This strategy was presented to EF China board in Jun 2021, and subjects to regular updates.
Outline

1. Context
2. Key policymakers
3. Overall goals
4. Theory of change
5. Barriers and drivers
6. Key intervention prongs
Context: Focus of Part II Strategy and Rationale

Mobile source criteria air pollutants (CAPs) emissions

Part II strategy

Road Transport

Off-Road Transport

Off-Road Machineries

Transport CO₂ emissions
Off-Road Sector
Off-road mobile sources accounted for 44% and 76% of total NOx and PM emissions respectively from mobile sources in 2019.
Off-road mobile sources are lagging far behind on criteria pollutants (CAPs) emissions reduction

Emissions standards implemented by dates for different mobile sources

Source: 2020 Mobile Source Environment Management Annual Report
Fuel consumption from off-road transport (aviation, water, rail) was about 20% of total transport energy consumption, excluding electricity.

Source: 2020 Energy Data Annual Report by Qingyi Wang
Transport System
China needs to avoid relying too much on road and aviation (as the U.S. does) for passenger transportation

Source: China Statistic Bureau; BTS in U.S.
China could learn from U.S. to increase railway freight market share

### Ton-Kms by modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Trillions</th>
</tr>
</thead>
<tbody>
<tr>
<td>rail</td>
<td>CN-2019: 3.00, US-2018: 3.00</td>
</tr>
<tr>
<td>road</td>
<td>CN-2019: 5.00, US-2018: 6.00</td>
</tr>
<tr>
<td>river</td>
<td>CN-2019: 0.00, US-2018: 0.00</td>
</tr>
<tr>
<td>air</td>
<td>CN-2019: 0.00, US-2018: 0.00</td>
</tr>
<tr>
<td>pipeline</td>
<td>CN-2019: 0.00, US-2018: 0.00</td>
</tr>
</tbody>
</table>

### Shares of ton-kms by modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>rail</td>
<td>CN-2019: 21%, US-2018: 33%</td>
</tr>
<tr>
<td>road</td>
<td>CN-2019: 34%, US-2018: 34%</td>
</tr>
<tr>
<td>river</td>
<td>CN-2019: 9%, US-2018: 19%</td>
</tr>
<tr>
<td>air</td>
<td>CN-2019: 0%, US-2018: 0%</td>
</tr>
<tr>
<td>pipeline</td>
<td>CN-2019: 4%, US-2018: 4%</td>
</tr>
</tbody>
</table>

Note: excluding international marine

Source: China Statistic Bureau; BTS in U.S.
Inter-city passenger-kms significantly declined while ton-kms was relatively stable due to Covid-19 in 2020 in China.

Source: China Statistic Bureau
However, China has huge potential for more aviation trips

Flights per capita by region

Source: China Statistic Bureau; BTS in U.S.
Prioritizing HSR and metro development could help reduce inter-city aviation and private car trips

Source: China Statistic Bureau; Ministry of Transport
Different cities and regions need different mobility strategies

### City Category

(population range)

<table>
<thead>
<tr>
<th>Category</th>
<th>Population Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>$P &lt; 0.5 m$</td>
</tr>
<tr>
<td>Medium I</td>
<td>$0.2 m \leq P &lt; 0.5 m$</td>
</tr>
<tr>
<td>Medium II</td>
<td>$P &lt; 0.2 m$</td>
</tr>
<tr>
<td>Medium I</td>
<td>$0.5 m \leq P &lt; 1.0 m$</td>
</tr>
<tr>
<td>Medium II</td>
<td>$1.0 m \leq P &lt; 3.0 m$</td>
</tr>
<tr>
<td>Large I</td>
<td>$1.0 m \leq P &lt; 5.0 m$</td>
</tr>
<tr>
<td>Large II</td>
<td>$3.0 m \leq P &lt; 5.0 m$</td>
</tr>
<tr>
<td>Very Large I</td>
<td>$5.0 m \leq P &lt; 10.0 m$</td>
</tr>
<tr>
<td>Very Large II</td>
<td>$1.0 m \leq P &lt; 10.0 m$</td>
</tr>
<tr>
<td>Super Large I</td>
<td>$P \geq 10 m$</td>
</tr>
</tbody>
</table>
Mobility for vulnerable groups needs more attention

Source: China Statistic Bureau, China Disabled Persons’ Federation, LTS project supported by EFC
Future Mobility
Electric 2- & 3-wheelers are feeding into public transportation and reduce the last mile demands for cars and urban delivery trucks.
Shared mobility is reducing the demand for owning a car

