	120 000		50 000	12.50	625 000	55	11 364
3W	5	100 000	2.5	40 000	12.50	500 000	109	4 587
<b>Total</b>	<b>100</b>	<b>2 000 000</b>		<b>501 111</b>				<b>110 954</b>

Delhi Metro Rail Ridership (per day in year 2011)=2,000,000  
 2W=two wheeler, 2W-2S=two wheeler two stroke, 2W-4S=two wheeler four stroke, 4W=four wheeler, 4W-P=four wheeler gasoline, 4W-D=four wheeler diesel, 3W=three wheeler

Source: (Niraj Sharma et. al, 2014)

Vehicular shift from Road transport modes due to Introduction of Delhi metro



When you see the mode shift from road transport modes to Delhi Metro in 2011, so again you can see the total 2 million commuters were shifted towards Metro from like 55 % people were from buses and then 20 % from two wheelers, so that way the total 100 % the figure was around 2 million, so this is the growth story, but the 2011 figure itself says that it has been very popular.


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### Vehicular emission saved by Mode shift to Delhi Metro

Category of Vehicles	Pollutant (t/yr)					CO <sub>2</sub> (t/yr)
	CO	HC	NO <sub>x</sub>	PM	Total	
Year-2006						
Buses	114	102	169	9	394	21 978
2W-2S	367	203	3	6	579	2 078
2W-4S	247	98	40	4	389	3 028
4W-P	318	44	44	1.1	407	8 763
4W-D	14	8	16	2.8	41	5 051
3W	58	15	29	0.9	103	2 911
<b>Total</b>	<b>1 097</b>	<b>463</b>	<b>299</b>	<b>23</b>	<b>1 882</b>	<b>43 809</b>
Year-2011						
Buses	505	475	787	38	1 805	102 213
2W-2S	870	531	1	26	1 428	13 132
2W-4S	1 553	727	312	48	2 640	34 683
4W-P	1 637	151	121	4.1	1 913	66 028
4W-D	25	23	69	5.9	123	33 973
3W	285	74	142	14.2	515	14 180
<b>Total</b>	<b>3 882</b>	<b>1 811</b>	<b>1 320</b>	<b>107</b>	<b>7 120</b>	<b>264 208</b>

Source: (Niraj Sharma et. al, 2014)

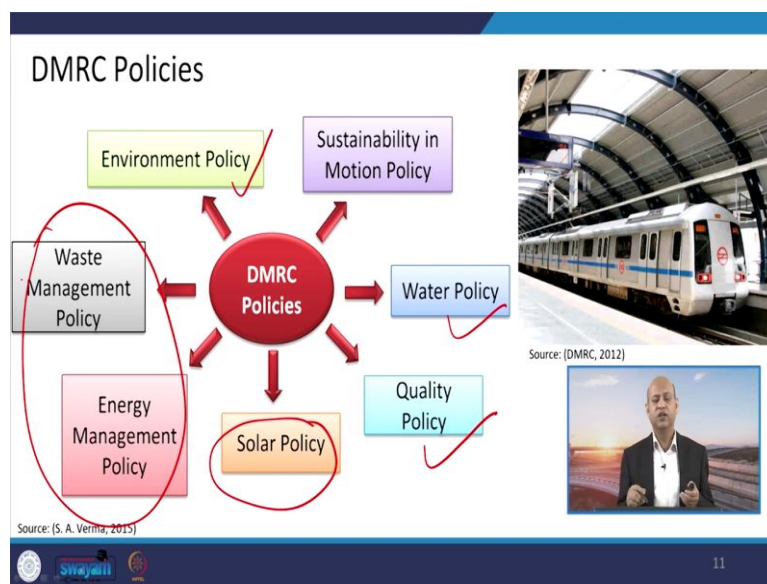
Vehicular emissions saved due to shifting of commuters from Road-based transportation to Delhi metro



If you see the vehicular emissions saved by mode shift, because when we are going from fossil fuel based road traffic to Delhi Metro, then naturally we are reducing the exhaust emissions, because Delhi Metro is run by electricity although as I narrated in one lecture that people argue that electricity is also produced by fossil fuels by coal power plants, but as I said because the vehicular pollution is in the range of our breathing process, so that way the health benefits are much more because the stack emissions get diluted when they reach to the ground level, so compression is not so straight anyway, if you see the CO reduction from different categories of vehicles like buses, etc., so around 3882 tonnes per year saving of CO.

Similarly, hydrocarbons or NOx emissions particulate matters, so total is around 7000 tonnes per year reduction in the emissions of air pollutants, if you focus on greenhouse gas emissions or you can say carbon dioxide CO2 tonne per year, so you see the huge figure over around 265,000 around means it is to 264, but it may be around 265,000 estimated figure it is there is not where absolute value, so those emissions have been avoided because of this Metro, what are the different policies which have been integrated to make it very popular.

