# THE EFFECT OF FLEXIBLE TOLLING ON HIGHWAYS

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# Outline

1. Motivation of Analyzing Flexible Tolling
2. Development of Toll Roads and Non-Tolled Roads in Japan
3. Necessity of Flexible Tolling on Toll Roads
4. Theoretical Ground of Flexible Tolling: Analogy to Value Pricing
5. Political Feasibility of Flexible Tolling and Value Pricing
6. Experimental Outcome of Flexible Tolling

# 1. Motivation of Analyzing Flexible Tolling

## ♦ The flexible tolling vs. Construction and Maintenance cost based tolling

- Compared to construction cost based tolling, the flexible tolling can bring larger social welfare.

Flexible tolling can greatly improve…

- ◆ Mobility of vehicles
- ◆ Environment of roadside residential area

- Why it has not been implemented in Japan?

- What would be the outcome of the flexible tolling?

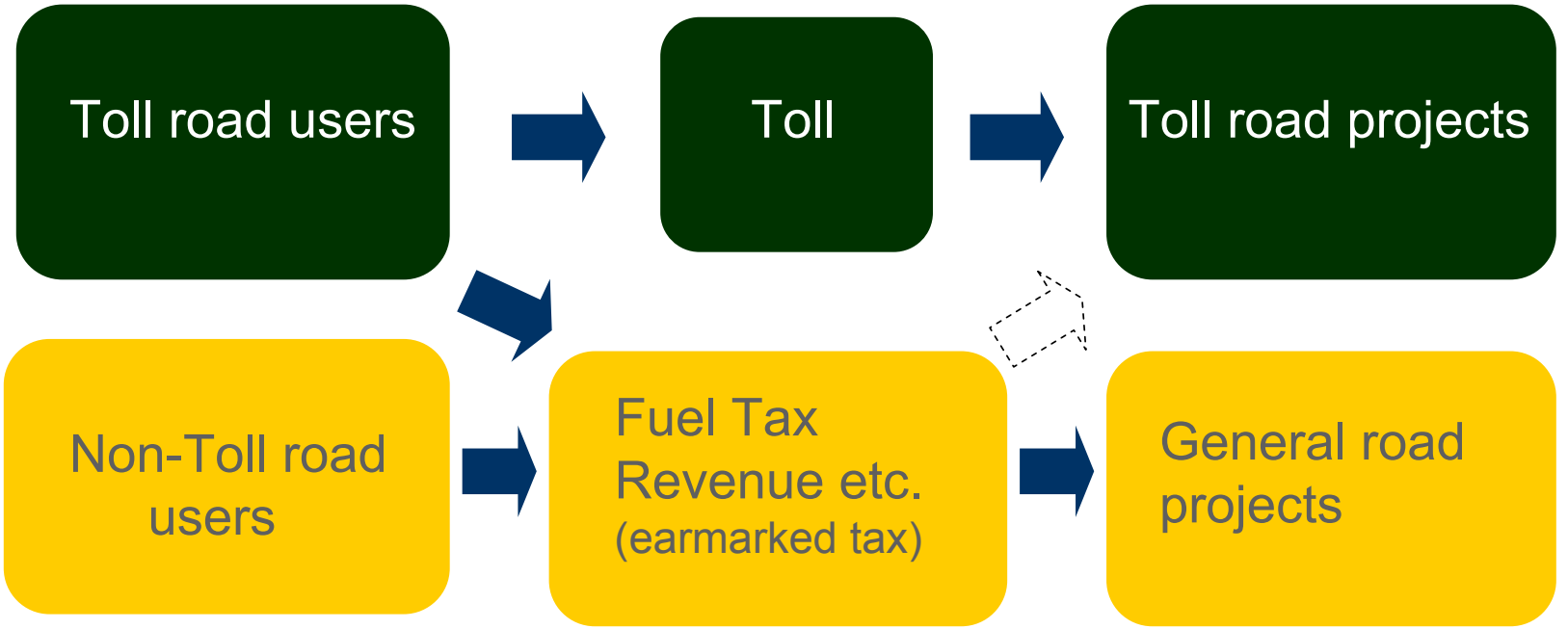
## 2. Development of Toll Roads and Non-Tolled Roads in Japan

♦ Road Financing Systems in Japan

- Road development is supported by the earmarked funds derived from the fuel tax revenue.
- Japanese highway system consists of many tolled access-controlled roads.

