7 May 2026
Green Roads Webinar Series, Episode 34
Asian Development Bank

Decarbonizing Freight Transport in Japan: Policy Impacts, Intermodal Networks, and Autoflow Road Vision

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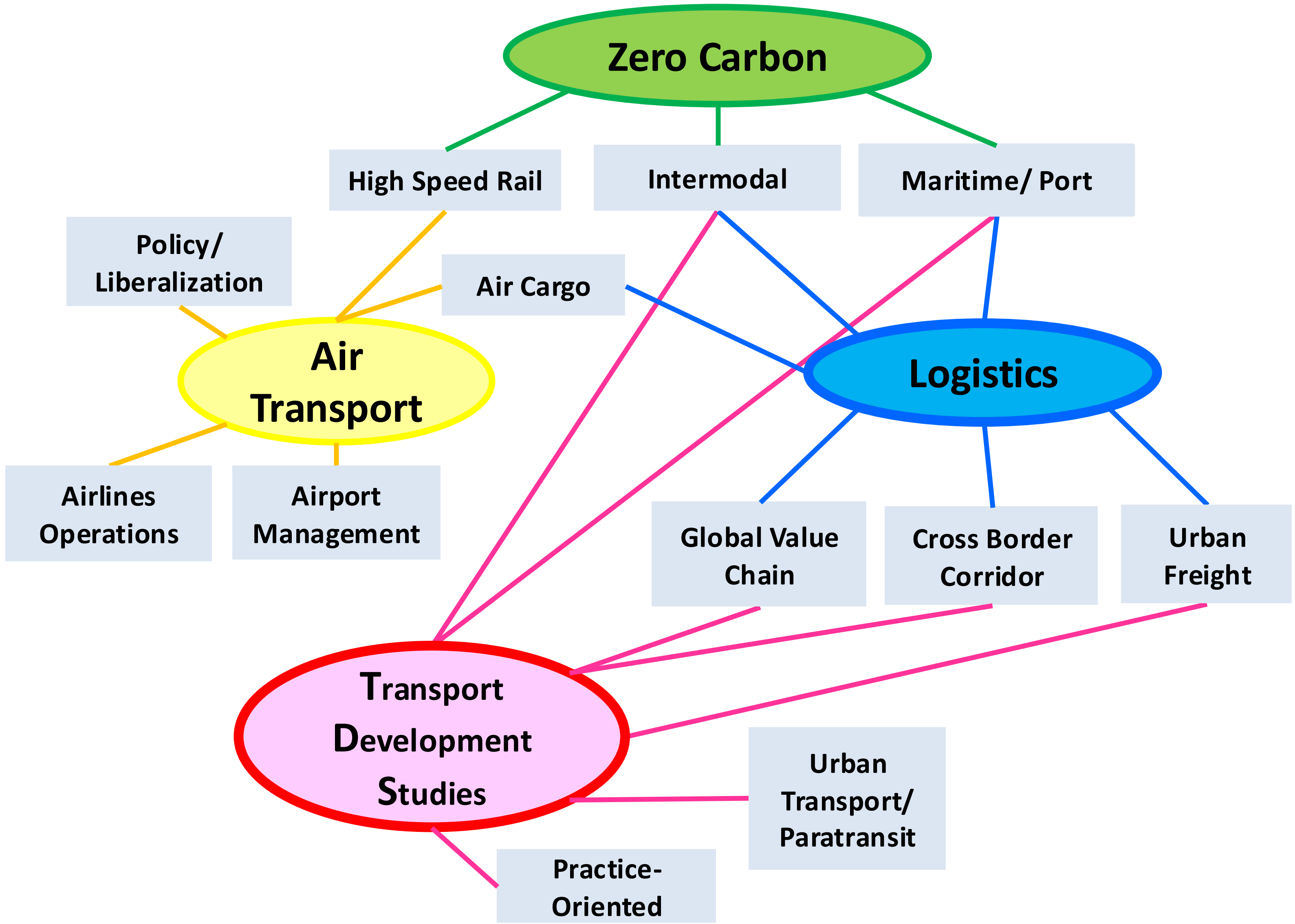
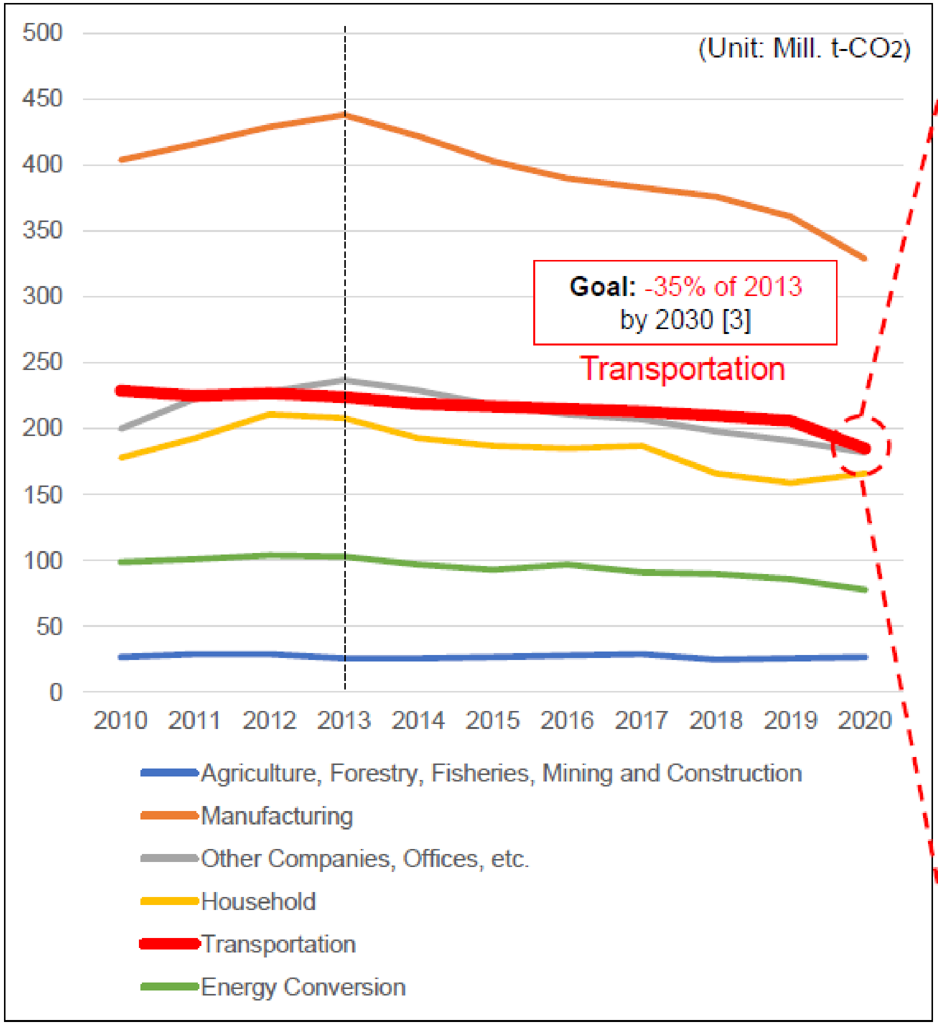
Research Area



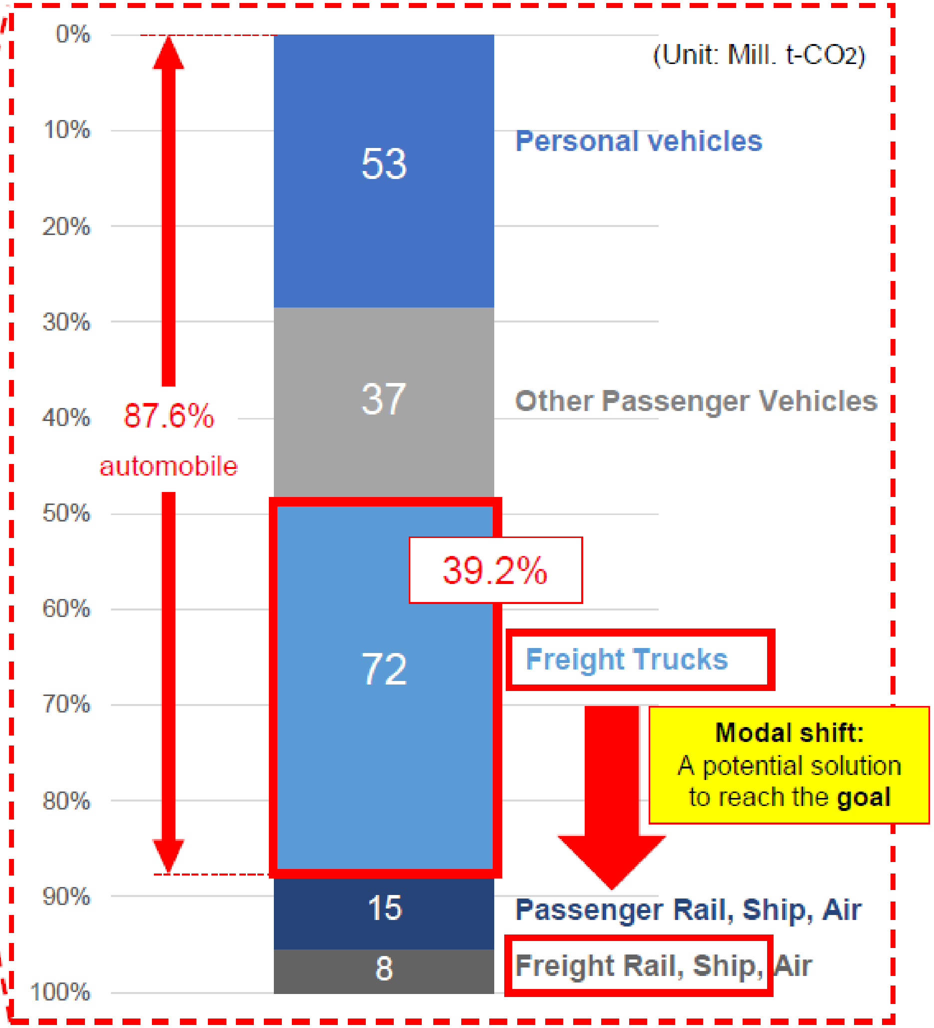
Introduction: CO_2 emission by transportation sector in Japan

CO_2 Emissions by Sector



Source： Agency of Natural Resources and Energy [1]

Emissions by transportation mode (2020)



Source： National Institute for Environmental Studies [2]

