Analysis of Metro rail Project selection Bias with Principal-Agent Model

A case of Delhi, Bangalore, Mumbai, Jaipur and Chennai

Vinod Rathod
Background

- Urban Metro Projects have proven to be very useful in decongesting large cities.
- **148 cities** around the world had Metro System.
- In World Metro systems carry **150 million** passengers per day.

- In India, many cities are now considering the **Metro system as an alternative**
- The **12th fifth year plan** Urban Transport group has recommended, Metro is only one of the Options for decongestion.

Growth of Metro rail system

(Canavan, 2015)
Background

- Metro rail Transit is attached with the **High capital and operating costs**. It found that most of the metro systems around the world are not financially viable.

- Public investment in rail transit has long been **controversial** (Wenling, 2006)

- **Failures of rail projects to materialize the targeted performance** in terms of ridership speed, operating costs, and development benefits, on which grounds they had been justified (Pickrell, 1989)

- Anticipated **project objectives are moderately** met but at **very high costs**.

- **Under-investment** on low-cost and more cost-effective transit alternatives, such as the conventional bus or Bus Rapid Transit (BRT), because resources are often allocated to light rail investments. (Wenling, 2006)
Need of Study

India's great Metro-Rail opportunity

The impact of the Delhi Metro has not been lost on policy makers and now metro-rail projects dot various cities.

Amit Bhardwaj | indiaspend.org
January 20, 2015 Last Updated at 13:26 IST

When you think oil fields, you usually think oil-rigs in the deep sea or a forest of rigs in the desert.

What does not come to mind is a bustling metropolis.

But if you believe the adage that “a penny saved is a penny earned”, the Delhi Metro doubles up as an oil

NATION. CURRENT AFFAIRS

Rs 100 crore loss for Delhi Metro despite riders!

DC | SANJAY KAW
Published Oct 13, 2014, 12:16 pm IST
Updated Jan 10, 2016, 8:38 am IST

Most of the DMRC projects are running behind the schedule

Mumbai Metro faces financial crisis

Bets big on the HC order on fare revision & assistance from Maharashtra Govt

METRO RAIL | ON LOSS, BUT ON TRACK

By Suchith Kidiyoor, Bangalore Mirror Bureau | Oct 12, 2016, 02:00 AM IST

The word “loss” instantly disaster for any ongoing project, with the Bangalore (BMRCU’s five-year-old) incurred a loss of Rs 60.3 crore, almost double its previous year’s loss of Rs 31.68 crore.

But considering these entries from a range of wagging in the city’s metro rail service

Jaipur Metro witnesses steep fall in ridership

TNM | Updated: Feb 17, 2017, 09:53 AM IST

Most of the DMRC projects are running behind the schedule

Chennai Metro Rail sees fall in passenger footfall

Why Such a huge Capital Intensive Project???
Analysis of Metro Rail Project Selection Bias with Principal agent Problem model

- To Analyze performance of metro rail project investments in terms of objective, ridership, revenue, and capital cost
- To identifying the causes of metro rail forecast errors and its sources
- Test the hypothesis through the application of the Principal-agent problem to Metro rail funding process
Methodology

1. Literature Review
   - Reviewing papers and Metro rail policy
   - Identification of Metro rail Operation Indicators
   - Decision Making Concept (Economic Behaviour Theory)

2. Need for the study
   - Identification of Metro rail failure reason
   - Identification of different actor(s) role in decision process.