## 2. Development of Toll Roads and Non-Tolled Roads in Japan

- Two financing systems have supported the development of the highway system under the tight budget. (Began in the early 1950s)



# 2. Development of Toll Roads and Non-Tolled Roads in Japan

♦ Concept of “Earmarked tax revenue for road projects”

- Automobiles and fuels taxes
  - A major source of revenue for ordinary non-tolled road
- Law restricts specified tax use
  - Only for road development and maintenance
- The “5-year Road Improvement Program”
  - Basic program for road improvement and maintenance

5-year Road Improvement Program

- First designed in 1954
- Renewed every 5 years
- Integrated into the “Long-Term Plan about the Main Development of the Social Infrastructure” in 2003.

# 2. Development of Toll Roads and Non-Tolled Roads in Japan

♦ Toll road system

- **The "law concerning special measures for highway construction"**
  **- establish toll roads**
- **The law allows tolls for:**
  **-The National Expressways**
  **- Part of national highways**
  **- Prefectural roads**
  **- Municipal roads**
- **Toll should be set to cover the entire cost, such as:**
  **- construction expenditure**
  **- maintenance and operating cost**
  **- interest / - other expenses**

## The idea of the pool system

- Several toll roads are "networked" on a nationwide and regional basis.
- "Networked" roads can be regarded as a single road for calculating revenue and expenditure for redemption.

- 4 highway related public corporations
  - Established during 1956 to 1970
- Toll road projects by the public corporations
  - 18% of the total spending for roads in FY2004
- Total length of the toll roads
  - Up to 9,500 km (approx) in 2001

# 3. Necessity of Flexible Tolling on Toll Roads

A flexible charging scheme is recognized to be necessary for managing the demand for road transport.

- Toll rate is basically set in terms of the construction & maintenance cost of highways.
- Slow economy of recent years
- Advancement in cost management in logistic industry

↓

Road users tend to avoid travelling on toll roads.

↓ → Decrease in Toll Revenue

Higher toll has caused on non tolled roads

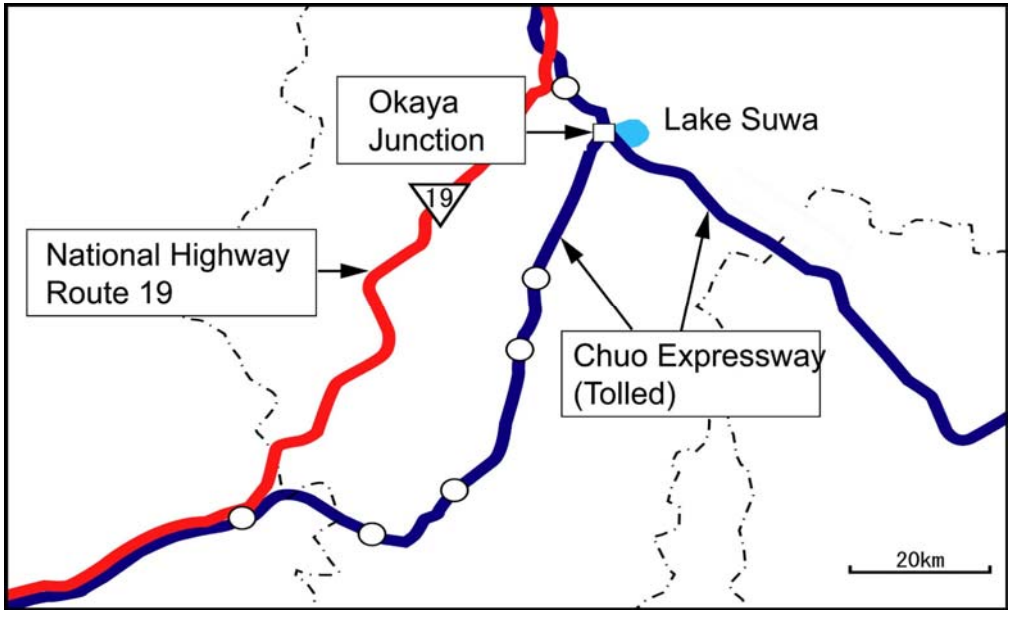
- Traffic congestion
- Traffic safety problems
- Environmental problems