- Maximize the utilization of a car for resources efficiency
- Benefit vehicle electrification
- Delay the demand for purchasing a car before mature EV
- Reduce mobility cost for vulnerable groups
- Help jobless
- Might reduce the attractiveness of buses
Key issues in summary

- No or poor CAPs and CO₂ regulations for off-road transport and machineries
- Aviation is increasing fast & trucks dominate the freight market while there are uncertainties on their zero emissions technology pathways
- Lack of differentiated mobility strategy based on city and region difference
- Lack of clear strategy and plan to embrace micro and shared mobility
- Poor attention to mobility demands from vulnerable groups
China invested 3.9 trillion RMB to improve transport infrastructure in 2019, & has an ambitious infrastructure plan by 2035

Transport Infrastructure Investment by Modes in 2019

Transport Infrastructure Development Targets by 2035

Source: Ministry of Transport, 《国家综合立体交通网规划纲要》
Key policymakers

- Transport infrastructure development, including metro
- Carbon peaking action plan

- Public transportation and green transportation development plan
- Comprehensive transportation development plan, including rail, aviation, water, and road transport

- Manufacturing of vehicles, vessels, airplanes, etc.
- Energy efficiency promotion and new energy vehicle industry development

- Climate and air quality targets
- Climate and air pollution control action plan
- Tailpipe emissions standards
Theory of Change

- **Increase rail competitiveness to reduce trucks, inter-city car trips, and aviation**
- **Accelerate metro development in Tier I & II cities to reduce urban car driving**
- **Encourage 2 & 3 wheelers in Tier I & II cities to feed public transport & reduce short-distance car trips**
- **Improve bus services in Tier III & IV cities to provide choices other than private cars**

**Technology**

- Electrify equipment, vessels, & airplanes where possible
- Tighten off-road emissions and fuel efficiency standards

**Structure**

- Safe
- Economic
- Low-carbon
- Clean
- Fast
- Convenient
- Reliable
- Comfortable
Increase railway freight market to 25% by 2050 from 15% in 2019

Source: EFC internal modeling and analysis, excluding urban freight
Shifting trucks to rail could account for more than 50% of total freight fuel consumption savings before 2030

Source: EFC internal modeling and analysis
Increase rail and metro passenger market to 38% by 2050 compared to 20% in 2019

Source: EFC internal modeling and analysis
Electrification dominates the fuel savings for passenger transportation, with aviation as the remaining hard bone by 2050.

Source: EFC internal modeling and analysis
Key barriers & drivers

Barriers:

• Lack of the law to mandate the integration of different transport modes, including infrastructure development and service supply

• Railway operates like a government and lacks the market competitiveness

• The government is not used to innovative market-based mobility service, such as sharing

• Lack of data on urban logistic and national and local commodities flow

• Immature zero emissions technologies for vessels and airplanes

• Lack of enough attention to vulnerable groups’ mobility

Drivers:

• Air quality improvement and health protection

• National and urban carbon peaking and neutrality

• International requirements to reduce emissions from international aviation and marine vessels

• Transportation cost and economic development

• National and city operation efficiency and attractiveness

• Transportation safety and fairness
Key intervention prongs

- CT law, strategy, plan, standards
- Railway competitiveness
- Infrastructure development & investment plan
- Regional and local pilots
- Off-road leapfrog where possible & tightening standards
- Micro-mobility & bus in non-mega cities
- Enable ICAO & IMO regulations
- Data, modeling, and capacity
- Communication

Part II Strategy
Annex
Transport is accounting for growing local \( \text{PM}_{2.5} \) pollution in both Beijing and Shanghai.
Off-road engines account for ~18% of total engine sales

Source: China Internal Combustion Engine Industry Association
About 8m off-road engines are sold each year without strict emissions standards and no fuel efficiency regulation

Source; China Internal Combustion Engine Industry Association
As of 2019, 43m agricultural & construction machineries are operating in the field, with largest fraction meeting China 2 emissions standard

Agricultural machineries by categories & emissions standards

Construction machineries by categories & emissions standards

Source: Vehicle Emissions Control Center
As of 2019, 5.3m construction machineries are operating in the field, mostly meeting China 2 & 3 emissions standards

Source: Vehicle Emissions Control Center
38m agricultural machineries, mostly meeting China 2 emissions standards