3. Process
   - Data Collection (Metro DPRs & Policy documents)
   - Converting raw data into graphs
     - Delphi Method
     - Interview with Experts
     - Schedule of Survey and Analyzing the questionnaire prepared

   - Primary Data
   - Secondary Data
Methodology

4. Comparative Analysis

- Preliminary analysis of data
- Study the Operation Performance of Metro rail Project (Forecast versus Actual)
- Study the forecast errors
- Application of Principal-agent model on Metro rail funding policy

5. Conclusion & Suggestion
Literature Review

Various Researchers > Developed and used Public transport Operation Indicators to measure performance

Two broad Indicators categories for Public transport measurement:

- Metro rail Operation Performance Indicators
  - Quality of Service
  - Service Supply
  - Average Speed, Average Headway
  - Passenger trips per capita, Passenger revenue per hour, Average Trip length

- System Management
  - Cost Efficiency
  - Fare box revenue

- Daily ridership, Passenger per kms
- Operation cost per kms, Cost contingencies, Revenue per kms, Cost overrun
Forecast errors in metro rail are attached as followed

- Ridership: In Baltimore and Portland, it ranges from 66% to 85% below the original forecasted. (Don H, 1990)

- Capital Outlay: The project cost at Pittsburgh’s light rail project were actually 11% below as their actual forecast value, whereas Sacramento’s light rail and Miami metro project is 13% and 106% less than forecast. (Don H, 1990)

- Operating Expenses: In case of Buffo’s Light rail (12%), Washington (200%), Atlanta (200%) and Miami’s metro project (84%) above their foreseen level. (Don H, 1990)


- Contingency allowance to cover cost escalation: The contingency allowance for -rail project is ranging from 5 to 10% of estimated project costs. (Don H, 1990)
<table>
<thead>
<tr>
<th>Theory</th>
<th>Strengths (Regarding the Research Problem)</th>
<th>Weaknesses (Regarding the Research Problem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game Theory</td>
<td>Mathematical derivation of recommendations regarding interdependent choices and actions,</td>
<td>• Highly restricted viewpoint requires scenario modelling</td>
</tr>
<tr>
<td>Institutional Theory</td>
<td>Defines coercive, normative and mimetic pressures that lead to the sustainable behaviour of organizations</td>
<td>• Lack of understanding of non-conforming organizational behaviour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• provides no explanations for incentive mechanism design</td>
</tr>
<tr>
<td>Network Theory</td>
<td>Descriptive character that may be used to map the interplay between MoUD and Local authority regarding sustainable funding mechanisms</td>
<td>• Lack of theoretical foundation and explanatory power of mapped interplay</td>
</tr>
<tr>
<td>Resource-Based View</td>
<td>Insights into the capabilities and resources that are required to achieve competitive.</td>
<td>• Lack of explanatory power regarding incentive mechanisms</td>
</tr>
<tr>
<td>Theory</td>
<td>Strengths (Regarding the Research Problem)</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Transaction Cost Economics</td>
<td>Concerns internal and external costs that result from the sustainable behaviour of local authority</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Dominance of transaction costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No explanations for incentive mechanism design</td>
<td></td>
</tr>
<tr>
<td>Principal-Agent Theory / Agency</td>
<td>• Structure of the design of incentive mechanisms regarding information asymmetries and agency problems (ex-ante and ex-post contract)</td>
<td></td>
</tr>
<tr>
<td>Theory</td>
<td>• Derivation of recommendations for incentive design with respect to the suggestions of agency theory</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Restricted view on static MoUD and local authority relationships terminate of efficiency objectives and opportunistic behaviour that may conflict with legitimacy-driven sustainable behaviour</td>
<td></td>
</tr>
<tr>
<td>Strategic Choice Theory</td>
<td>Insights into the development of interorganizational sustainability strategies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Dominance of strategic decisions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No explanations for incentive mechanism design</td>
<td></td>
</tr>
<tr>
<td>Stakeholder Theory</td>
<td>Explanatory theory that maps the interplay of markets and resources, explains sustainable behaviour as a consequence of stakeholder pressures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No explanations for incentive mechanism design</td>
<td></td>
</tr>
</tbody>
</table>
Analysis

1st Objective: To Analyze performance of metro rail project investments in terms of objective, ridership, revenue, and capital cost

Case study: Delhi, Bangalore, Mumbai, Jaipur and Chennai

2nd Objective: To identifying the causes of metro rail forecast errors and its sources
Delhi Metro rail project-Brief

Delhi MRTS objective was to provide non-polluting, efficient and affordable rail based MRTS, duly integrated with other modes of Transport.