Decreasing total user benefit

# 3. Necessity of Flexible Tolling on Toll Roads

## The Chuo Expressway and National Highway Route 19

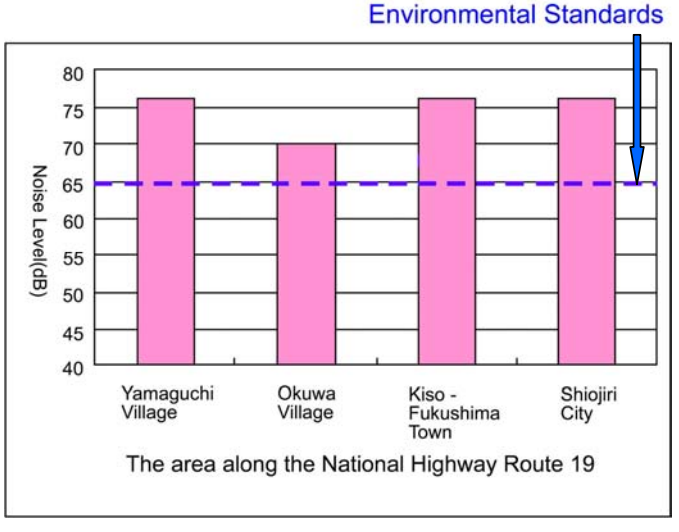
**Many cost sensitive trucks, especially at night, use non-tolled alternative (National Highway Route 19) instead of the Chuo Expressway with tolls.**



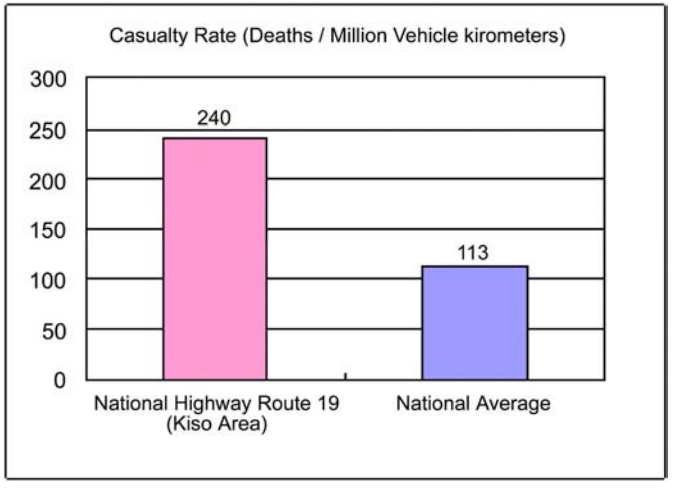

Trucks are running through National Highway Route 19 at night.

# 3. Necessity of Flexible Tolling on Toll Roads

The construction and management cost based toll setting on toll roads may severely undermine the welfare of the whole region as well as road users.




Noise level on route 19




Casualty rate

# 3. Necessity of Flexible Tolling on Toll Roads

In 2002, the Council for Infrastructure have reported that the government should introduce more flexible tolling on roads.

- Effect can be dependent on the regional environment and utilization of road networks.
- It is difficult to predict or analyze the consequence of those flexible tolling.
- There should be various ways of addressing those problems or concerns.