Introduction: Current progress of Modal shift

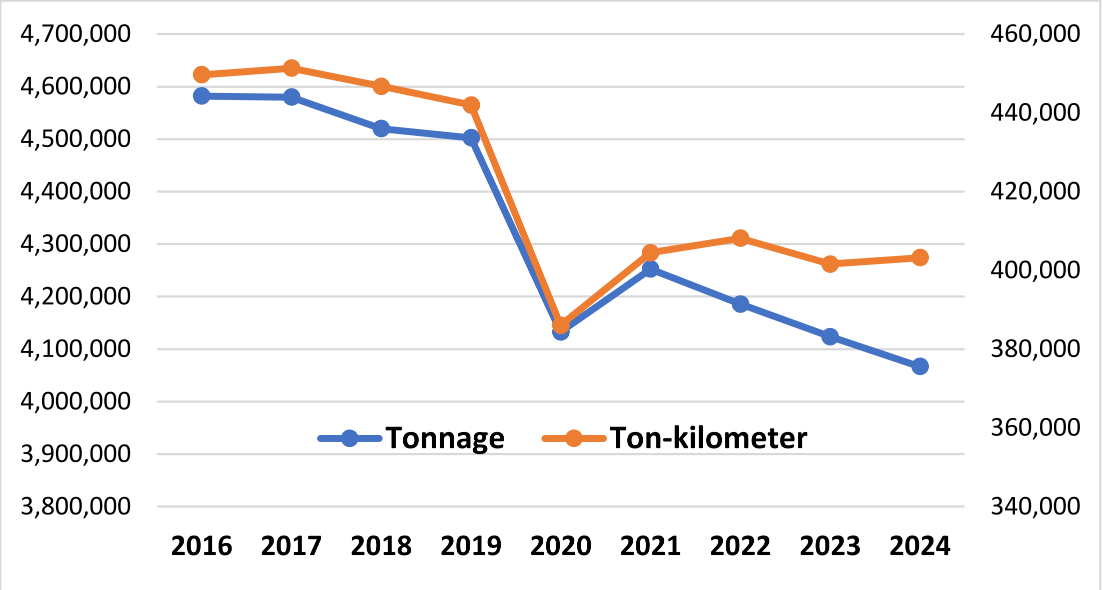
Modal Share of Freight Transport in Japan

Tonnage [thousand]

FY	Truck		Railway		Waterway		Airway		Total
2016	4,172,572	91.1%	44,089	1.0%	364,485	8.0%	909	0.02%	4,582,055
2017	4,173,666	91.1%	45,170	1.0%	360,127	7.9%	904	0.02%	4,579,867
2018	4,122,174	91.2%	42,321	0.9%	354,445	7.8%	823	0.02%	4,519,763
2019	4,117,399	91.5%	42,660	0.9%	341,450	7.6%	781	0.02%	4,502,290
2020	3,786,998	91.6%	39,124	0.9%	306,076	7.4%	428	0.01%	4,132,626
2021	3,888,397	91.4%	38,912	0.9%	324,659	7.6%	479	0.01%	4,252,447
2022	3,825,999	91.4%	38,264	0.9%	320,929	7.7%	549	0.01%	4,185,741
2023	3,780,504	91.7%	38,294	0.9%	304,404	7.4%	555	0.01%	4,123,757
2024	3,724,797	91.6%	38,475	0.9%	302,741	7.4%	618	0.02%	4,066,631

Ton-kilometers [million]

FY	Truck		Railway		Waterway		Airway		Total
2016	246,991	54.9%	21,265	4.7%	180,438	40.1%	960	0.21%	449,654
2017	247,782	54.9%	21,663	4.8%	180,934	40.1%	969	0.21%	451,348
2018	247,394	55.4%	19,369	4.3%	179,089	40.1%	881	0.20%	446,733
2019	251,471	56.9%	19,993	4.5%	169,680	38.4%	835	0.19%	441,979
2020	213,419	55.3%	18,340	4.8%	153,824	39.8%	464	0.12%	386,047
2021	224,095	55.4%	18,042	4.5%	161,795	40.0%	528	0.13%	404,460
2022	226,886	55.6%	17,984	4.4%	162,663	39.9%	599	0.15%	408,132
2023	229,180	57.1%	17,802	4.4%	154,015	38.4%	601	0.15%	401,598
2024	231,646	57.4%	17,870	4.4%	153,059	38.0%	659	0.16%	403,234



Overview of Railway freight transportation in Japan ①

Table. Overview of Railway Freight Transportation in Japan (FY2015)[8]

		JR Freight	Other Private Railway	Total	Share of JR Freight
Transport tonnage		30,564,772	12,645,917	43,210,689	70.7%
	Container	22,077,935	2,676,149	24,754,084	89.2%
	Car load	8,486,837	9,969,768	18,456,605	46.0%
Transport ton-kilometer		21,211,526,290	170,019,362	21,381,545,652	**99.2%**
	Container	19,927,275,462	24,185,022	19,951,460,484	**99.9%**
	Car load	1,284,250,828	145,834,340	1,430,085,168	**89.8%**
Income (thousand JPY)		118,399,135	6,371,679	124,770,814	**94.9%**

JR Freight is the only operator with a freight transportation network covering whole Japan. It has almost **100% share** in container transport by ton-kilometer, hence business condition will directly affect the railway freight transportation in Japan.

Transportation way

Container

Industrial product etc. [9]

Car load（車扱）

Coal, limestone, cement, petroleum, etc. [10]

Other Private Railway including

100% Private Railway

Ex. Hikoroichi Line（日頃市線）[11]

Third sector Railway

Ex. Coastal Railway (臨海鉄道) [12]

Overview of Railway freight transportation in Japan ②

Hindrance to modal shift [8]

①Difficulty in using the service

Railway schedules are rigid and it is difficult to flexibly meet the demands of shippers. Increased risk of damage due to transshipment at stations/ terminals, etc.

②JR Freight's management policy

In response to the decline in operating revenues, JR Freight has been trying to survive by reducing the scale of its business, especially its railway network. The has created a mismatch in the needs of shippers for railway transportation.

Possible solutions [8]

1. Expand transportation capacity of main line
2. Ensuring safe and stable transportation
3. Improve information systems
4. Modernization of stations
5. Replacement of aging rolling stock
6. Improvement of container service level

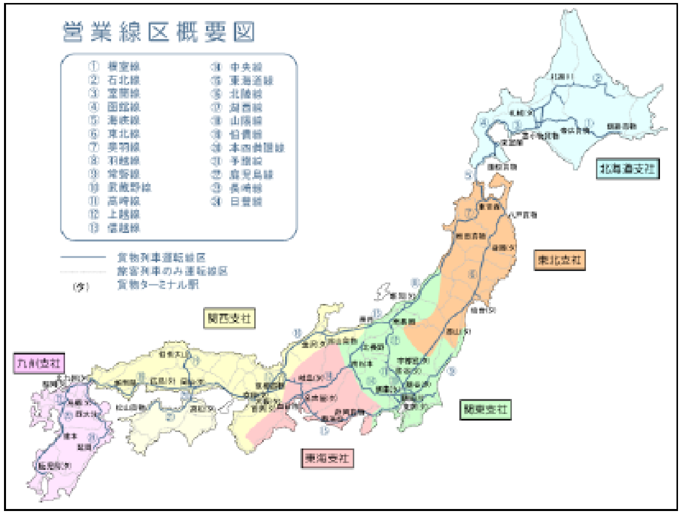


Fig. Main line of JR Freight [13]

Overview of Waterway freight transportation in Japan ①

Waterway

- Tramper
  - Oil, cement, etc.
    <u>High-volume, mono-material industry freight</u>
- Liner
  - Container
    - Industrial, General product etc.
  - RORO
    - Products are loaded and discharged from a vessel.by truck/ forklift etc.

Figure. Transportation type of waterway [14]

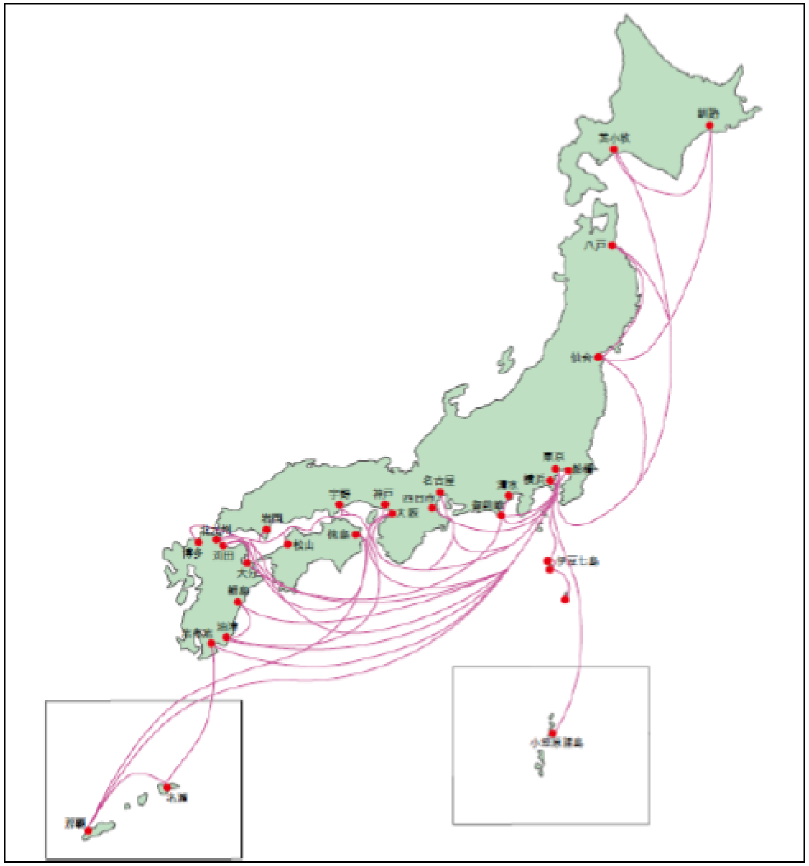


Figure. Liner waterway in Japan [15]

Overview of Waterway freight transportation in Japan ②

Hindrance to modal shift

① Low cost competitiveness

It is at a disadvantage in terms of cost because it is exposed to competition from truck transportation which has a discounted highway system, and seaway which has reduction in operating tax.

② Large number of small businesses

Industry is dominated by small-scale businesses. The number of operators is decreasing year by year due to the extremely weak management base with very little internal accumulation of capital.

③ Shortage of workers and aging population

Similar with truck industry, the number of young workers is decreasing due to the special characteristics of maritime labor, such as social isolation, insufficient wages, bad working environment etc.

④ Difficulty in using the service

Same with railway, schedules are rigid and it is difficult to flexibly meet the demands of shippers. Increased risk of damage due to transshipment at stations/ terminals, etc.

Possible solutions

1. Tax relief and other incentives (Increasing modal shift subsidies etc.)
2. Promote cooperation among operators and strengthen the cost bargaining power toward shippers
3. Training of workers and supply of workers by groups
4. Improve information systems
5. Improvement of wharves and cargo handling facilities (berth depths, warehouses, roads)
6. Make ports open 24 hours a day
7. Increase the number of terminals dedicated to waterway

Research objective

The emission of CO_2 during transportation has emerged as a **critical factor in the mode choice decisions** of shippers (Qi et al., 2022 [7]).

The Japanese government has set a goal of achieving **carbon neutrality** by 2050 [8], and is taking **political measures (regulation, incentives)** [9] to reach this goal.

1. Formulate decarbonization policies and incorporate them into the generalized cost function for shippers' mode choice.
2. Develop an **large-scale (national) intermodal transport network model** for **OD analysis of domestic freight in Japan,** to simulate the overall impact of decarbonization policies **on freight volumes and CO_2 emissions.**
3. Understand the **quantitative and geospatial impact of decarbonization policies** on intermodal networks.