The first section of phase-1 was opened in 2002 and currently, 193.20 km (in 2016) of Metro rail network is operating.

Forecast ridership

<table>
<thead>
<tr>
<th>Year</th>
<th>Phase-1 Ridership</th>
<th>Phase-2 Ridership</th>
<th>Phase-3 Ridership</th>
<th>Total Ridership</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>589234</td>
<td>1505038</td>
<td>18556426</td>
<td>3950698</td>
</tr>
<tr>
<td>2021</td>
<td>696458</td>
<td>1835994</td>
<td>2300542</td>
<td>4832994</td>
</tr>
<tr>
<td>2026</td>
<td>814698</td>
<td>2146550</td>
<td>2719146</td>
<td>5680394</td>
</tr>
<tr>
<td>2031</td>
<td>948988</td>
<td>2472714</td>
<td>3141264</td>
<td>6562966</td>
</tr>
</tbody>
</table>

Metro Network

Source: The Metro Guys
## Delhi Forecast Outcomes

<table>
<thead>
<tr>
<th>Phase</th>
<th>Metro System</th>
<th>Delhi Forecast Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase-1</td>
<td>133234</td>
<td>200220032004200520062007200820092010201120122013201420152016</td>
</tr>
<tr>
<td>Phase-2</td>
<td>18798</td>
<td>Forecast</td>
</tr>
<tr>
<td>Phase-3</td>
<td>10813</td>
<td>Outcomes</td>
</tr>
</tbody>
</table>

### Operating Cost
- **Ridership**: 27,68,420 pax/day in 2016
- **Phase-1 Ridership**: 29,10,000 pax/day in 2016
- **Achieved Ridership**: 105.11%

### Project Cost
- **Estimate Cost for Phase-1 (as per 2011)**: Rs. 4859 Cr.
- **Actual Completion cost of Phase-1 (as per 2011)**: Rs. 10571 (118% difference)

### Network (in kms)
- **Metro System**: 0
- **Network (in Kms)**: Delhi Phase-1 10813, Delhi Phase-2 18798, Delhi Phase-3 10813

### Estimate versus Actual project cost
- **Opex per kms**: Rs in 24.86 Cr
- **Revenue per kms**: Rs.21.37 Cr.
- **Average per kms**: fare Rs. 0.5

### Operating Cost
- **Rs in Cr**
- **Rs 4859 Cr.**
- **Rs 10571 (118% difference)**

### Passenger revenue per kms
- **Rs 11624**
Mumbai Metro rail project-Brief

The objective of the metro system was to achieve affordable, safe and environmentally free public transport system.

The first section of phase-1 was opened in 2014 and currently 11.4 km of Metro rail network is operating.

<table>
<thead>
<tr>
<th>Year</th>
<th>Daily Ridership</th>
<th>Hourly Ridership</th>
<th>PHPDT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>475046</td>
<td>38004</td>
<td>17356</td>
</tr>
<tr>
<td>2011</td>
<td>513338</td>
<td>41067</td>
<td>18580</td>
</tr>
<tr>
<td>2021</td>
<td>664703</td>
<td>53176</td>
<td>23321</td>
</tr>
<tr>
<td>2031</td>
<td>882533</td>
<td>70603</td>
<td>30491</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Corridor Length (Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vesova-Andheri-Ghatkopar 15</td>
</tr>
<tr>
<td>Colaba-Mahim-Charkop 36</td>
</tr>
<tr>
<td>Mahim-Munkhurd 12.8</td>
</tr>
<tr>
<td>Charkop-Dahisar (east) 7.5</td>
</tr>
<tr>
<td>Ghatkopar-Mulund 12.4</td>
</tr>
<tr>
<td>BKC to Kanjur Marg via Airport 19.5</td>
</tr>
<tr>
<td>Andheri(east)-Dahisar(east) 18</td>
</tr>
<tr>
<td>Hutatma Chowk-Ghatkopar 21.8</td>
</tr>
<tr>
<td>Sewri-Prabhadevi 3.5</td>
</tr>
</tbody>
</table>