Demonstration Projects of Flexible Tolling

# 4. Theoretical Ground of Flexible Tolling: Analogy to Value Pricing

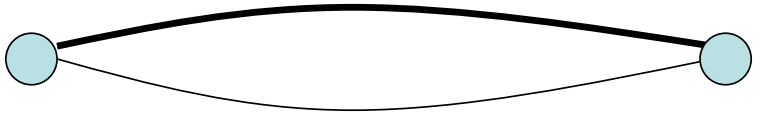
## Comparison with the Value Pricing Projects in the US

| **The typical flexible tolling project in Japan** | **Value Pricing Project (US:SR91)** |
|---|---|
| Project Description | |
| Discounting on toll roads where there is a parallel non-tolled alternative | Construction of tolled lane along with the congested existing roads |
| Basis for setting toll rates: | |
| set to recover the construction and maintenance cost | Set to realize the smooth flow condition of tolled lanes<br>Revenue recovers the cost of increasing the number of lanes |

# 4. Theoretical Ground of Flexible Tolling: Analogy to Value Pricing

## A model to analyze the welfare of pricing

Small and Yan (2001)'s parametric analysis for the SR91



Two routes have the same length L
Different unit travel-time Tr(Nr), which depends on the traffic volume Nr

User of type i (i = 1, 2) traveling on roads from the origin to the destination

Travel cost *c* consists of operating cost and time cost

User cost of using roads

$$c_{ir}(N_r) = \beta L + \alpha_i T_r(N_r) L \qquad \text{———————(1)}$$

$\beta$ = Unit cost for running some length of roads

$\alpha_i$ = Unit time cost that differs between user groups

# 4. Theoretical Ground of Flexible Tolling: Analogy to Value Pricing

## A model to analyze the welfare of pricing

Small and Yan (2001)'s parametric analysis for the SR91 (2)

Demand by each group

$$N_i(P_i) = a_i - b_i P_i \quad \text{——————————(2)}$$

$a_i$ , $b_i$ = Positive parameters
$P_i$ = "Inclusive price" or "full price"

Inclusive Price: Minimum combination of travel cost plus toll for the user group

$$P_i = \underset{r}{Min}[c_{ir} + \tau_r] \quad \text{——————————(3)}$$

Welfare of users

We use the inverse demand function for equation (2).

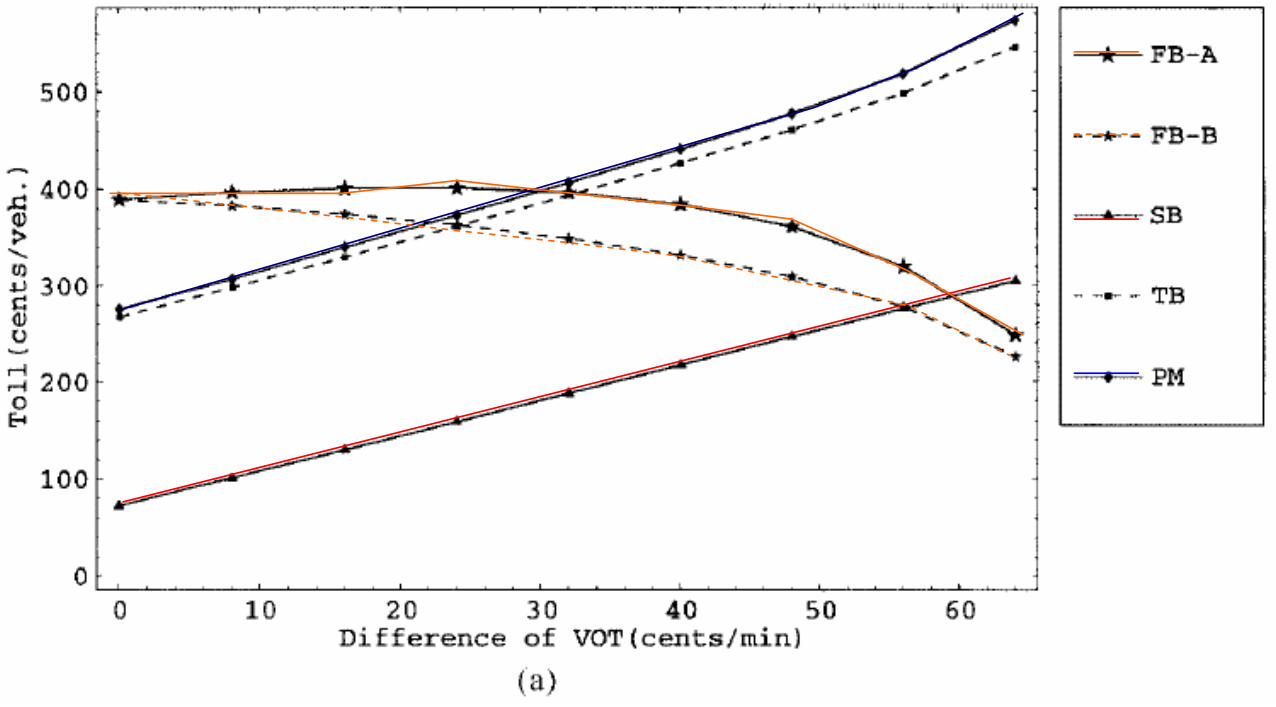
$$W_U = \sum_{i=1}^{2} \int_0^{N_i} P_i(t)dt - \sum_{i=1}^{2} \sum_{r=A}^{B} N_{ir} c_{ir} \quad \text{——————————(4)}$$