Methodology: Expression of intermodal network

Base on Wang et al. (2016) [10]
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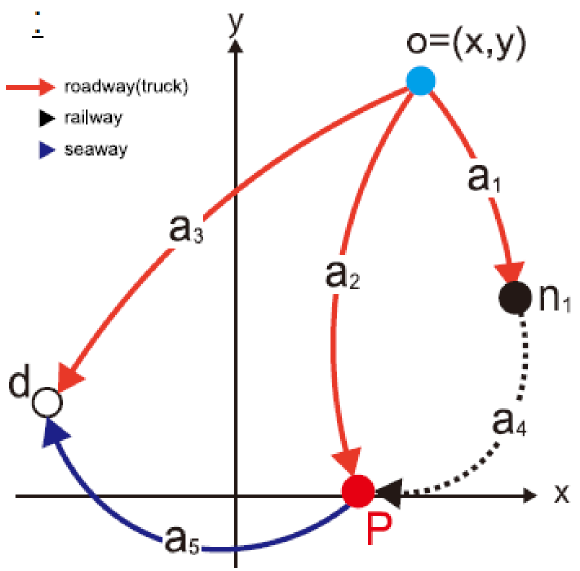


o	The origin of shipper
d	The destination of shipping
P	The target port
$R(x,y)$	The set of routes connecting (o, d)
$R_P(x,y)$	The set of routes pass through P
l	A route from o to d
$a \in A_l$	link
$n \in T_l$	transfer node

Average cost of route

$$\mu_l = \sum_{a \in A_l} \tau_a + \sum_{n \in T_l} \lambda_n$$

Variance of route cost

$$\sigma^2 = \sum_{a \in A_l} \mathrm{Var}[\varepsilon_a] + \sum_{n \in T_l} \mathrm{Var}[\gamma_n]$$

Cost function of route(l):

$$c_l = \sum_{a \in A_l} c_a + \sum_{n \in T_l} c_n$$

Cost function at a link(a):

$$c_a = \tau_a + \varepsilon_a$$

Average (τ_a); Random Noise (ε_a)

$$\tau_a = \rho_0 + \{[\rho_a + (\beta_a \times V.t. \times t_a)] + (c \times EF_a \times C_a)\} \times s_a$$

ρ_a	Constant fee charged per TON
ρ_a	Fee charged per TON per distance
β_a	Weight parameter
$V.t.$	Value of time of the freight
t_a	Time spent
c	shippers' consciousness parameter
EF_a	CO2 emission per TON per distance
C_a	price of CO2 emission per TON (carbon tax)
s_a	Travel distance

Cost function at a node(n):

$$c_n = \lambda_n + \gamma_n$$

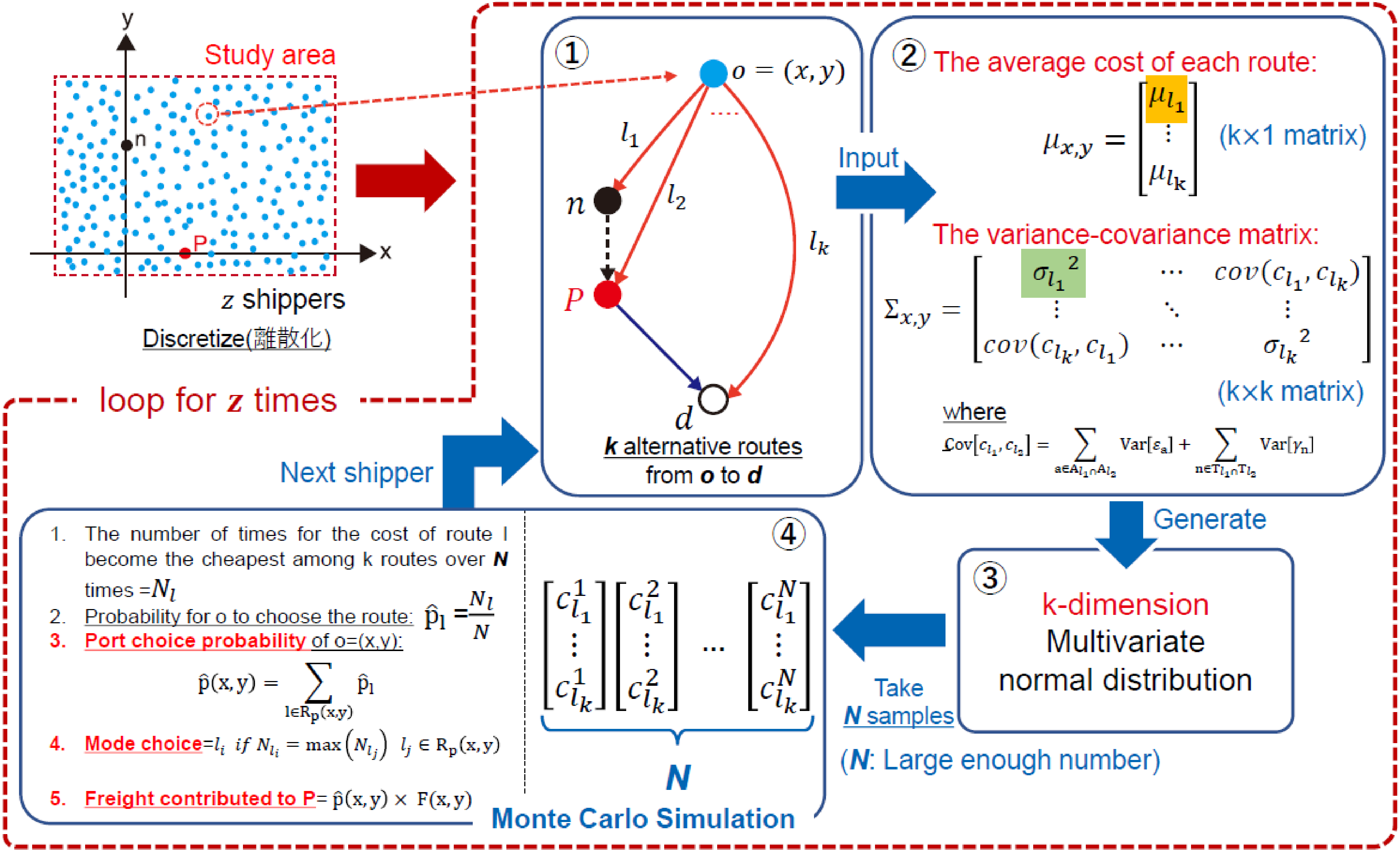
Average (λ_n); Random Noise (γ_n)

$$\lambda_n = \rho_n + \left[(\omega_n \times V.t. \times t_n) + \theta_1 \left(\frac{\omega_n \times V.t.}{f_a}\right)^{\theta_2}\right] - S_n$$

ρ_n	Loading/ Transshipment fee per Ton
ω_n	Weight parameter
$V.t.$	Value of time of the freight
t_n	Time spent
f_a	Service frequency
θ_1, θ_2	Unknown parameter
S	Terminal subsidies

Wang, X., Meng, Q., and Miao, L., 2016. Delimiting port hinterlands based on intermodal network flows: Model and algorithm. Transportation Research Part E: Logistics and Transportation Review, 88, 32-51.

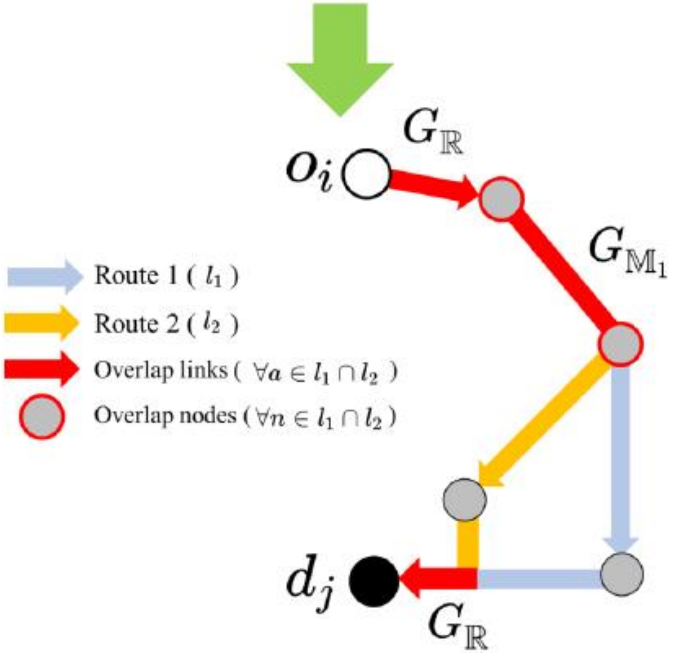
Methodology: The Monte Carlo Simulation based algorithm



Methodology: Dynamic generation of variance-covariance structure

1. Construct network for each mode

$$\{G_{\mathbb{R}}, G_{\mathbb{M}_1}, G_{\mathbb{M}_2}, \cdots\}$$



$$cov(c_{l_1}, c_{l_2}) = \sum_G \left\{ \sum_{\forall a \in A_{l_1} \cap A_{l_2}} \sigma^2_{\tau_a} + \sum_{\forall n \in T_{l_1} \cap T_{l_2}} \sigma^2_{min(\lambda_n, \lambda'_n)} \right\}$$

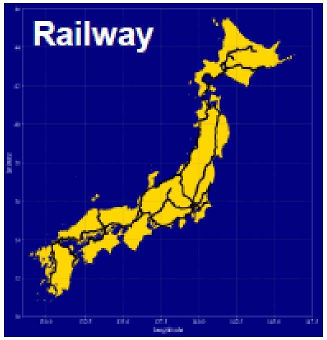
Sum of variance of overlap links costs and sum of the variance of minimum overlap node costs for **all overlap graph between routes.**

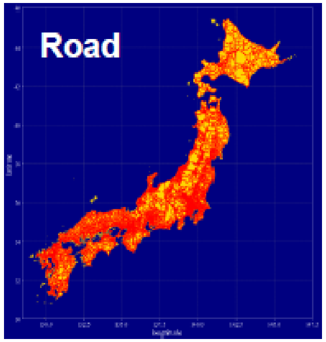
2. Example of application

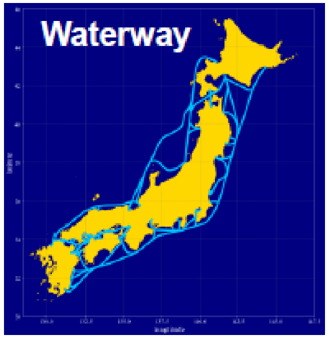
By applying the methodology, the **over-consideration of variance** between routes can be eliminated and hence raising the model accuracy.