Agricultural machineries by categories & emissions standards

- Large tractor
- Small tractor
- Harvester
- Diesel irrigation
- Fishing boat

Agricultural machineries by emissions standards

- China 0, 3034060, 8%
- China I, 5857618, 15%
- China 3, 5641176, 15%
- China 2, 23647722, 62%

Source: Vehicle Emissions Control Center
In addition to vehicles, off-road transport is also critical

River-going: 119,500  
Costal: 10,364  
International marine: 1,664  
Electric locomotives: 13,700  
ICE locomotives: 8,000  
Air carrier: 3,818  
General aviation: 2,707
Both the number of airports and aircrafts are increasing quickly in China

Source: Civil aviation development statistics
Enable China to proactively support and advocate more stringent environment targets and actions at ICAO

Goals:
2% annual fuel efficiency improvement through 2050
carbon neutral growth from 2020 onwards

- Aircraft technology improvements (Airplane CO₂ Standard (2017))
- Operational improvements
- Sustainable aviation fuels
- Market-based measures (CORSIA)
ICAO technical standards on engine emissions

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Targeted pollutants</td>
<td>NOx, HC, CO, liquid fuel venting, smoke*</td>
</tr>
</tbody>
</table>

*Smoke is expected to be superseded by the nvPM Standard to be approved in 2020

NOx reduction targets by ratio

Source: EPA and ICAO
Enable China to proactively support and advocate more stringent environment targets and actions at IMO

**MARPOL Annex VI EEDI & SEEMP**

Carbon intensity reduced by 30%

2014 2025

**Initial GHG Strategy**

Carbon intensity reduced by 70%
GHG emissions reduced by 50%

2008 2030 2050 2050

EEDI: Energy Efficiency Design Index
SEEMP: Ship Energy Efficiency Management Plan (SEEMP)
Fuel quality improvement and engine emissions standards are the key approaches to reduce SOx and NOx emissions for international marine in MARPOL VI

Source: ICCT
The number of vessels in China is decreasing, but the total available tonnage capacity is increasing.

Source: Transportation statistics from MOT
China has made first step to regulate vessel emissions but still need to do more

- Vessel SOx, NOx, and PM emissions reduced by 65%, 20%, and 30% in Bohai Rim Waters, Yangtze River Delta, and the Pearl River Delta by 2020
- Commercial ships energy and carbon intensity reduced by 6% and 7%, and port energy and carbon intensity reduced by 2% in 13th FYP period
Leapfrog domestic off-road sources towards zero emissions where possible together with more stringent emissions standards
Freight ton-kms might have stabilized in China

Source: China Statistic Bureau, excluding urban logistics
Road dominates the total tons of freight movement

Source: China Statistic Bureau, excluding urban logistics
Water accounts for about half of total ton-kms of freight in China, and railway has slightly increasing market recently.

Source: China Statistic Bureau, excluding urban logistics
With the economy upgrading and shifting away from coal, China is expecting decreasing freight movement demand.

Shares of ton-miles by commodities by rail in 2014

Coal: 43%
Others: 15%
Coke: 4%
Oil: 9%
Steel: 8%
Metal ore: 6%
Fertilizer: 5%
Wood: 4%
Cement: 1%
Gravel: 1%
Non-metal ore: 2%
Salt: 1%
Cotton: 1%
Food: 1%

Shares of ton-miles by commodities by trucks in 2019

Building materials & cement: 27%
Coal related: 23%
Medicine and light-weight materials: 15%
Equipements: 13%
Metalic ore: 10%
Agricultural products: 12%
Others: 15%
Agricultural products: 12%

Source: China Statistic Bureau; Ministry of Transport
Similarly, road dominates the inter-city passenger movement.
However, road is losing its inter-city passenger-kms market quickly, while both rail and aviation are increasing significantly.

Source: China Statistic Bureau
Aviation is increasing its passenger-kms market share quickly

Source: China Statistic Bureau
Inter-city passenger-kms accounted for 54% of total passenger-kms in China

Inter-city Passenger Trips by Modes

Inter-city Passenger-Kms by Modes

Source: China Statistic Bureau; EFC internal analysis, excluding walking and bicycling
Cars dominated the urban passenger transportation at about 70% of total urban passenger-kms

Source: China Statistic Bureau; EFC internal analysis, excluding walking and bicycling
High-speed rail has strong competition capacity with private driving and aviation