# 4. Theoretical Ground of Flexible Tolling: Analogy to Value Pricing

Small and Yan (2001)'s parametric analysis for the SR91 (3)

The second best toll in which road operator can charge toll only for route A, is shown to be below the profit maximization toll.

If the heterogeneity in road users' value of time are not extremely large. → The second best toll is usually lower than the first best toll
(First best toll: The road operator can charge toll for both A and B).



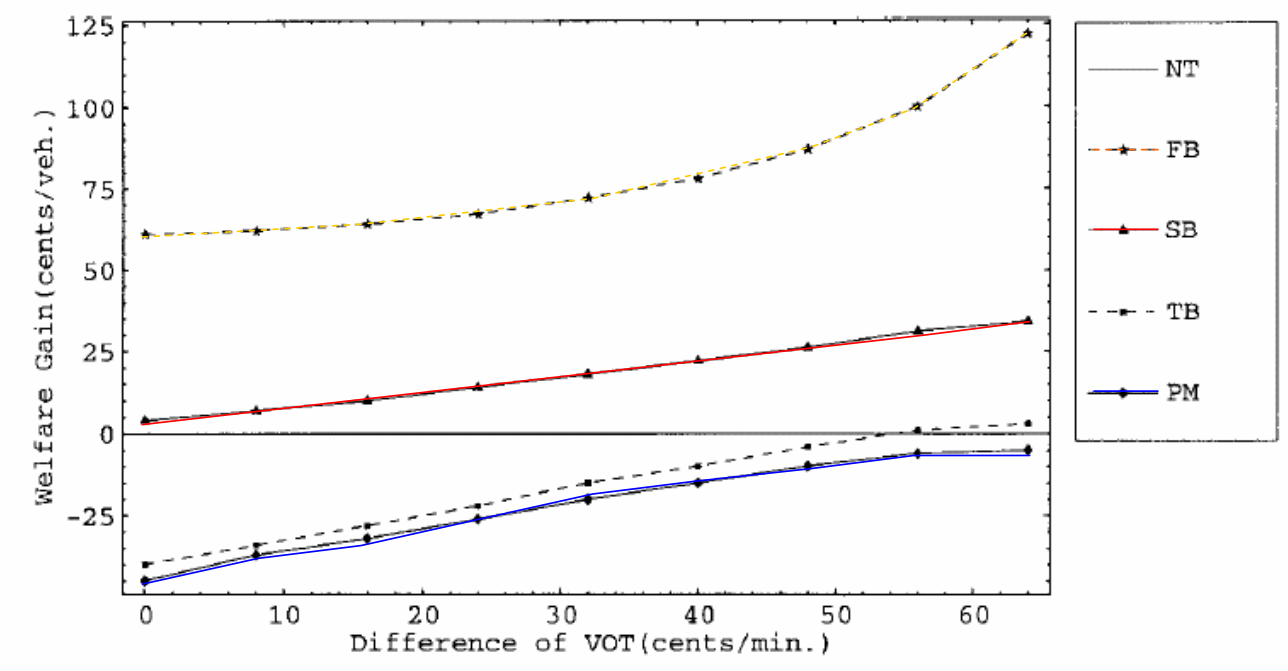
(a)