- **1969-1991**: Concept of Metro, proposed for the first time in Mumbai. Metro project reflected in Development Plan.
- **1997**: Metro Project Feasibility study carried out by MMRDA.
- **2003**: Metro Project Master Plan Initiated by MMRDA.
- **2004**: Metro Project DPR Report and Public Consultation prepared by DMRC.
- **2006**: Metro Project got principal approval from the Central Government. It awarded on PPP mode.
- **June-2014**: Operation of Phase-1 start.
Forecast versus Actual Ridership

<table>
<thead>
<tr>
<th>City</th>
<th>Projected ridership pax/day</th>
<th>Projected Year</th>
<th>Actual ridership pax/day</th>
<th>Actual Year</th>
<th>Achieved Ridership %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mumbai</td>
<td>5,13,338</td>
<td>2011</td>
<td>2,60,000</td>
<td>2015</td>
<td>50.65%</td>
</tr>
</tbody>
</table>

Metro System PHPDT (in 2016)

Operating Cost

- **Annual earning cross Rs 135 Cr. still in loss** (opex per kms Rs 44.41 Cr and Revenue per kms Rs 19.25 Cr)
- **Fuel and Electricity** cost is higher compare to other metro system
- Average per kms fare Rs.3.9

Project Cost

- Estimate Cost for Line-1 (as per 2011) : Rs.2356 Cr.
- Actual Completion of Line-1 (as per 2011) : Rs.4151 Cr. (85% difference)
Jaipur Metro rail project-Brief

- The objective for metro system is to provide fast, safe and hassle free movement of the public in the city.

- The first section of phase-1 was opened in 2015 and currently 9.3 km (in network is operating

<table>
<thead>
<tr>
<th>Year</th>
<th>Corridor</th>
<th>Sectional Load (PHPD T)</th>
<th>Daily Riders (in lakhs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>Mansarovar-Badi Chaupar</td>
<td>11264</td>
<td>2.1</td>
</tr>
<tr>
<td>2021</td>
<td>Mansarovar-Badi Chaupar</td>
<td>16376</td>
<td>2.9</td>
</tr>
<tr>
<td>2031</td>
<td>Mansarovar-Badi Chaupar</td>
<td>27750</td>
<td>4.2</td>
</tr>
<tr>
<td>2014</td>
<td>Sitapura Industrial Area-Ambabari</td>
<td>12901</td>
<td>3.2</td>
</tr>
<tr>
<td>2021</td>
<td>Sitapura Industrial Area-Ambabari</td>
<td>18683</td>
<td>4.9</td>
</tr>
<tr>
<td>2031</td>
<td>Sitapura Industrial Area-Ambabari</td>
<td>22429</td>
<td>6.8</td>
</tr>
</tbody>
</table>

Developed Network

<table>
<thead>
<tr>
<th>Description</th>
<th>Underground (km)</th>
<th>Elevated (km)</th>
<th>Total (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-W Mansarover to Badi Chaupar</td>
<td>2.789</td>
<td>9.278</td>
<td>12.067</td>
</tr>
<tr>
<td>Sitapura Industrial Area to Ambabari</td>
<td>5.095</td>
<td>18.004</td>
<td>23.099</td>
</tr>
</tbody>
</table>
### Metro System PHPDT (in 2016)

<table>
<thead>
<tr>
<th>City</th>
<th>Projected ridership pax/day</th>
<th>Projected Year</th>
<th>Actual ridership pax/day</th>
<th>Actual Year</th>
<th>Achieved Ridership Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaipur</td>
<td>2,10,000</td>
<td>2014</td>
<td>25,486</td>
<td>2016</td>
<td>12.14%</td>
</tr>
</tbody>
</table>