<table>
<thead>
<tr>
<th>Distance</th>
<th>Less than 100 km</th>
<th>Around 100-300 km</th>
<th>Around 300-500 km</th>
<th>Around 500-800 km</th>
<th>Around 800-1200 km</th>
<th>More than 1200 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving</td>
<td>64</td>
<td>40</td>
<td>15</td>
<td>6</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>High-Speed Trains</td>
<td>17</td>
<td>43</td>
<td>68</td>
<td>73</td>
<td>57</td>
<td>42</td>
</tr>
<tr>
<td>Inner-City Buses</td>
<td>13</td>
<td>14</td>
<td>11</td>
<td>6</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Taxies</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Airplanes</td>
<td>-</td>
<td>1</td>
<td>4</td>
<td>15</td>
<td>34</td>
<td>51</td>
</tr>
</tbody>
</table>

Source: Market survey done by IPSOS with the supported from EFC
HSR significantly reduces the demand for aviation

Average change in passenger activity on selected air routes after high-speed rail implementation

Sources: Xia (2016); Börjesson (2014); Givoni (2013); Chen (2017); Commissariat Général au Développement Durable (2016).

Note: The periods of time vary from line to line in this figure, which needs to be taken into account when comparing these elements.

Source: IEA, The Future of Rail
73% of rail tracks and 63% of locomotives are electric in 2020 in China, and railway development continues with significant annual investment.

Source: China Statistic Bureau; Ministry of Transport
The transport investment increased 20% annually on average from 2013 to 2019 in China mainly due to road construction.
With good public transportation, private car mileage is decreasing steadily in mega cities, which might become a trend in top cities if with rapid metro development.

Source: EFC internal analysis, Vehicle Emissions Control Center, Beijing Transport Institute, Shanghai Urban-Rural Transport Research Institute, Chengdu VECC
Passenger & freight transportation are determined by population and land area, and the amount & structure of economy & energy.

Source: China Statistic Bureau; BTS in U.S.; [https://www.worlddata.info/country-comparison.php?country1=CHN&country2=USA](https://www.worlddata.info/country-comparison.php?country1=CHN&country2=USA)
Rail and pipeline accounted for 33% and 19% of domestic ton-miles in 2018 in USA

Source: BTS in U.S.
Freight ton-kms grew only 26% since 1980 in U.S.

Source: BTS in U.S.
However, passenger-kms grew 120% since 1980 in U.S.

Source: BTS in U.S.
Passenger-kms keep increasing in both countries

Source: China Statistic Bureau; BTS in U.S.
U.S.’s transport sector consumed twice as much fuel as China, while China consumed much more electricity in 2019

Transport Energy Consumption by Categories in 2019

- Gasoline: China 3.2 billion tons, US 1.6 billion tons
- Diesel: China 1.5 billion tons, US 0.8 billion tons
- Residue fuel oil: China 0.1 billion tons, US 0.05 billion tons
- Kerosine: China 0.05 billion tons, US 0.03 billion tons

Electricity Consumption in Transport

- China: 550 million kwh
- US: 100 million kwh

Source: 2020 Energy Data Book from Qingyi Wang, China Statistic Bureau, BTS, the 2nd National Pollution Census Report in China; excluding electricity for EVs
Autonomous vehicles?

- How soon? BEV-based or ICE-based?
- How smart? Smart vehicle & Smart city?
- How to use? Private owned or shared mobility?

**SAE international’s levels of driving automation for on-road vehicles**

<table>
<thead>
<tr>
<th>Level</th>
<th>Human driver monitors the road</th>
<th>Automated driving system monitors the road</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>NO AUTOMATION</td>
<td>N/A</td>
</tr>
<tr>
<td>1</td>
<td>DRIVER ASSISTANCE</td>
<td>SOME DRIVING MODES</td>
</tr>
<tr>
<td>2</td>
<td>PARTIAL AUTOMATION</td>
<td>SOME DRIVING MODES</td>
</tr>
<tr>
<td>3</td>
<td>CONDITIONAL AUTOMATION</td>
<td>SOME DRIVING MODES</td>
</tr>
<tr>
<td>4</td>
<td>HIGH AUTOMATION</td>
<td>SOME DRIVING MODES</td>
</tr>
<tr>
<td>5</td>
<td>FULL AUTOMATION</td>
<td>SOME DRIVING MODES</td>
</tr>
</tbody>
</table>

- Steering and acceleration/deceleration
- Monitoring of driving environment
- Fallback when automation fails
- Automated system is in control
In order to reduce the risks for carbon neutrality, freight ton-kms in China need to decrease quickly after 2035 with structure continuously improving.

Source: CATS, ICT, EFC’s internal analysis