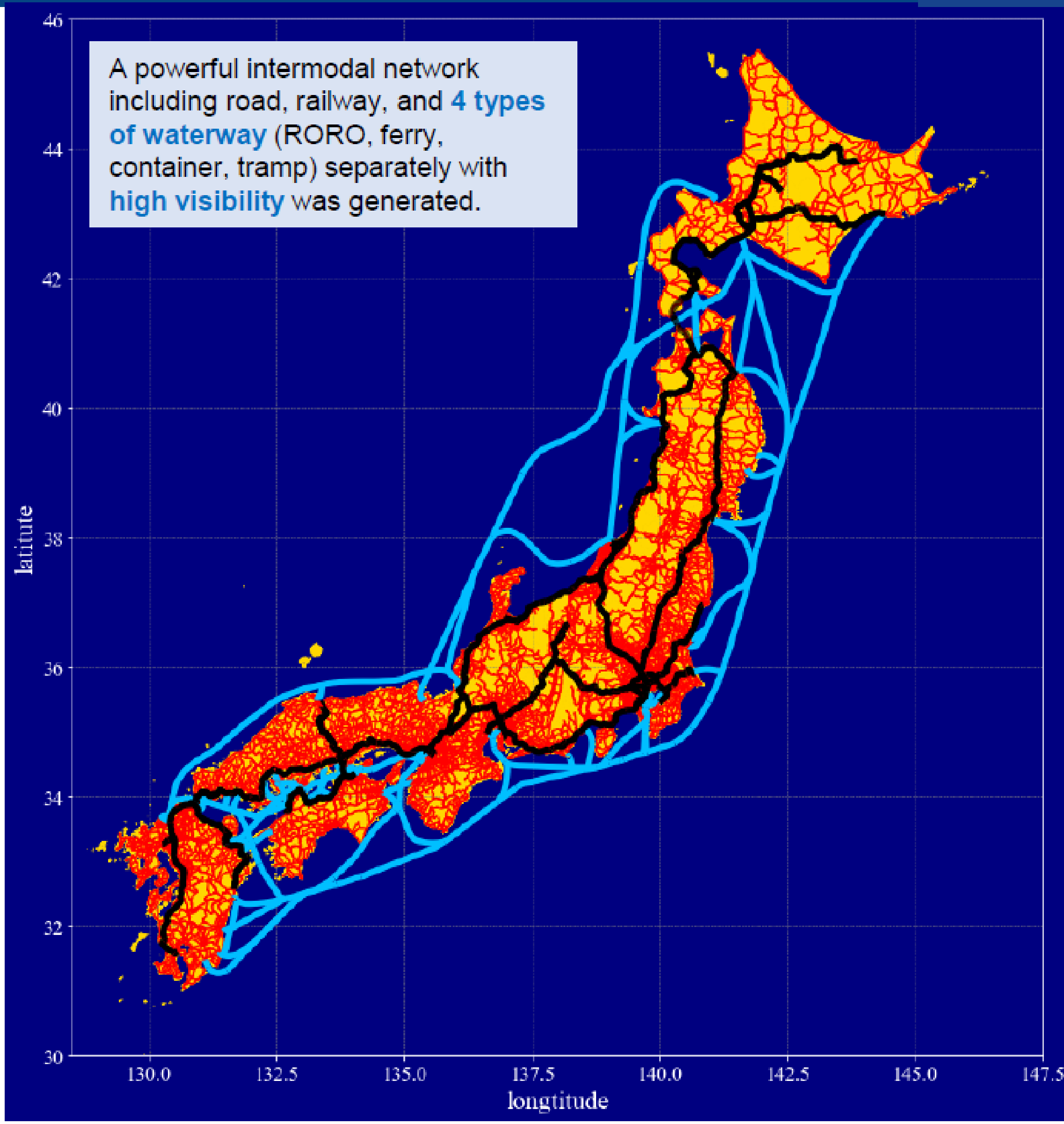
Data processing: Creation of intermodal network

Data	Outline
OD data	Among 196 livelihood spheres, Extending OD among prefectures through economic data of cities
Representative Points	Randomly generated
Road network	From National Land Information 32211 vertices and 46936 edges.
Railway network	132 stations from JR freight time table 10,587 vertices and 10,746 edges.
Waterway network	64 ports with domestic liner service 3,434 vertices and 3,658 edges.









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Scenario analysis: The settings

Scenario table

Scenario	Modification	Variables	Description
Basic scenario	-	-	Current situation.
Scenario1	Raise **shipper consciousness** for 5 times	c	Recently, the industry has become more aware of decarbonization. What happens when shippers' consciousness takes precedence **and no involvement from policy makers?**
Scenario2	Scenario 1 + **Raise carbon tax for 5 times**	c , C_a	Carbon tax is a typical example of decarbonization policy. What will happen if Japan **raises the tax in the future?**
Scenario3	Scenario 2 + **Subsidy 5 USD/Tonnage for ports operating RORO liners**	c , C_a, S	Currently, several major ports offer modal shift subsidies to shippers in order to attract freights. What would happen if such **subsidy policies were rolled out at more ports**?

c , C_a are the variables of cost function of links, and S is the variable of cost function of nodes.

The emission factors for each mode are assumed constant, where:

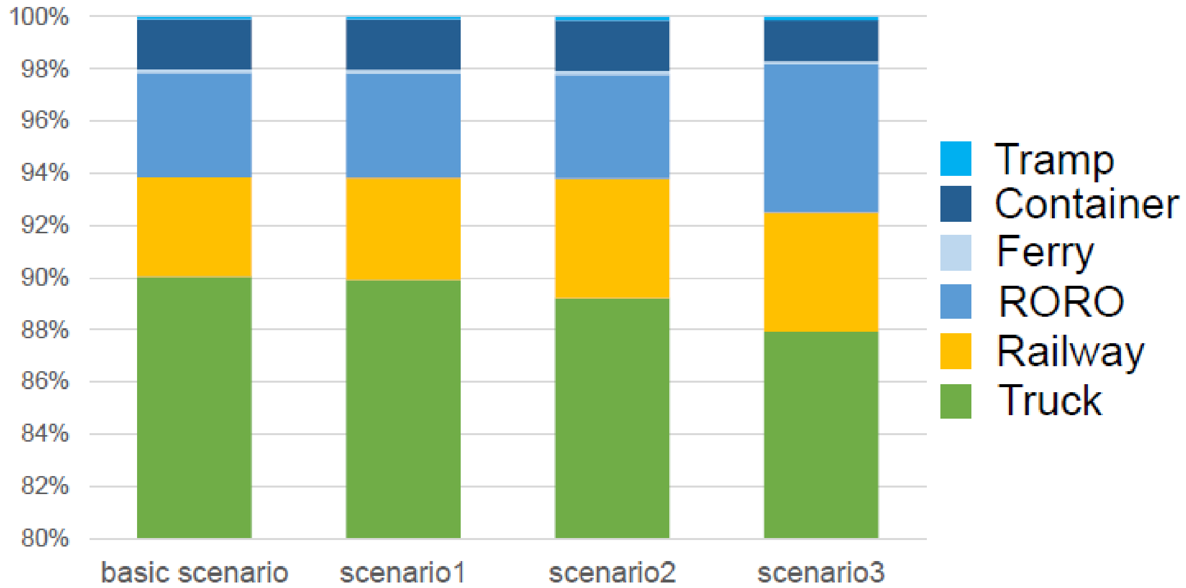
	Truck	Railway	Waterway
EF_a(g/km/Ton)	216	21	43

（Source： MLIT [11])

Result: Modal share

Scenario	Modification
Basic scenario	-
Scenario1	Raise shipper consciousness for 5 times
Scenario2	Scenario 1 + Raise carbon tax for 5 times
Scenario3	Scenario 2 + Subsidy 5 USD/Tonnage for ports operating RORO liners

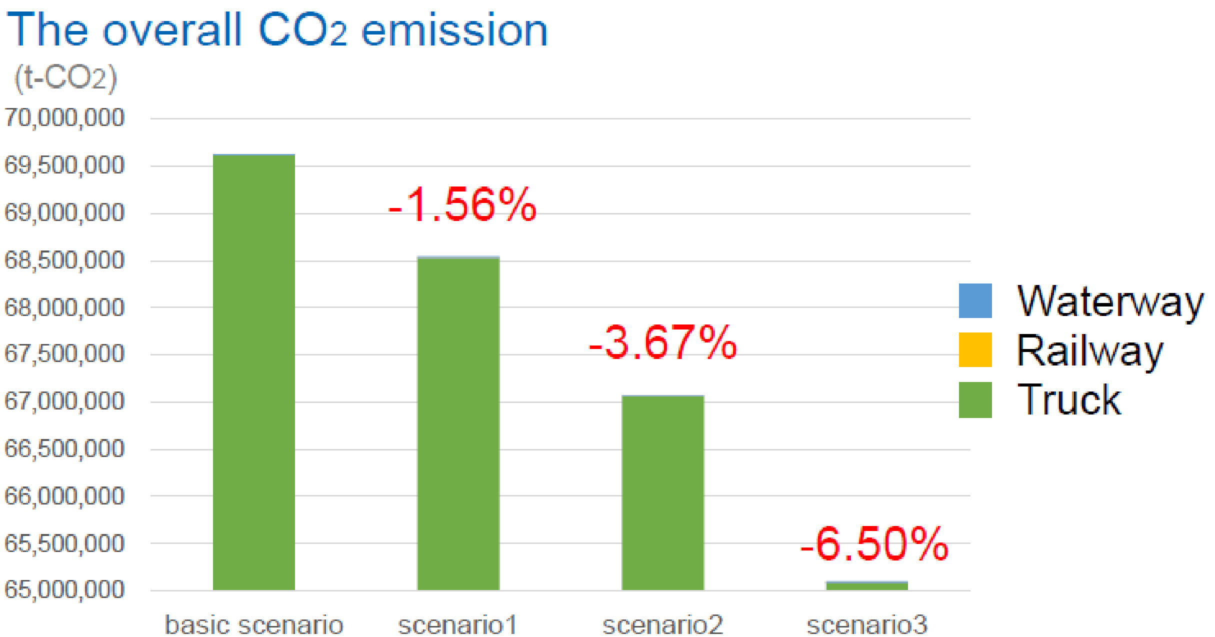
The overall modal share



	basic scenario	scenario1	scenario2	scenario3
Truck (%)	90.05	89.91 (-0.14%)	89.22 (-0.83%)	87.93 (-2.12%)
Railway (%)	3.79	3.92 (+0.13%)	4.59 (+0.8%)	4.56 (+0.77%)
RORO (%)	4.00	4.00	3.98 (-0.02%)	5.69 (+1.69%)
Ferry (%)	0.16	0.16	0.16	0.11 (-0.16%)
Container (%)	1.90	1.90	1.92 (+0.02%)	1.58 (-0.32%)
Tramp (%)	0.10	0.11 (+0.01%)	0.14 (+0.04%)	0.13 (+0.03%)

Result: CO_2 Emissions

Scenario	Modification
Basic scenario	-
Scenario1	Raise shipper consciousness for 5 times
Scenario2	Scenario 1 + Raise carbon tax for 5 times
Scenario3	Scenario 2 + Subsidy 5 USD/Tonnage for ports operating RORO liners