#### Operating Cost
- Opex per kms Rs 12.21 Cr
- Revenue per kms Rs 2.83 Cr
- Average per kms fare Rs 1.6

#### Project Cost
- Estimate Cost for Phase-1A (as per 2011) : Rs. 3149 Cr.
- Actual Completion cost of Phase-1A (as per 2011) : Rs. 5000 Cr (59% difference)

---

### Operation versus Revenue

<table>
<thead>
<tr>
<th>Metro Network (in kms)</th>
<th>Passenger revenue per Kilometer (in lakh)</th>
<th>Operation Cost per Kilometer (in Lakh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaipur 2015 Forecast</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Jaipur 2016 Outcomes</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

### Estimate versus Actual project cost

- Estimated Cost at April 2011 (in Cr.)
- Estimated Cost at April 2011 (in Cr.)
- Estimated Cost at April 2011 (in Cr.)
- Estimated Cost at April 2011 (in Cr.)
Comparison of five metro rail performance

Forecast versus Actual ridership

Ridership

- 3,500,000
- 3,000,000
- 2,500,000
- 2,000,000
- 1,500,000
- 1,000,000
- 500,000
- 0

(in Kms)

- 2,500,000
- 2,000,000
- 1,500,000
- 1,000,000
- 500,000
- 0

Passenger Per km

- 25,000
- 20,000
- 15,000
- 10,000
- 5,000
- 0

(in Kms)

- Operationa
- l Network (in Kms)
- Projected ridership pax/day
- Actual ridership pax/day

- Delhi
- Bangalore
- Jaipur
- Mumbai
- Chennai

- Delhi
- Bangalore
- Mumbai
- Jaipur
- Chennai
## Comparison of five metro rail performance

### Ridership Comparison

<table>
<thead>
<tr>
<th>Project (Country)</th>
<th>No. of projects (N)</th>
<th>Quartiles (25/50/75%)</th>
<th>Average difference (%)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>India (2016)</td>
<td>5</td>
<td>-49/-88/-93</td>
<td>-58.56</td>
<td>39.34</td>
</tr>
<tr>
<td>Europe (2007)</td>
<td>6</td>
<td>-29/-4/45</td>
<td>-20.7</td>
<td>77.30</td>
</tr>
<tr>
<td>North America (2007)</td>
<td>10</td>
<td>-69/-63/-53</td>
<td>-60.0</td>
<td>17.0</td>
</tr>
</tbody>
</table>

### Metro rail Operation Cost

- **Operational Cost (in lakh)**
- **Employ expense (in lakh)**
- **Other Expence (in lakh)**
- **Fuel & Electricity cost (in lakh)**
- **Facilities Management Services (in lakh)**
## Comparison of Five Metro Rail Performance

### Table:

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>India (2016)</td>
<td>5</td>
<td>33/51/70</td>
<td>30.21</td>
<td>25.18</td>
</tr>
<tr>
<td>Europe (2008)</td>
<td>6</td>
<td>39/45/57</td>
<td>43.30</td>
<td>21.30</td>
</tr>
<tr>
<td>North America (2008)</td>
<td>10</td>
<td>33/42/54</td>
<td>35.80</td>
<td>30.40</td>
</tr>
</tbody>
</table>
3rd Objective: Test the hypothesis through the application of the Principal-agent problem to Metro rail funding process
Principal –Agent problem Model

Why Principal –agent model?

- Structure information asymmetries and principal-agent problem that inherent the interrelationship between the state and central government regarding the metro rail project selection.
- It applied when the private information of agent creates a problem for the Principal.

What is Principal–agent problem?