# 4. Theoretical Ground of Flexible Tolling: Analogy to Value Pricing

The heterogeneity in road users' value of time is large.

We may gain quite large welfare.

By charging either one route:
We provide the high speed toll road service and low speed and non-tolled road service at the same time.




- The second best toll is not easily determined by the text book theory.

# 4. Theoretical Ground of Flexible Tolling: Analogy to Value Pricing

Welfare of Road-side residents (Non-tolled Roads)

$$W_R = -\sum_{r=A}^{B} RC_r(N_r) \qquad \text{———————(5)}$$

Where, $RC_A(N_A) \le RC_B(N_B)$ if $N_A = N_B$ , $RC_r'(N_r) > 0$ and $RC_r''(N_r) > 0$ ,

| | |
|---|---|
| $W_R = 0$ | Lane pricing of Value Pricing Program |
| $W_R < 0$ | Flexible tolling where more residents are located near by the non-tolled route(route B) |

- When we consider the welfare of residents for flexible tolling, we may gain more welfare gain than the case of value pricing (SR91 Case) by attracting traffic to tolled highways.

# 5. Political Feasibility of Flexible Tolling and Value Pricing

## Allocation of benefit and financial cost of value pricing lanes

| | Benefit | Financial Cost |
|---|---|---|
| Road Users on Tolled &High-Speed Highways | + | - |
| Road Users on Non-Tolled & Low-Speed | + | ± |
| Residents | ± | ± |
| Government | N/A | + (If enough users exists) |

- The measure may be acceptable to the area where:
  a) there is heavy congestion on roads
  b) there are also enough toll-lane users to cover the lane construction cost
- One of the reasons for the opposition is that the pricing is regressive.

# 5. Political Feasibility of Flexible Tolling and Value Pricing

## Allocation of benefit and financial cost of introducing flexible tolls

| | Benefit | Financial Cost |
|---|---|---|
| Road Users on Tolled & High-Speed Highways | ± | + |
| Road Users on Non-Tolled & Low-Speed | + | ± |
| Residents | + | N/A |
| Government | N/A | - |

- All the stakeholders except for the government obtain benefit from the policy.
- Budget constraint is the only reason that the government will not introduce the policy.

# 6. Experimental Outcome of Flexible Tolling

Road operator should:

- Fully capture the evidences for the effect of pricing
- Provide these evidences nationally

Japanese government has:

- Conducted experiments of flexible tolling
- Taken the strategy of acquiring data and examples
- Studied the actual behaviour of users with various tolls