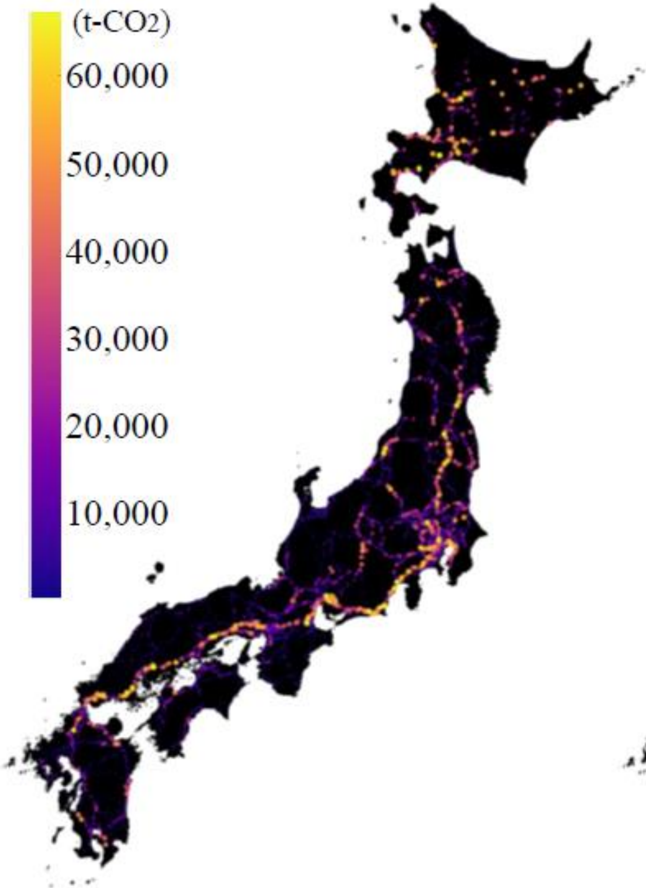


	basic scenario	scenario1	scenario2	scenario3
Truck (t-CO2)	69,616,750	68,530,729 (-1.56%)	67,060,829 (-3.67%)	65,090,225 (-6.50%)
Railway (t-CO2)	2,423	2,684 (+10.74%)	2,930 (+20.93%)	2,926 (+20.74%)
Waterway (t-CO2)	8,138	8,148 (+0.13%)	8,167 (+0.36%)	9,215 (+13.24%)
Total (t-CO2)	69,627,311	68,541,560 (-1.56%)	67,071,927 (-3.67%)	65,102,366 (-6.50%)

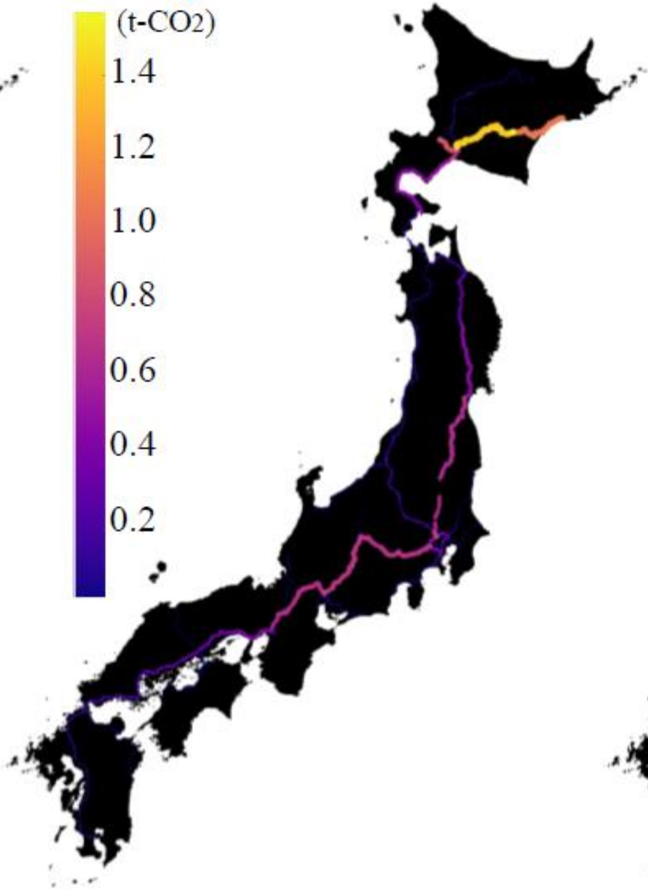
Result: Visualization of link CO_2 emission

Basic scenario

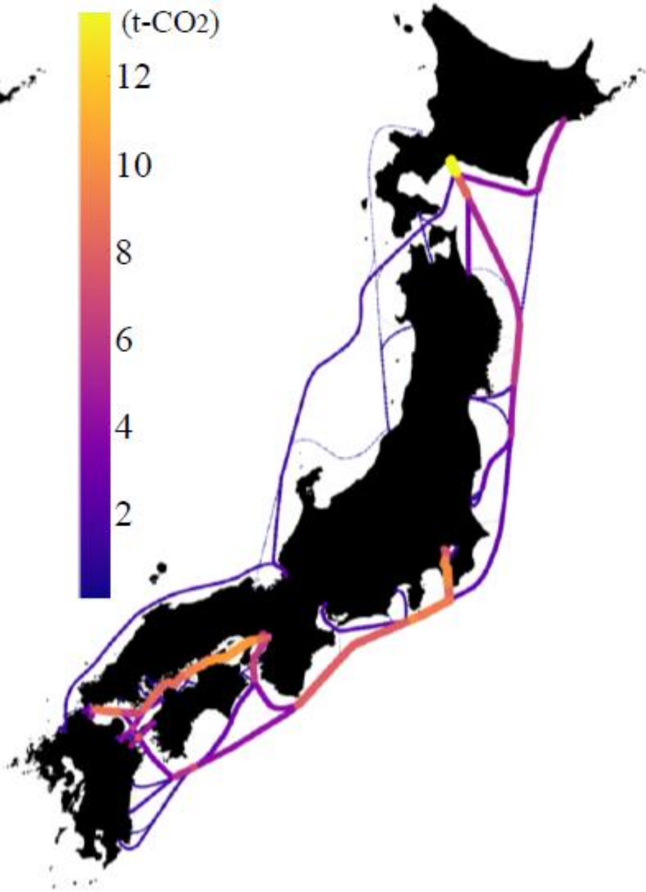
Road network



Railway network

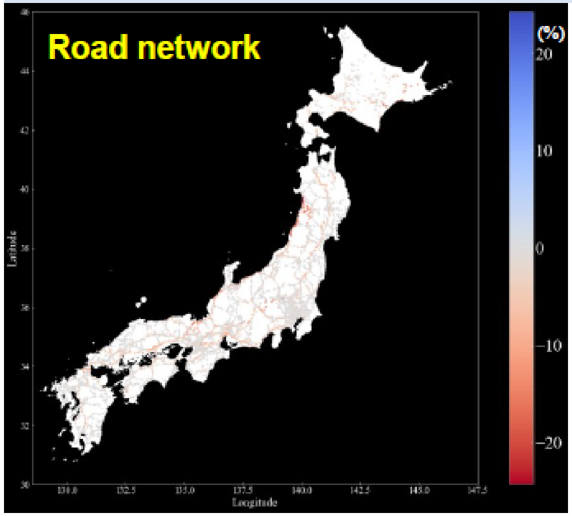


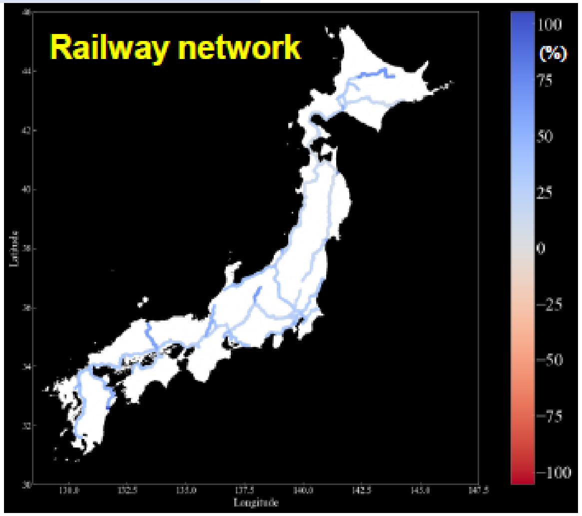
Waterway network

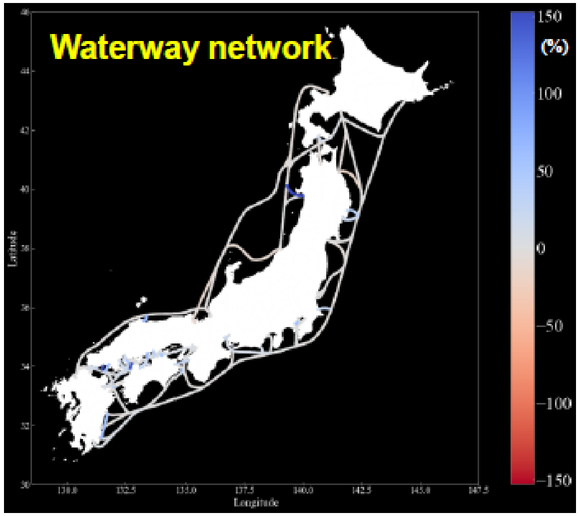


Result: Transition of link emission across links

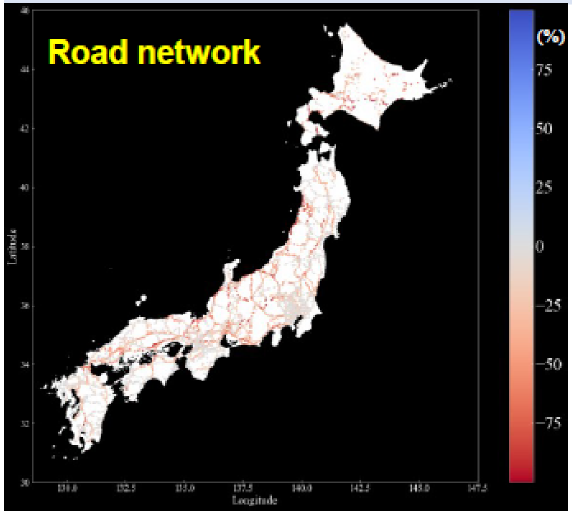
Difference between basic scenario and scenario2

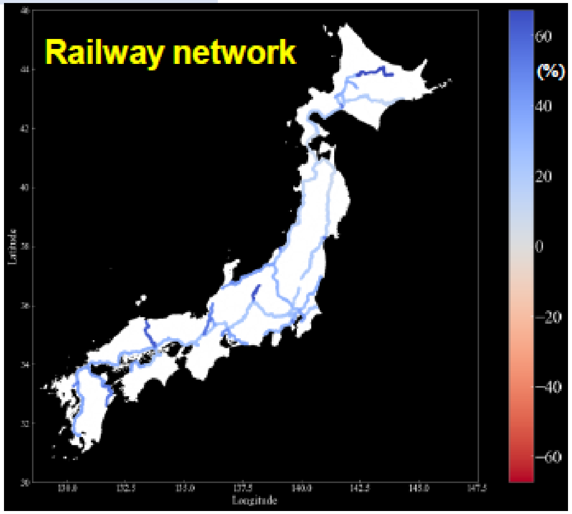


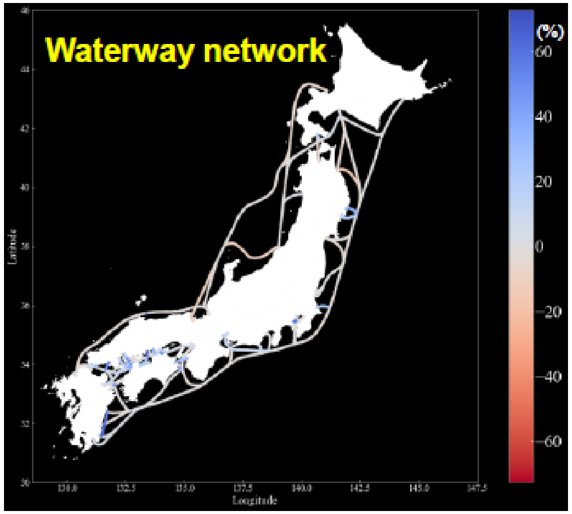




Difference between basic scenario and scenario3







Conclusion

1. A mere increase **in shippers' consciousness is insufficient to achieve a modal shift**.
2. Increase in the **carbon tax** can lead to an increase in the **utilization rate of railways.**
3. Carbon tax would be inadequate to strengthen waterway sector. Instead, **strong incentives** for waterway are necessary.
4. Furthermore, modal shift may not be a sufficient reduction measure, **as road transport accounts for the majority of emissions.** Therefore, technological innovation, such as a shift to electric vehicles, should be considered in parallel with modal shift.