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Because, environment policies there, how to make it environment friendly we will see different aspects later on then sustainability in motion policy, again the reliability and punctuality all those things, water policy we will see that how recycled water is being used and how it is really using the wastewater treatment through, wastewater treatment plants etc., quality policy, the quality control is there in terms of comfort level as well as our timings, solar policy means solar energy is being integrated an energy management policy means



several kinds of energy sources even waste energy resources are there, so the waste management and energy resources are being integrated, so that way this DMRC policies is wonderfully linked to each other to make it a sustainable case study for transportation systems.

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### DMRC Policies are consistent with the Environmental Laws

All DMRC Policies, activities and initiatives are consistent with the following environmental laws and regulations:

- Environmental Protection Act, 1986 ✓
- Air (Prevention and Control of pollution) Act, 1981 ✓
- Water (Prevention and Control of pollution) Act, 1974
- The Noise pollution (Regulation and control) Rules, 2000
- Control of Noise from Diesel generator sets, 2002-07.
- Recycled Plastics Usage Rules, 1998
- Delhi Tree Preservation Act (1994)
- Batteries (Management & handling) Rules
- Flyash Utilization Notification, 1999, 2003
- Waste (Management & Handling) Rules, 2010

Source: (DMRC, 2012)


12

If you see this DMRC policies in terms of the environment, it follows all the rules and regulations or environmental laws of the land, so whether it is environmental protection Act 1986 or Air Pollution Act of 1981, so all these environment related acts and regulations have been properly integrated and implemented in the management system of DMRC.

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### DMRC Green Initiatives

- DMRC received the "Green Leadership Award" in 2019 for Green initiatives of metros.
- DMRC corporate office "Metro Bhawan" is rated "GREEN" by the US Green Building Council (USGBC).
- All Phase III metro stations and depots are designed and constructed according to the Platinum level Green rating system (highest level).
- Benefits of Green stations:
  - 30-35% energy saving ✓
  - 50% reductions in Lighting Power density (LPD)
  - 10-15% improvements in efficiency of Heating, Ventilation and Air Conditioning (HVAC) systems, over the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) or Energy Conservation Building Code (ECBC) requirements



Source: (A. K. Singh, 2016)

13



If you see this green Leadership Award of 2009, which was given to Delhi Metro, because of its very various initiatives for green environment and saving energy, then this Metro Bhawan was rated this big office complex as green by the US Green Building council so that means, you can see it systems best practices of the world have been implemented in the management of DMRC.

And then you can see this platinum level green rating system for all construction activities of Metro Station reports have been integrated and 30 to 35 % energy saving in all green stations which have been built, so this have been the part of planning and execution, 50 % reduction in lighting power density, all these benefits means whether it is lighting or energy or air conditioning system or heating system, all things have been designed as per the best practices of green energy or green rating or green leadership practices.

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**Energy Conservation measures**

- CO<sub>2</sub> monitoring in Metro station areas
- Extensive use of Variable Frequency Drives (VFDs) for controlling the speed of motors in AC's.
- Solar panels are installed on top of elevated metro stations, depots and parking areas.
- Live controlling and monitoring of all auxiliary load through Building Management System (BMS) at stations and at Operational Control Centre (OCC).

Source: [UNEP, 2014]

Source: [A. K. Singh, 2016]

14

Energy conservation measures have been in place like CO<sub>2</sub> monitoring at Metro stations areas automatic systems are there which measure the CO<sub>2</sub> levels, so that it should not increase beyond certain level and there are ways to control it, then there are air conditioning systems and solar panels are also there plus there is management of air flux between underground in tunnels and how this Metro goes and then there is push up the air from behind and it adds to the fresh air.

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### Green Initiatives: Reducing Energy consumption

**Clean Development Mechanism**

- First Metro rail and Rail based system in the World to earn Carbon credits for reducing GHG emissions.

Reduces pollution levels in Delhi by 6.3 lakh tons every year

Source: (S. A. Verma, 2015)

This green initiative if you compare this kind of scenario earlier when all these fossil fuel waste vehicular categories or vehicular these automobiles etc, they are burning lot of fuels and they are emitting a lot of whether air pollutants or greenhouse gases, but this is quite clean, there is no exhaust emissions of course, there may be little bit some like wheel, abrasion and friction very minute quantity, but in comparison to this is kind of negligible and there is the reduction of pollution around 6.3 lakh tonnes per year has been estimated with this claim development.