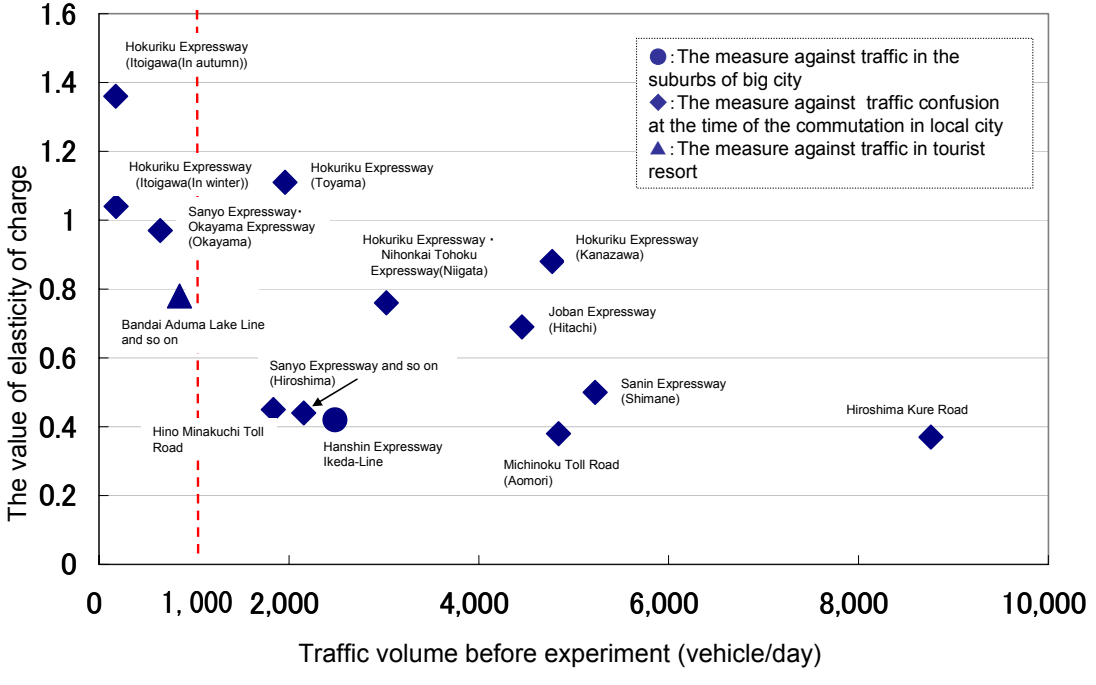
# 6. Experimental Outcome of Flexible Tolling

## Price elasticity of the experiment

Elasticity for these experiments

- Roughly between 0.4 and 1.0

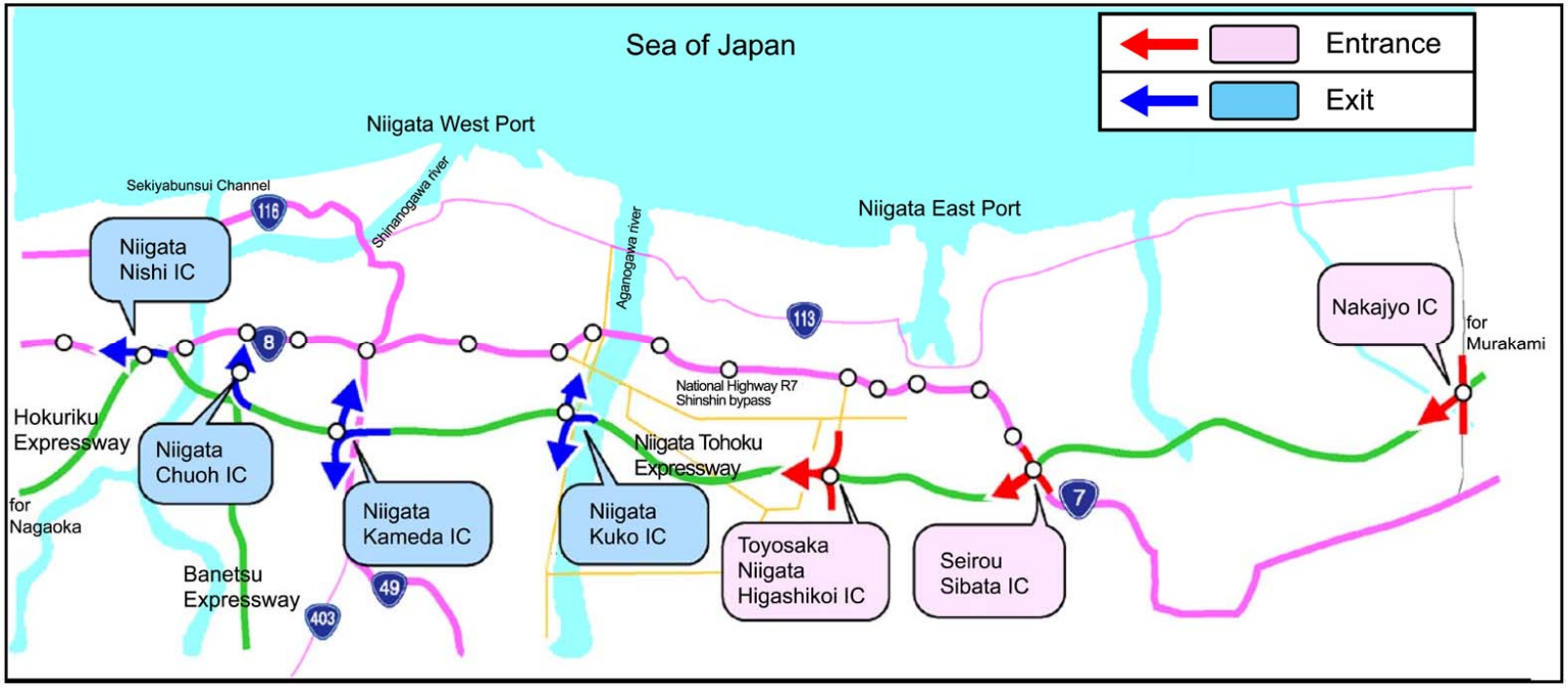
for highways with more than 1,000 vehicles per day.