Limitation

1. The congestion cost of links and nodes in the transportation network is not considered.
2. The characteristics and heterogeneity of the goods are not taken into account.
3. Does not consider regional and geographical difference while estimating the parameters.

Journal of Cleaner Production 496 (2025) 145117

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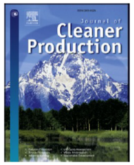

Geospatial extent of CO2 emission of transportation and the impact of decarbonization policy in Japan

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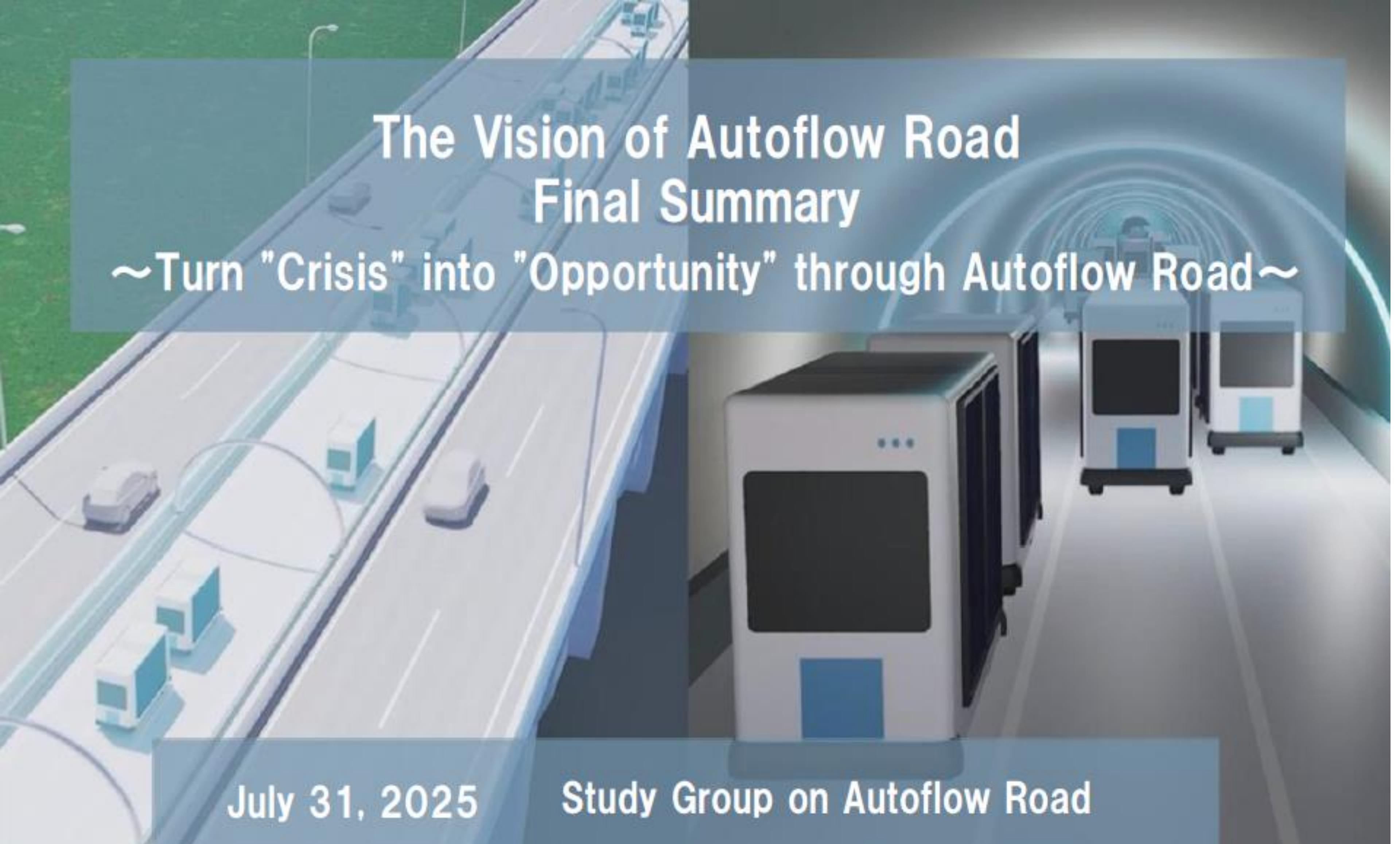
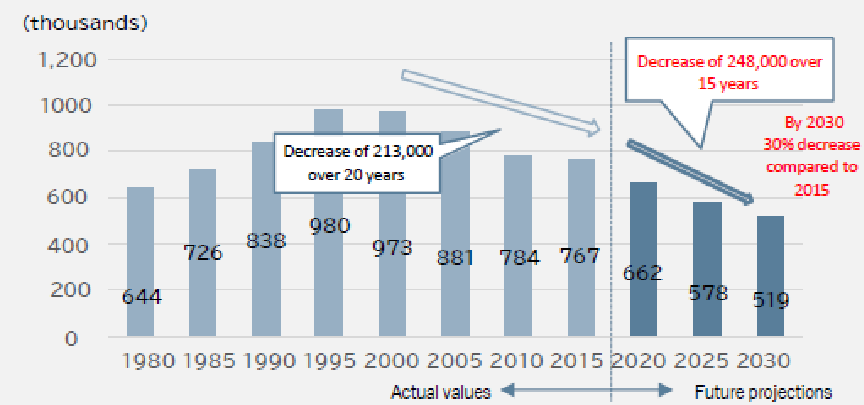


Autoflow Road is a new logistics system that transports goods using unmanned, automated transportation means powered by clean energy, with dedicated logistics spaces within a highway.

Source: https://www.mlit.go.jp/road/ir/ir-council/buturyu_douro/pdf/sai-honbun-en.pdf

Shortage of truck drivers

As Japan faces declining birthrates, an aging population, and overall demographic shrinkage—with the working-age population projected to fall to around 55 million, we are confronting a structural logistics crisis, due to relatively high average driver age compared to other sectors and the anticipated rapid decline in the labor force.



Source: Japan Institute of Logistics Systems (JILS), "Logistics Concept 2030"

In particular, the so-called "2024 problem" is looming, as overtime work regulations came into effect in 2024, and without any countermeasures, logistics could come to a standstill. It is estimated that by the FY2030, transportation capacity could fall short by 34% (equivalent to 940 million tons), making it impossible to transport goods as before.

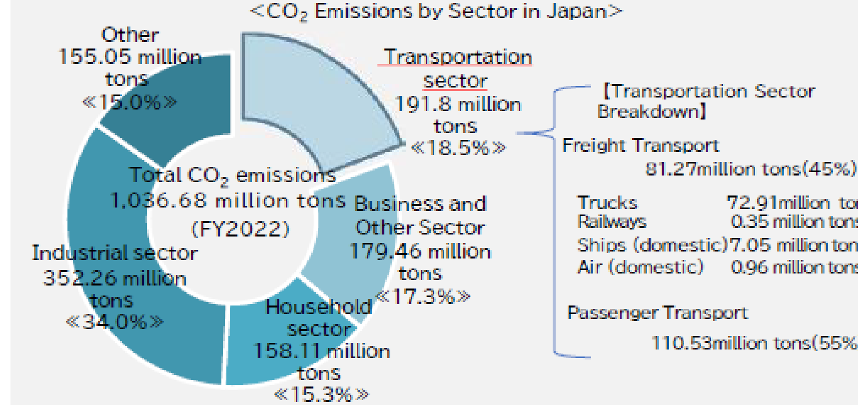
<Estimated Impact of Overtime Work Regulations>

If no further measures are taken ▶ By FY2030, there is a projected shortage of 34% (equivalent to 900 million tons).

Source: Compiled from the "Final Summary" of the Study Group on Achieving Sustainable Logistics (August 2023)

Carbon neutral

With the goal of achieving carbon neutrality by 2050, the transportation sector accounts for approximately 20% of CO_2 emissions, with 45% of that coming from the logistics sector. The Plan for Global Warming Countermeasures (approved by the Cabinet on February 18, 2025) sets a target of reducing CO_2 emissions by 35% by FY2030 (compared to FY2013 levels), making the reduction of CO_2 emissions in the logistics sector an urgent priority.



Source: Greenhouse Gas Inventory Office, National Institute for Environmental Studies, "Greenhouse Gas Emissions Data for Japan (1990-2022 Fiscal Years)"

Others

- Issues of Logistics such as small-volume, high-frequency shipments and inefficient cargo waiting and handling
- Promotion of standardization and modal shift
- Intensification and increased frequency of natural disasters such as heavy rain and snow, and the imminent threat of a major earthquake
- Declining international competitiveness (GDP ranking: 2nd in 2000 → 5th in 2050) etc.

<Small-volume, high-frequency shipments>

	1990	2015	2021
Per shipment Cargo volume	2.43 ton/shipment	0.98 ton/shipment	0.83 ton/shipment
Trends in number of shipments (3-day survey)	13,656 thousand	22,608 thousand	25,080 thousand

<Various cargo types, pallet sizes>

Source: Created based on data from the Ministry of Land, Infrastructure, Transport and Tourism's "National Freight Flow Survey (Logistics Census)"

Source: https://www.mlit.go.jp/road/ir/ir-council/butsuryu_douro/pdf/sai-honbun-en.pdf

1b. Interim Summary - The Vision of Autoflow Road -

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) established an advisory panel on Autoflow Road (chaired by Professor Hideo Hato of the University of Tokyo Graduate School of Engineering) in February 2024 (hereinafter referred to as the "Study Group"). In July 2024, the Study Group issued an interim summary report on the future direction of Autoflow Road.

■ Concept of Autoflow Road

The concept is to "utilize road space to create dedicated spaces" and to "transport goods using unmanned and automated transportation measures enabled by digital technology." Furthermore, by achieving unmanned and automated operations, the infrastructure should operate 24 hours a day. The space within Autoflow Road should not only be used for transportation but also as storage areas for goods, thereby providing a "buffering function" to level out logistics demand and create an environment conducive to optimizing the overall logistics system.

Construction of a new logistics form, "Autoflow Road"

Utilizing road space to create dedicated lanes ✚ Utilizing digital technology to achieve unmanned and automated transportation measures

➤ Target, Cargo Characteristics

- Focusing on small-volume, high-frequency shipments that contribute to increased logistics workload, the transport unit is standardized based on palletized load dimensions.
- The size should comply with the standard specifications recommended by the Public-Private Logistics Standardization Consultation Committee's Pallet Standardization Promotion Subcommittee.

※Base size: 1,100mm × 1,100mm
※Including roll box-type pallets.