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### Green Initiatives: Total Emission Reduction

**EMISSION REDUCTION - 2014**

CO<sub>2</sub> Emission Reduction - 6.7 Million Tons

Metro Operation, 67,04,518

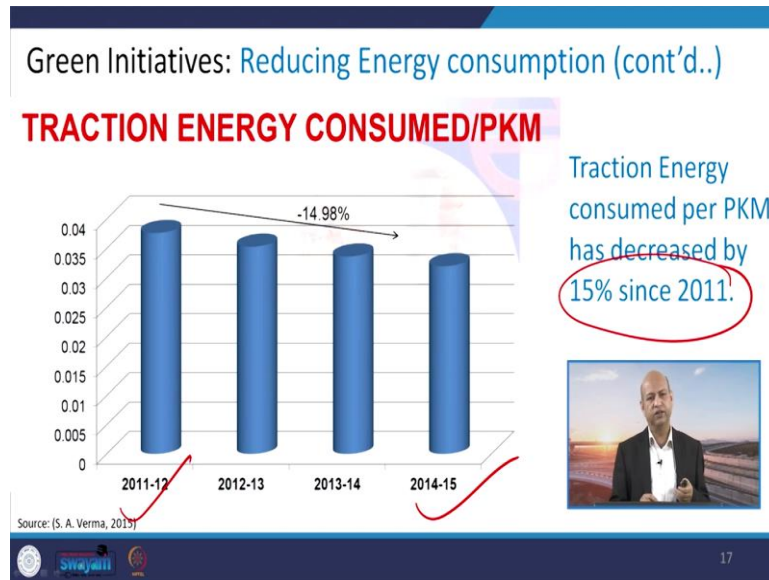
Energy Efficient Building, 24,000

ACHIEVED

Source: (Dr. Mangu Singh, 2015)

If you see the total scenario then the CO2 emission reduction has been estimated around 6.7 million tonnes reduction that has been achieved, in 2014 this estimated figure is, so that is the reduction.

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And then traction energy consumed per passenger kilometre, so this is also reducing from 2011 to 2014 if you see, so those traction in energy consumed has been like 50 % reduction with respect to 2011, so those practices have been implemented to achieve these targets.

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### Co-Benefits from Delhi Metro: A CRRRI study

Descriptors	Phase-I 2007	Phase-I & II 2011	Phase-I & II 2014*
No. of vehicles off the road daily	16895	117249	390971
Annual reduction in fuel consumption (t)	24691	106493	276000
Annual reduction in pollutants (t)	31520	179613	577148
Savings in time per trip (minutes)	31	28	32
Annual reduction in fatal accidents (No.)	21	111	125
Annual reduction in all accidents (No.)	93	591	937

Source: (S. A. Verma, 2015)


There are several CO-Benefits also CO-benefits means, when some additional benefits become automatically without aiming for that for example, if this annual reduction in fuel consumption, because this is working on electric cars, so in phase 1 this much of reduction is there phase 2 and phase 6, so it is reduction in fuel consumption is increasing in every phase, then reduction in pollutants or the trip or time saving, reduction in fatal accidents means these are just outcomes of this better or safer system in terms of Metro or MRTS in comparison to the road transport system, so these are reduction in accidents or reduction in fatal accidents all those have been increasing from 1 phase to another one, so this is a success story of CO-benefits.

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Co-Benefits from Delhi Metro: A CRRRI study (cont'd..)

Descriptors In Cr of Rs	Phase -I & II 2014
Cost of saved time by metro passengers	4,107
Cost of savings in fuel	1,972 <sup>#</sup>
Saving of Vehicles (capital + Operating) cost	2,617
Cost of less pollution saved	489
Cost of accident saved	63
Cost of time and fuel saved due to decongestion	491
Cost of saved in annual infrastructure maintenance	625
<b>Total Cost of all Benefits</b>	<b>10,364</b>

Source: [S. A. Verma, 2015], Note: 1 Cr = 10 Million





Also, if you see that save time, so that much if you convert it into crores of rupees one crore is 10 million, so if you compare different activities, so the total benefit is around 10 crore or 100 million, so that is a huge benefit, if you see in terms of monetary gains.

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### DMRC is Carbon Neutral

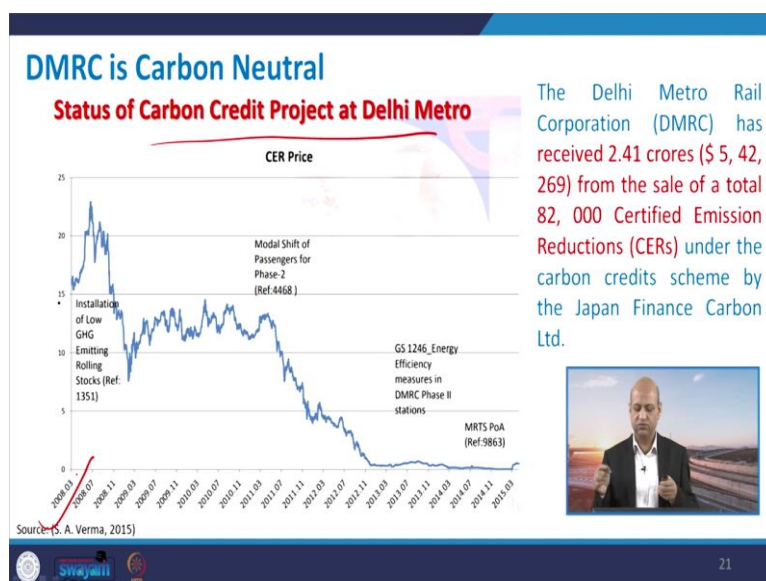
Year	Annual Passenger Flow (million pass.)	Emission Offset due to Modal Shift (tCO <sub>2</sub> e)	Emission Due to Electricity Consumption (tCO <sub>2</sub> e)	Emission Due to indirect Trip (tCO <sub>2</sub> e)	Emission - DMRC Feeder Bus Operation (tCO <sub>2</sub> e)	Carbon Neutral (tCO <sub>2</sub> e)
		a	b	c	d	[a - (b+c+d)]
2012-13	702.9	7,73,860	5,87,964	76,198	6,961	1,09,697
2013-14	801.7	8,71,486	6,24,068	85,867	14,160	1,47,391
2014-15	870.6	9,39,684	6,75,543	92,647	14,160	1,57,334