- Conflict objective
- Adverse selection
- Moral hazard
Lack of coordination between the DMRC and DDA regarding the metro route selection

- Master plan was not referred by DMRC (In 1st phase)
- Tassel for Metro route alignment

DPR report by RITES (data not cross check by DDA)

- Forecast and Actual result of metro is biased “The fact that transport modelling for ridership was not carried out accurately by RITES”
- Transportation modeling for ridership was not carried out accurately by RITES

- The statement of ridership projection is very high in Delhi
- Hidden agenda
- Manifesto of

- DDA proposed Dwaraka sector-21 corridor (DMRC refuse, Traffic study result not supported for MRTS)
- Forecast ridership changed 3 times
- Two metro corridor was closed (ridership result was not efficient)

- Honesty
Principal-agent Model-A case of Mumbai Metro

CONFLICT

- Weightage base Metro route selection
- Absence of Social concern in Metro route selection process

OBJECTIVE

- Multiple Agency had produced Traffic data (All private Consultants)
- Overlapping Information
- Traffic data was not cross check by MMRDA
- Master Plan was not preferred in Phase-1

ADVERSE SELECTION

- Funding Problem (VGF controversy)
- Hidden Agenda, Over estimation of Fare and Cost

MORAL HAZARD

- Legal Controversy of Metro act and Tram act
- Diffused in Fare decision process
- Argument raised by the private company (MMOPL) that, the project completion cost reached up to 4321 Cr. whereas the original cost estimated in DPR was 2356 Cr.
- Absence of transparency in Project Cost
Principal-agent Model-A case of Jaipur Metro

**CONFLICT OBJECTIVE**

- Modern Technology for Traffic solution rather than adopting hierarchy of Transport mode as per requirement
- Political promise and Biased for Mass transit system
- Client Based Consults, e.g. Inflated Ridership and less capital investment
- Metro board chairmanship conflict

**ADVERSE SELECTION**

- Absence of Alternative Transport Plan (Prepaid by Wilbur smith Associates)
- No coordination between the JMRCL and JDA regarding the Metro route selection
- No Master Plan and JDA involved in MRTS route selection process
- Two different approaches for Traffic Management by JDA and JMRCL (Asymmetric Information) (e.g. during the construction of phase-1, There are historical monuments were found while drillings. This study was not capture in DPR)
Overview of Principal agent problem

Lack of power
Absence of Committee
Fare change

Lack of Coordination bwt
Local authority &
SPV
Absence of Land
use transport
integration

Lack of governance
structure
Conflict in power

Lack of initiative to
explore other mode
of funding
More depending on
JV model

Different Objective
Hidden Information
(client based consults)

Absence of mass
transit alternative
Leapfrog hierarchy
Manifesto of politician

Cross check result

Lack of Capacity
building
Absence of committee
to review pre and post
performance
Conclusion

Principal – Agent Problem

Next Waiting line for Metro Rail Project
Design a contract in such way that the **objective of principal and agents are incorporated** while designing the funding agreement.

**Revelation of principal;** scheme should be design for the truthful information. It may **penalty or rewards rates, as per the revelation of Information**. The rewards (penalty) would be decided based on the performance (e.g. operation performance).

**NUTP review committee** should formulate **certain indicators to evaluate mass transit option** for different size of cities.

**Special committee formulate** under the power of NUTP, who can analyze all report produced during the mass project selection. (Feasibility, Technical, Social & Economic, and EIA report).

Increased the **capacity building of staff** in NUTP committee. Involved different field of **Expert in NUTP committee.**
The MoUD (principal) need to provide **minimum level of incentives** in terms of funds. Due to minimum incentive State (agent) are willing to participated in the contract game mechanisms. The minimum incentive should be worked based on the **objective functions of State** (agents).

- If the projects are developed as state sector project MoUD may contribute by way of **grant equivalent, as VGF in a PPP project**.
- Projects which are **viable with admissible VGF without providing real estate** rights to the concessionaire may be taken under PPP.
- **Failure in awarding bid** should result in project being taken in government sector.

**Establishment of SPV**

- If **central projects being developed under government sector** (due to requisite autonomy in decision making) it provides, 50:50 JV.
- During shareholder agreement, **liability of GoI would be limited to equity and sub-ordinate debt agreed** at the time of formation of JV.
- JV may provide within the ambit of transparency bodies and would be audited by **Comptroller and Auditor General**.
- Metro board **chairmanship should be under Central Government**.
Thank You