4

➤ Assumed route

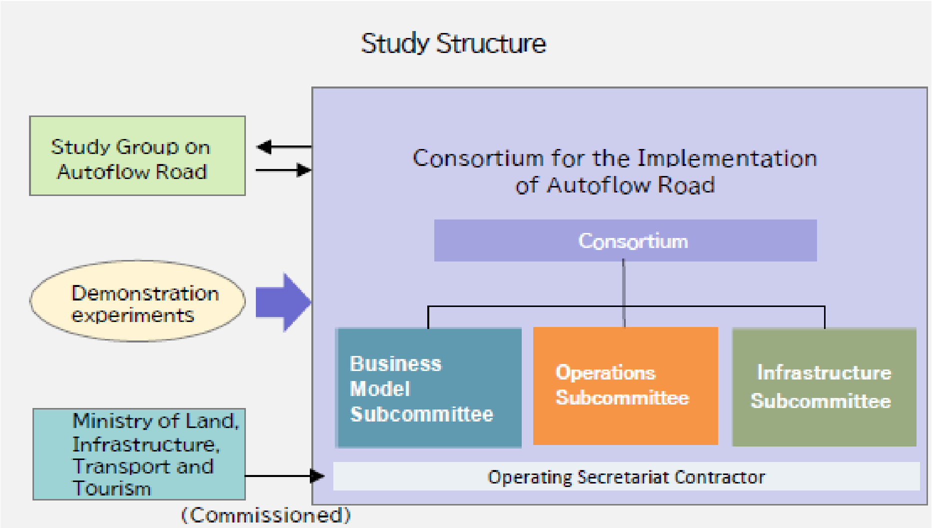
- Tokyo-Osaka corridor, which has the highest logistics volume
- Aiming for implementation by 2030 in sections where experiments or small-scale improvements are feasible, such as the under-construction sections of the Shin-Tomei Expressway.

Source: https://www.mlit.go.jp/road/ir/ir-council/buturyu_douro/pdf/sai-honbun-en.pdf

1c. - Consortium for the implementation of Autoflow Road -

■ Establishment of the Consortium for the Implementation of Autoflow Road

In May 2025, the "Consortium for the Implementation of Autoflow Road" was established to promote discussions toward the implementation of Autoflow Road. The consortium aims to facilitate information sharing and discussion among private-sector companies interested in the operation and use of Autoflow Road, public institutions, and entities holding relevant technologies, with the goal of exploring business models, technical demonstrations of operations, strategies to promote technological development, and the appropriate approach to infrastructure development. (As of July 31, 2025, 104 private-sector companies are participating. Membership is open on a rolling basis.)



➢ Items for discussion

	Fiscal Year 2025	Fiscal Year 2026 and beyond
Business Model Subcommittee	• Extraction of issues and challenges for business establishment • Business simulation	• Services to be provided • Requirements for Service Operators • Review of business simulations
Operations Subcommittee	• Setting Use Cases to be verified in this year's demonstration experiments • Technical development Direction (Roadmap)	• Phase 2 Experiment • Unverified use cases (Phase 1) • Specific technical requirements
Infrastructure Subcommittee	• Consideration of infrastructure configuration • Case studies on infrastructure aspects for specific sections	• Specific route and structural conditions • Site location/area based on the above

Source: https://www.mlit.go.jp/road/ir/ir-council/buturyu_douro/pdf/sai-honbun-en.pdf

2. The Role of Autoflow Road

■ The Role of Autoflow Road

In response to the logistics crisis in Japan, it is extremely important to continue reviewing business practices and public-private initiatives for logistics efficiency based on the "Policy Package" approved at the meeting of relevant ministers in June 2023, and to secure transportation capacity. However, it is <u>also crucial to realize a world where goods are transported automatically, by utilizing Japan's advanced technologies, rather than a world where goods are transported manually,</u> in order to ensure future logistics. Autoflow Road should aim to realize the following as a new logistics system that addresses medium to long-term transportation capacity shortages and provides stable transportation services. To this end, <u>we will address technical challenges toward implementation through collaboration between industry, government, and academia.</u>

Optimization of the entire logistics system

➢ Standardization・Automation

Standardize pallets and data to realize the physical internet and optimize overall logistics.

➢ Flexible transportation planning

By utilizing 24/7 operation of Autoflow Road, small-lot transportation, and buffering functions, we level out truck transportation demand and enable pre-positioning of cargo with Autoflow Road based on anticipated demand, thereby enhancing transportation planning flexibility and reducing lead times.

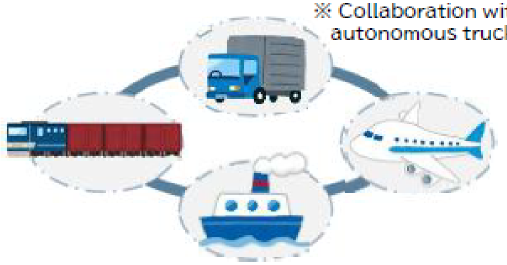
➢ Transforming business practices and improving working conditions

Reduction of driver's workload by altering the business practice of "transporting goods by truck at night and delivering them the next morning," and by reducing waiting times through the integration of truck location information with hub functions.

Seamless integration of logistics modes

As a strength of the road network, roads are connected to various transportation hubs such as logistics facilities, airports, freight terminals, and ports. <u>Autoflow Road aims to leverage this strength to build next-generation logistics networks that integrate other transportation modes.</u>

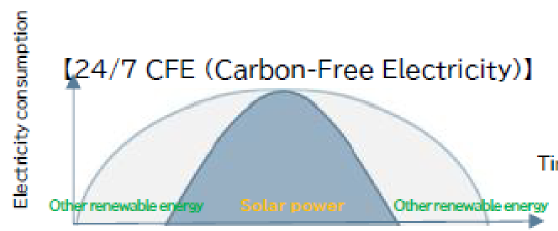
Additionally, it is necessary to consider collaborative approaches that reflect the current development status and future adoption of autonomous trucks, which are currently undergoing pilot tests on expressways.



Achieving Carbon Neutrality

<u>Autoflow Road will be developed and operated based on low-carbon technologies and clean energy</u>, with efforts to facilitate technological development and implementation. In doing so, collaboration will be explored with initiatives for power generation, transmission, distribution, and storage utilizing road space, in accordance with the Road Act lastly revised in 2025.

Additionally, by enhancing transportation efficiency through the physical internet, greenhouse gas emissions will be reduced, <u>and a nationwide carbon-neutral transportation network will be established through collaboration between railways and/or inland waterways, and Autoflow Road.</u>



➢ Ensuring stable logistics during disasters

・We will design infrastructure under the assumption of frequent occurrence of large-scale disasters. <u>Autoflow Road will secure dedicated logistics spaces, minimizing human access and the impact of wind, rain, and other environmental factors</u>. This will enable <u>normal operations unaffected by weather conditions</u> and serve as <u>a critical transportation means</u> to maintain <u>logistics networks during disasters</u>, thereby contributing to business continuity planning (BCP) and establishing an effective logistics system.

Source: https://www.mlit.go.jp/road/ir/ir-council/butsuryu_douro/pdf/sai-honbun-en.pdf

3a. Required Functions of Autoflow Road

Services Provided

Autoflow Road should provide the following services, while meeting the basic requirements of automation, standardization, and carbon neutrality.

Specific details such as routes, hub locations, hub functions, cargo specifications, and transportation speeds are critical issues directly linked to the services and business model of Autoflow Road and should be further discussed within the consortium and refined.

Target section: Tokyo-Osaka as the principal route, with expansion to Kanto, East Kanto, and Hyogo also under consideration

Hubs: Set up multiple hubs, including intermediate points, should be established, with consideration integration with other modes.

Automated loading and unloading between transport equipment and trucks is necessary, and features such as refrigeration and automatic sorting should also be considered.

Cargo shape: Standard specification pallet (flat size) (including roll box-type pallets) and set a height restriction of 2.2 meters.

Speed: Aiming for a service equivalent to the current lead time, targeting 70–80 km/h (technical development required)

Other: Approach to liability for risks such as accidents, advantages compared to other modes, pricing, and reservation methods.

Required Technical Development and Establishment of Coordination Area

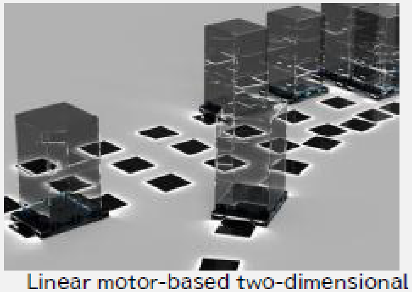
To realize the services provided, demonstration experiment should be implemented promptly to verify each element of technologies, and future action items should be organized. To promote technological development in private companies, establishing a public-private roadmap is also effective.

In addition, while referring to discussions in the preceding autonomous driving (Autonomous Driving Service Support Road Promotion Strategy Working Group), it is necessary to organize competitive and cooperative areas in Autoflow Road, taking into consideration, for example, safety evaluation methods for transport vehicles, roadside infrastructure, communication environments, and data integration platforms.

【Market Sounding on Technologies for Autoflow Road】(December 2024–January 2025)

22 companies submitted 36 technical proposals. Regarding transportation methods, it was confirmed that further technological development is necessary. Additionally, regarding automated cargo handling technology, issues such as loading and unloading onto transport equipment were identified, and it is necessary to clarify feasibility and challenges through future demonstration experiments.

< Examples of transport equipment (interviews)>



Linear motor-based two-dimensional cargo transport system (Cuebus Co., Ltd.)

Tire-mounted cart (Infroneer Holdings Co., Ltd.)

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Source: https://www.mlit.go.jp/road/ir/ir-council/buturyu_douro/pdf/sai-honbun-en.pdf

3b. Required Functions of Autoflow Road

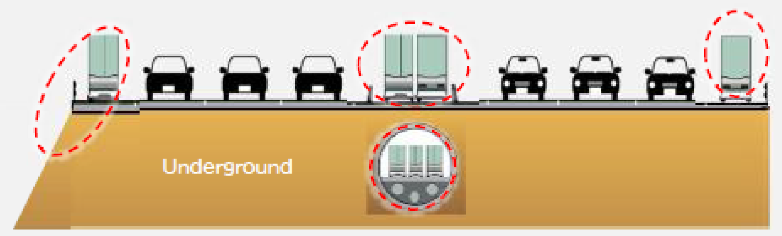
■ Required Infrastructure (Roadway section and Hub)

➢ Roadway Section

When constructing the roadway above ground, it is necessary to accommodate intersections with general traffic at interchanges (IC), junctions (JCT), service areas (SA), and parking areas (PA). Additionally, relocation of underground utilities and above-ground structures, elevation adjustments and alignment modifications at connection points between structures, and particularly in bridge sections, large-scale reinforcement of bridge piers and foundations due to the widening of existing bridges are required, among other construction challenges. Additionally, construction periods may be prolonged due to traffic restrictions. While constructing at sufficiently deep underground levels is relatively advantageous, underground construction entails higher construction costs compared to over ground construction and new challenges such as the disposal of excavated soil must be considered.

Furthermore, Autoflow Road are designed to operate 24 hours a day while minimizing human access, therefore methods that do not hinder logistics operations during the maintenance should be established. To achieve this objective, it is necessary to engage in technological development for sustainable labor-saving and automation, including unification of the structural design of infrastructure.

【Road Space Utilization Concept】



➢ Hub

A surrounding road network capable of handling a large volume of truck traffic is necessary. When developing new hubs, it is also necessary to consider land use regulations under the Urban Planning Act, etc., and from the perspective of securing land, options such as diversifying hub locations or collaborating with existing logistics facilities should be explored.