Source: [S. A. Verma, 2015]

This is the carbon neutral, carbon neutral means there is no addition of carbon emissions because of Metro running on the rails for example, this is the emission offset due to modal shift, so this is more than the emission due to electricity consumption, as I said that some people argue that electricity is also being produced by some fossil fuel, but if you are deriving electric energy by solar panels or maybe from hydro power generated electricity if you are buying then you are not adding to emissions of carbon, so that is the thing you can see that net reduction is there of carbon emissions, so it is not adding to the carbon emissions.

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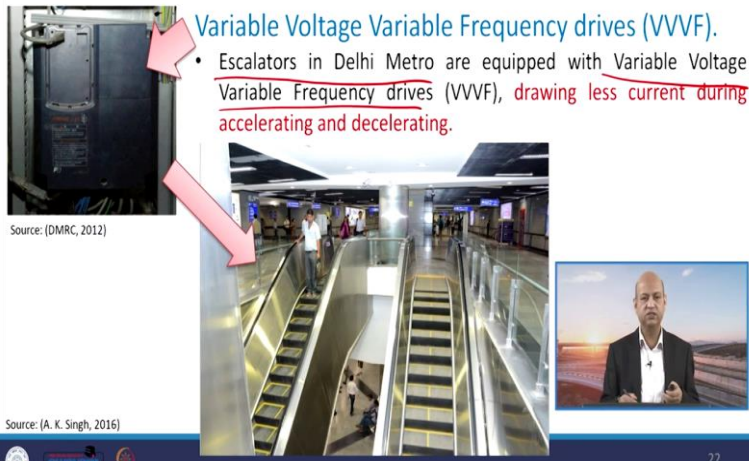
In the same sense carbon credit project have been implemented from very earlier years of 2008 and several crores of rupees saving have been achieved by this particular example.

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### Green Initiatives: Reducing Energy consumption

**Variable Voltage Variable Frequency drives (VVVF).**

- Escalators in Delhi Metro are equipped with Variable Voltage Variable Frequency drives (VVVF), drawing less current during accelerating and decelerating.



Source: (DMRC, 2012)


Source: (A. K. Singh, 2016)

22


Then, there are other initiatives like energy consumption related these issues in the escalators, so they are having variable voltage frequency drive kind of equipments, which uses optimization of energy consumption in these escalators, so that way it is very energy efficient.

(Refer Slide Time: 18:14)

### Green Initiatives: Energy efficient HVAC systems



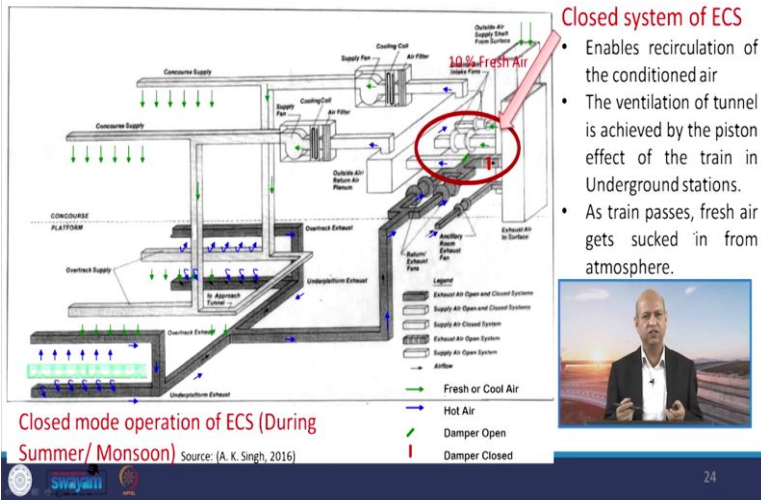
- Energy efficient screw chillers and controlling of underground air conditioning through Open or closed loop mechanism of ECS (Environmental Control system)