Furthermore, since the development of hubs may contribute to addressing disaster prevention and other issues at the municipal level, collaborative efforts such as social experiments in partnership with proactive municipalities should also be considered.

Source: https://www.mlit.go.jp/road/ir/ir-council/buturyu_douro/pdf/sai-honbun-en.pdf

4. Effects of Autoflow Road

Direct Effects

Autoflow Road is expected to cover approximately 8% to 22% of the future shortage in transportation volume, thereby supplementing freight transportation that cannot be handled due to labor shortages.

※ Percentage of the estimated transportation shortage of 940 million tons in FY2030 (as outlined in the "Final Summary" of the Study Group on Achieving Sustainable Logistics)

In that case, the number of driver workdays that can be covered is estimated to be approximately 20,000 to 57,000 person-days, and the CO_2 emissions that could be reduced are estimated to be 2.4 million to 6.4 million (t-CO_2/year).

【Estimated Effect (Assuming a Loading Rate of 79.3%)】

◆ Coverable working hours

Truck drivers:
21,280 ~
56,747 person-days※1

◆ CO_2 emissions reduction

Truck CO_2 emissions:
2,396,476 ~
6,390,486 (t-CO_2/year)※2

※Estimation Conditions

◆ 0.78 million tons to 2.1 million tons/year of freight transport capacity
Transport speed: 30–80 km/h, per ton,
10-meter vehicle spacing, 24-hour operation
→ Capacity of Autoflow Road (Tokyo-Osaka, 500 km):
216,000–576,000 tons (per day/3 lanes)

[Reference] 2023 fiscal year freight transport volume: 3.8 billion ton (of which 2.51 billion ton were commercial freight)
(Ministry of Land, Infrastructure, Transport and Tourism, Fiscal Year 2023 (2023) "Automobile Transportation Statistics Annual Report")

<Reference Data>

※1 Total number of truck drivers: 940,000 (Ministry of Health, Labour and Welfare, "2024 Wage Structure Basic Statistics Survey")

※2 Annual CO_2 emissions from trucks: 72,911,083 (t-CO_2/year)
(Source: "Greenhouse Gas Emissions Data in Japan (1990–2022 Fiscal Years)")

Other Ripple Effects・Project Viability

It is necessary to proceed with the calculation of economic effects resulting from the development of Autoflow Road.

Regarding the feasibility of the project, case studies and pilot experiments should be conducted to identify and organize the costs that need to be considered, such as estimated project costs, manufacturing and development costs for transport equipment, power supply facilities and costs, and large-scale reconstruction costs, and these should be discussed within the consortium.

1

Source: https://www.mlit.go.jp/road/ir/ir-council/butsuryu_douro/pdf/sai-honbun-en.pdf

Sounding-type Market Survey on the Operational Structure of Autoflow Road (October–November 2024)

Regarding the business scheme, 46 companies have submitted their opinions, pointing out various risks in each phase of the business operations for the construction, operation, maintenance, and possession of Autoflow Road.

Risk

Construction

- High costs and long project duration.
- Cost uncertainty
- Funding risk

·Unable to secure financing due to concerns about the viability of the project
·Credit risk from private sector contractors may prevent internal approval

Operations

- Uncertainty of demand

・Deterioration of business revenue due to fluctuations in logistics demand

- Unprecedented business model making funding difficult
- Losses due to downward rigidity in toll fees for Autoflow Road caused by stagnant freight rates

Maintenance

- Deterioration of Autoflow Road
- Road Funding for major reconstructions
- Damage caused by force majeure such as disasters

Possession

- Burden of fixed asset taxes, occupancy fees, etc.
- Force majeure risks
- Asset adjustment with existing road authorities

Considerations on the Implementation of Autoflow Road

・From the perspective of logistics sustainability, private funding is assumed, and maximizing the utilization of private-sector vitality.

・To ensure service levels, discussions are necessary regarding the future regulatory framework, structural standards, and safety criteria for Autoflow Road.

Source: https://www.mlit.go.jp/road/ir/ir-council/buturyu_douro/pdf/sai-honbun-en.pdf

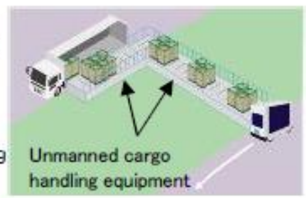
7. Next Steps - Technology for Realizing Autoflow Road -

Demonstration Experiments, etc.

In FY2025, the demonstration experiments will be conducted at existing facilities using existing technologies. Conducting this concept verification is extremely important for establishing a shared vision of the future of Autoflow Road. The primary focus will be on verifying the operational performance of transport equipment, but it will also be necessary to verify the required width, the length required for acceleration and deceleration, the feasibility of lane changes, and the loading and unloading from trucks to transport equipment at hubs.

Use Case 1
Hub: Streamlining cargo handling operations using unmanned cargo handling equipment

Verify the floor area, operation time, and other factors required for the automation of loading/unloading from trucks and transfer to transport equipment using unmanned material handling equipment

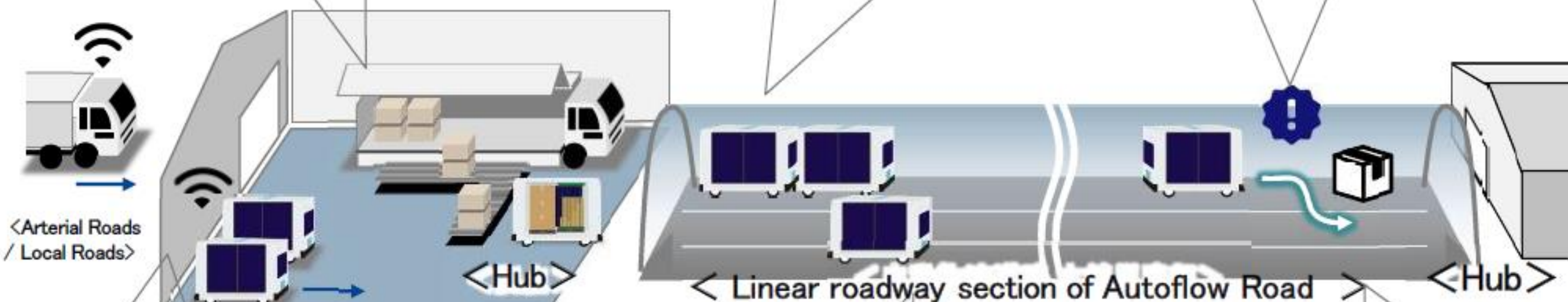


Use Case ②
Roadway section: Automatic conveyance equipment operation

Verify the automatic operation of transport equipment with varying speeds and cargo weights, the required road width, driving environment, and effects on cargo

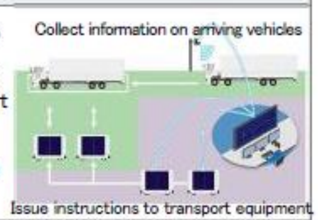
Use case ③
Roadway section : Abnormal condition detection and avoidance action of transport equipment

Verify the detection of abnormalities and the precision of driving technology and control in response to such abnormalities



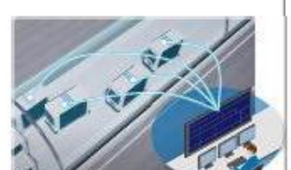
Use Case 6
Hub: Provision of information on arrival schedules for incoming vehicles

Verification of operations to receive vehicle arrival schedule information via the system and instruct transport equipment.
Set transport equipment to standby mode in preparation for vehicle arrival.



Use Case 5
Others: Transport equipment operation management

Verify the effectiveness and challenges of systems for managing the operational status of transport equipment and cargo.



Use Case ④
Roadway section : Communication stability of transport equipment

Verify whether autonomous driving is possible even under unstable communication conditions such as in tunnels.

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Source: https://www.mlit.go.jp/road/ir/ir-council/buturyu_douro/pdf/sai-honbun-en.pdf

7. Next Steps

- With the aim of commencing operations by the mid-2030s on sections where implementation is feasible through small-scale improvements, based on experiments conducted by 2027 on sections under construction of the Shin-Tomei Expressway (Shin-Tanabe to Shin-Gotemba), etc., feasibility should be confirmed through demonstration experiments, and efforts should be made to promote the development of a business environment, including institutional frameworks, to enable early transition to the development phase.
- From the next financial year onwards, it will be necessary not only to conduct verification experiments on the issues identified during this year's demonstration experiments. It will also be necessary to perform simulations related to intermodal connectivity and other areas.
- Beyond the consideration of a long-distance trunk route between Tokyo and Osaka, it is also effective to explore the feasibility of Autoflow Road in short-distance sections or areas where logistics efficiency improvements can be achieved and effects can be realized early, utilizing existing technologies, and such efforts should be advanced.
- Regarding transport equipment and systems, it is necessary to consider international standardization such as JIS and ISO standards in the future, and Japan should take the lead in creating a world where goods are transported automatically.
- Based on the conceptual guidelines outlined in this final summary, steps should be taken to move forward with demonstration and implementation.

3 Approach
(1) Industry and Innovation③

Solve logistics challenges through both technological and institutional approaches to enhance international competitiveness

To address driver shortages and labor hour regulations while optimizing logistics, enabling seamless intermodal connections, and achieving carbon neutrality, Narita Airport is developing an automated logistics road system (Autoflow Road) originating from its on-airport cargo facilities. Through 24-hour operation for stable transport and seamless intermodal connections, this system simultaneously achieves overall logistics optimization, labor reduction, and environmental impact reduction. This logistics infrastructure renewal will establish a "sustainable, smart, safe, and entirely new carbon-neutral logistics innovation platform" originating from Narita.

[Reference] Narita Airport "Airport City" Concept

3. Key Initiatives in the "2025 Business Plan"⑩

"Initiatives to Further Enhance the Role of Freight Rail Transportation"
(1) Initiatives Toward Realizing a Decarbonized Society
○ Introduction of a service providing CO_2 emission reduction information
○ Refinement of CO_2 emission calculation methods for rail transportation
○ Introduction of incentives clearly demonstrating customers' Scope 3 reductions
○ Encouraging Scope 1 reductions by transport operators
(2) Initiatives for Introducing New Technologies with Practical Effectiveness and Utilizing/Transporting Next-Generation Energy
○ Development of a Container Handling Management System (CHMS)
○ Studies toward streamlining loading inspections and enabling remote operation of shunting locomotives
○ Conducting demonstration experiments for swap body container transport compatible with both "autonomous trucks" and "freight rail"
○ Deepening studies on linking Autoflow Road, ports, airports, and freight transport via bullet trains

[Reference] FY2025 Business Plan (Summary) (Japan Freight Railway Company)

	Present to 2027 (Concept Validation Phase)	2028 to mid-2030s (Technology Development and Implementation Phase)	Mid-2030s (Implementation and Operation Phase)
Long-distance trunk line plan (Tokyo-Osaka)	Demonstration experiments at existing facilities and sections under construction of the Shin-Tomei Expressway, simulations of intermodal connections, etc.	Development (support) of transport equipment	Infrastructure development Manufacturing of transport equipment, etc.
		Consideration of international standardization	

(Other sections where effects can be realized early will be evaluated for feasibility)

Source: https://www.mlit.go.jp/road/ir/ir-council/buturyu_douro/pdf/sai-honbun-en.pdf