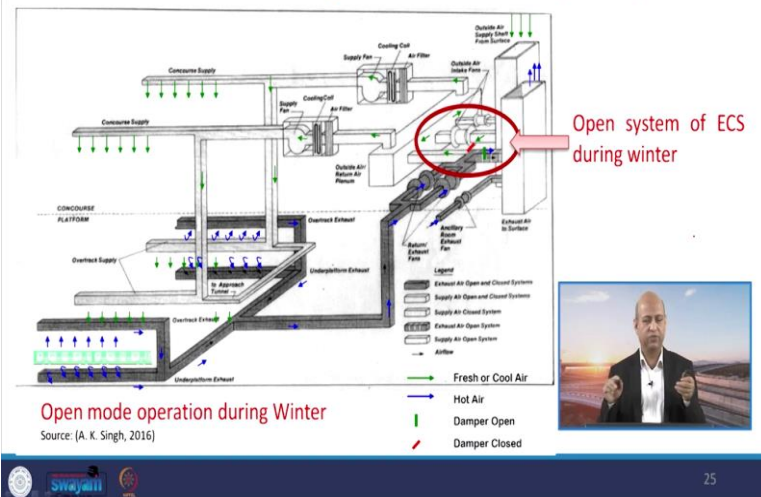
Source: (DMRC, 2012)

23

## Green Initiatives: Closed operation of HVACs (Summer/ Monsoon)



## Green Initiatives: Closed operation of HVACs (Winter)



And then if you see the these air conditioning and although systems, so environmental control system is there and they monitor every kind of thing whether it is moisture level or humidity or thermal and the controlling system automatically it starts some equipment to get the fasciae or it starts to add to the heating processes, if like in winter if some at some pockets temperature goes down.

(Refer Slide Time: 18:46)

### Green Initiatives: Solar Power plants

#### Solar Power plants at Depots and Stations




Source: (DMRC, 2016)

26

In solar power plants have been added in this particular depots and the stations, so the roofs have been converted into with solar panels a lot of energy is being produced by these initiatives.

(Refer Slide Time: 19:02)

### Solar panels at Rooftops of Stations



Solar panels on the roof of ITO Metro station, Delhi metro

Solar panels on the roof of Anand Vihar Metro station, Delhi metro

Source: (A. K. Singh, 2016)

Source: (S. A. Verma, 2015)

27

## Green Initiatives: Smart Lighting

**Smart lighting in Metro premises**

- Lighting is critical in **safe operations**.
- Maintains **standard Lux** (lumen per square meter) **levels**

Standard Lux level maintained at various areas

Source: [DMRC, 2016]

28

## Smart lighting

Smart LED lighting

Source: [DMRC, 2016]

29




You can see Anand Vihar Metro station this is the photograph of that and this ITO Metro station again these there so everywhere means those buildings and wherever they have got the opportunity they have used this solar panels to generate the electricity and Smart Lighting have been implemented, so the saving of energy as well as means were how much illumination is needed, so that way good software have been implemented to have the right quantity of the light or illumination of the light, so see this smart LED lights have been used, so very less amount of power consumption but very good lit area is their lighting.



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### Green Initiatives: Quality Coaches

- As of March 2020, DMRC has a total of **2206 coaches** (1296 Broad gauge & 910 Standard gauge)



Source: [DMRC, 2020]

Source: [S. A. Verma, 2015]

Source: [S. A. Verma, 2015]

30

### Green Initiatives: Landscaping and paved flooring

- Landscaping and paved flooring outside Metro stations



ITO metro station

Mandi House metro station

Source: [A. K. Singh, 2016]

31



And then quality coaches, because comfort levels should be there for people to travel, so these are the quality coaches which have been used in this DMRC system and there are landscaping and paved flooring means the aesthetic value has also been added there are like water harvesting all those things have been integrated with each other, so see these look so beautiful Monday house metro station, so means people feel very good when they approach the station, so otherwise you see when we go to the bus station, it is so crowded and you do not feel good, so those kind of infrastructure facilities really motivate you to go to using this particular system.



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### Green Initiatives: Noise and Vibration Monitoring

Noise and Vibration Monitoring at Metro premises and construction sites



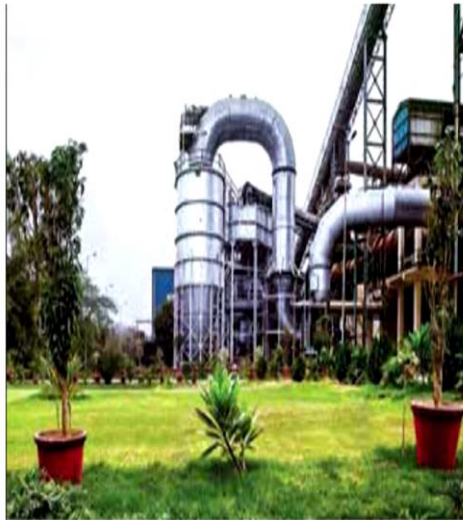
Noise Monitoring

Vibration Monitoring

Source: (DMRC, 2012)

32

### Green Initiatives: Waste-to-Energy powered Metro



- First metro in India to receive power generated from a Waste-to-Energy plant ✓



Source: (DMRC, 2020)

33

## Green Initiatives: Waste-to-Energy powered Metro

- Seven stage Pre-processing that converts waste to Refuse Derived Fuel of high Calorific value.
- Process 1300 tons per day (TPD) of Municipal solid waste and could generate 12 MW of Green Power (Total Plant capacity 2000 TPD)
- India's first WtE plant compliant with Euro norms, with highest standards of pollution control measures, with a Continuous Emission Monitoring System (CEMS).



Source: (<https://www.ifsindia.com/our-work/environment/waste-to-energy-plant-ghazipur/>)

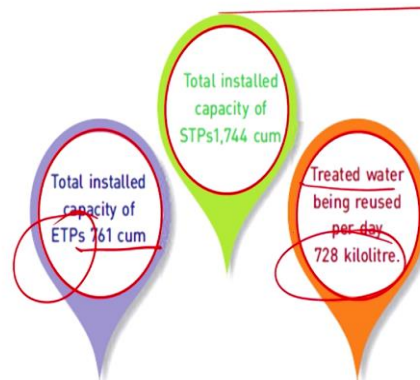


34

Then noise and vibration monitoring equipments are also there, so that can control the speed and other issues which affect the noise and vibrations, of course this is wonderful example of waste to energy powered Metro this is the first in India this particular plant which uses waste material to produce energy as per its calorific value, so in this slide it has been given these figures like 1300 tonnes per day of municipal solid waste it is being burnt and converted into energy plus there are equipments which control the air pollution, exhaust emissions from the STPs, so it is completely clean system, it is not like that, it is burning and then emissions are going into the atmosphere it is not like that, so good controlling of air pollutants system is there and that way, this is a green initiative, because it is converting waste into energy, so that way it is a green initiative you can call it.

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## Green Initiatives: Sewage Treatment Plants (STPs)



- 13 STPs operational in depots and colonies, resulting in reuse of 380 KLD of water.
- 5 STPs in metro stations, resulting in 10 KLD water used in flushing of toilets



Source: (S. A. Verma, 2015)






35

Then sewage treatment plants are there, so 13 STPs or sewage treatment plants are there, so as a result, they are using around 380 kilolitre per day of the water, so that is a wonderful achievement in that way. Effluent treatment plants are also there around 761 cubic metre of capacity and similarly treated water being reused per day around 728 kilo litres, so those are the things which make it towards environment friendly approach.

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### Green Initiatives: Water Treatment Facilities for Delhi metro



- 130 KLD seepage water from underground stations
- Separate pipe lines for RO and raw water, saving water upto 40 KLD.
- Reduced 336 KLD water consumption in 2015


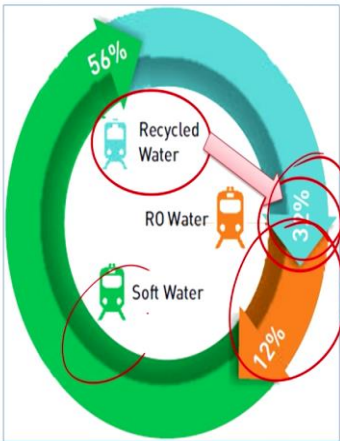
Water Treatment facilities

Source: (DMRC, 2012)

Source: (S. A. Verma, 2015)

36

### Water Consumption per coach in Delhi metro



32% Recycled water is used per coach

Water Type	Percentage
Recycled Water	56%
RO Water	32%
Soft Water	12%

Source: (DMRC, 2016)

37

Water treatment facilities, so in underground, there are some seepage some water losses, so those are collected and they are treated and they are reused in the system, so RO system is there plus this seepage water is again made proper to circulate, so that this picture shows how much water is being recycled 32 % of the recycled water is being used it is a big quantity in

fact 32 % is not less and this much only our water is being used and the 56 percent is the soft water, so that way optimization in water usage has been achieved.

(Refer Slide Time: 22:52)

**Green Initiatives: Waste Management**



**Reuse of Wooden Waste**

- From 2016, DMRC has set up carpentry workshops for converting its wooden waste from heavy machineries and rolling stock equipments into benches, stool, sofa sets etc.

**Bench made of Reused Wood waste**

**Organic waste Converter**

- An Organic Waste Converter (OWC), is used to process organic wastes at DMRC.
- Converts the organic waste from canteens and depots such as kitchen and garden waste into compost/fertilizer.



Source: (DMRC, 2016)

38

Waste management, another example is like they are a lot of good or other things which are sometimes wasted or outdated, so the DMRC has set up a carpentry workshop to use that discarded wooden furniture and they again try to make some useful things, for example, some benches by disused wood waste and then organic waste converter is also there that can process the organic waste of the DMRC and it can be taken from the canteen or depots and then maybe manure etc., and for kitchen garden those kinds of waste material has been converted into compost or fertiliser, so it is again used for gardening purposes, so that you can see the recycling of lot of things are going on in DMRC that is a big achievement.






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### Green Initiatives: Advanced Ticketing options

Digital-enabled Transactions (No paper tickets required)

- Delhi metro smart card **Top-up through Online systems**
- Mobile Applications for **Real time Passenger information**
- **SMS based** recharge
- **QR code based ticketing** facility launched for Airport Express lanes in 2020.



Source: (DMRC, 2016)

Source: (DMRC, 2020)





39

Also ticketing options of advanced nature, like you can use your mobile or these cards, etc., so there is no use of paper tickets and that way you are saving the trees, so that is again environment friendly approach and SMS or QR code kind of technological applications have been integrated with ticketing and travelling from one place to another.

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### Green Initiatives: Conservation of Ecology

- Tree plantation by DMRC has **potential capacity to remove approx. 5,512 t of CO<sub>2</sub> and produce 12,389 t of Oxygen per year**



Source: (S. A. Verma, 2015)

40

Then DMRC has also invested a lot for conservation of ecology, so it has planted a lot of trees and they produce around 12,000 tonne of the oxygen per year and they remove around 5000 tonne of the CO<sub>2</sub> means, because it is a sink CO<sub>2</sub> is used by plants as for producing their own food and they also give oxygen so that way a lot of plantation activities has been



funded by DMRC, so that is again a wonderful initiative in terms of the environmental protection.

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### Green Initiatives: Last Mile Connectivity

#### DMRC feeder buses for Connectivity




- The Delhi metro is **integrated with feeder bus services** to various locations
  - 149 Low floor buses
  - 25 Standard floor buses





Source: (DMRC, 2016)

41

### Green Initiatives: Bicycle facility for Metro passengers



- Presently available **at 18 lots** at different metro stations of Delhi metro



Source: (DMRC, 2016)

Source: (DMRC, 2020)

Bicycle facility for passengers at Metro stations

42

Last minute connectivity or last mile connectivity related, facility is or infrastructure have also been taken care of by Delhi Metro, so around 149 low floor versus and 25 standard floor versus have been used for this last mile connectivity, so that people do not feel, now or to wait for some other automobile to go from metro station to the destination then, there are initiatives like bicycle facility at certain locations around 18 lots of bicycle facility are there, you can just hire the bicycle and you can drop it at another station, so that way means it is

like benefit to the health as well as there is no emissions, so this non motorised vehicle categories have been integrated with Delhi Metro system, that is wonderful example.

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### Green Initiatives: Eco-friendly measures for Last mile connectivity

Some initiatives includes:

- Multi-modal integration at metro stations
- Feeder services using e-bikes and e-rickshaws
- Other facilities such as charging stations for e-vehicles, toilet blocks etc.

E-bicycles

E-rickshaws

Source: (DMRC, 2020)

43

Similarly, e-bicycles are also there e-rickshaws are also there, so all those multi modal integration have been achieved in metro stations to facilitate the passengers, so e-rickshaws out there and then charging stations are also there, so that they do not need to go here and there and they get opportunity to charge their e-rickshaws batteries very conveniently.

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### Green Initiatives: Cleanliness at Metro stations

Train Cleanliness & Comfort- 2nd rank

Information during travel- 1st rank

Real time service status information during travel- 3rd rank

Overall Satisfaction with metro services in the city - 3rd rank

Result of Passenger survey for Delhi Metro

Source: (DMRC, 2016)

44

### Green Initiatives: Safety for Women as Priority

**Safety: Women only Metro-car**

- DMRC has women only cars in every trains to ensure safety and convenience of women passengers





Source: (DMRC, 2016)



45

Then again, if you see the cleanliness and comfort level, so there was a survey and on the basis of that survey, it was known that information during travel, that is the very good means, first trend people say that this is the best, category or best practice or best aspect of this Delhi Metro system, then cleanliness of course, all these are of high rate, but if you rank in relative, so cleanliness is the second and the real time service is around the third rank, but they are of very good quality, only the comparison of these three variables are there plus there are certain coaches or cars which are dedicated to women passengers, so for their convenience for their safety, there are dedicated cars only for women, so this kind of facility is also in its Metro there.


(Refer Slide Time: 27:19)

### Green Initiatives: Other Safety Measures

**Incidence Management by Chain on Command**

Operational Control Center Source: (DMRC)




Source: (DMRC, 2016)

46


If you see the safety measure, so again control system is there and they constantly monitor automatic systems are there of any kind of deviation from protocol, so all kinds of possibilities are there will not be any kind of fatal accidents the metro will stop automatically, you might have read sometimes in newspapers that, there was power breakdown because of some unknown region and then Metro got stopped and there was, but some backup power, so that comfort level was not reduced for the passengers.

(Refer Slide Time: 27:59)

Green Initiatives: Other Safety measures



Mock drills for Passenger evacuation in case of an accident



Source: (DMRC, 2016)

47



Plus, there are some Mock drills, if something happened, because accidents are accidents, they do not come with the warning, so if somehow if those kinds of things happen then how to rescue the people, so those kinds of Mock drills are also conducted by DMRC time to time.



(Refer Slide Time: 28:19)

### Rapid Metro, Gurgaon, India

- A 6 km elevated Mass transit network system, Operational since 2013.
- Connects the **commercial center of Gurgaon**.
- Integrated with Delhi metro by a 90 m pedestrian bridge.
- In contrast to Delhi metro, **Rapid metro Gurgaon is a privately financed system** financed on a Build Operate Transfer (BOT) basis, with a 99 year concession period.



Source: [Rohit Sharma and Peter Newman, 2017]

48

### Challenges to Delhi metro: Economic aspects

#### Advertisements on Metro exteriors

- DMRC has aggressively increased the advertisements on metro coaches and platforms for improving its economic aspects.



pedestrian  
possibility for  
strains to  
to stations

constructing  
outside  
n



Source: (DMRC, 2016)

50

Then, there is the integration of rapid Metro Gurgaon as I said and this is around 6-kilometre elevated mass transit network and it is operational since 2013 wonderful part is that it is managed by privately owned agency and that way the integration of this Delhi Metro Corporation and that Gurgaon's rapid railway system is there.



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### Challenges to Delhi metro: Poor accessibility to stations

Poor pedestrian accessibility for pedestrians to Metro stations

Trees on footpath

Trees and Hawkers obstructing pedestrian footpaths outside Hauz Khaz Metro station

Hawkers

Key Plan

Source: (UNEP, 2014)

50

### Challenges to Delhi metro: Poor accessibility to stations (cont'd..)

Obstructions such as Open drainages, 2-wheeler parking and temples on pedestrian footpaths

Temple

Open Drainage line

2-wheeler Parking

Outside Hauz Khaz metro station

Source: (UNEP, 2014)

51

Challenges to Delhi metro: Poor accessibility to stations (cont'd..)

Other obstructions such as Light poles, Electric wires, Height of footpaths etc.

Outside Hauz Khaz metro station

Source: [UNEP, 2014]

52

Challenges to Delhi metro: Poor accessibility to stations (cont'd..)

Lack of maintenance of accessible roads

Lack of Maintenance

Source: [UNEP, 2014]

53

Then, there are certain challenges, because poor accessibility related things have been observed and people have complained, so as a kind of challenge or as a kind of scope for improvement I would like to share with you like at certain places you can find that like there are hawkers and mobility is not, so good in that sense you can even see these, like outside the Hauz Khaz some pictures have been taken open drainage and the potholes and then there is a huge gap between this platform walking pedestrian and the level, so those things are there and they should be taken care of these, see the height without one more step it is very difficult to climb this kind of footpath, so and then there are trees in between.


So, again if somebody nowadays people have you ever heard of reading something, text messages, etc., and there may be a chance of hitting this tree, so when Metro is planting so many trees, maybe they can take permission from the forest department to remove or to

transfer this tree from one place to another, so that the safety aspects are met for the passengers and people. Similarly, other pictorial representation are given, like these kind of these are the note good footpaths and these broken tiles or maintenance is not good on accessible roads.

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**Comparison, Conclusion, and Recommendation**

- DMRC is a **large metro network** compared to that of Hong Kong metro, in its stretch, but is way behind in revenue and ridership.
- **Significant green initiatives** are being implemented currently by DMRC such as switching to Solar power, energy conservation through smart lighting and HVAC systems, water conservation, waste management, landscaping etc.
- However, along with Green initiatives, policy measures to reduce automobiles on roads should be implemented for gaining economic benefits for Delhi metro.



54


So, those are the challenges where scope is there for the good improvement and I hope in near future these things will be addressed properly, so if we compare our DMRC with the Hong Kong Metro, then I mean there is a lot of scope to improve in terms of ridership or revenue generation, we are far behind from Hong Kong Metro.

But significant green initiatives really bring this DMRC at the forefront as a very good example of environment friendly or sustainability aspects integration into the whole system, and if we want to recommend something, then we can say that some economic benefits can be taken into account and those should be transferred to improve the system plus more automobiles and those policies should be that the usage of automobiles should be reduced in that way those policies should be implemented and those amenities which are not at par with the expectation of the people, those should be improved timely.

(Refer Slide Time: 31:40)

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55

So, that is all for today and this is the list of references, so anyone of you if you want to know more about certain aspect you can go to references and visit those reference to gain more knowledge and thank you for your kind attention and this is means we have completed two case studies, earlier one was on Bus Rapid Transport System BRTS and this is mass rapid transport system with the success story of Delhi Metro Corporation. Thank you again.