*Elasticity of Demand for Flexible Tolling Experiment*

# 6. Experimental Outcome of Flexible Tolling

## Experiment in Aganogawa city in 2003



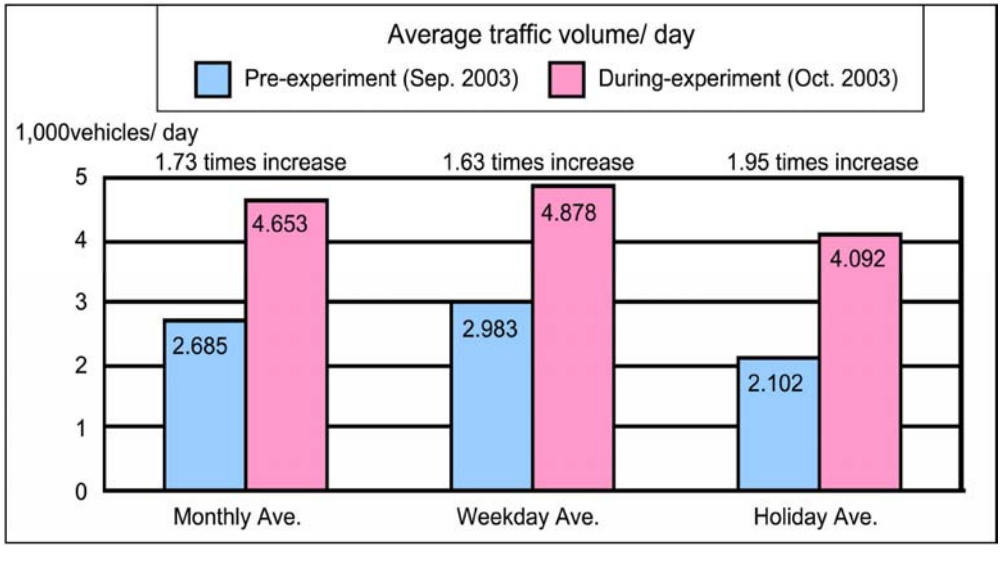
# 6. Experimental Outcome of Flexible Tolling

## Experiment in Aganogawa city in 2003

The half discount of toll caused large increase in traffic volume, especially on holidays.

Lowering toll rates can:

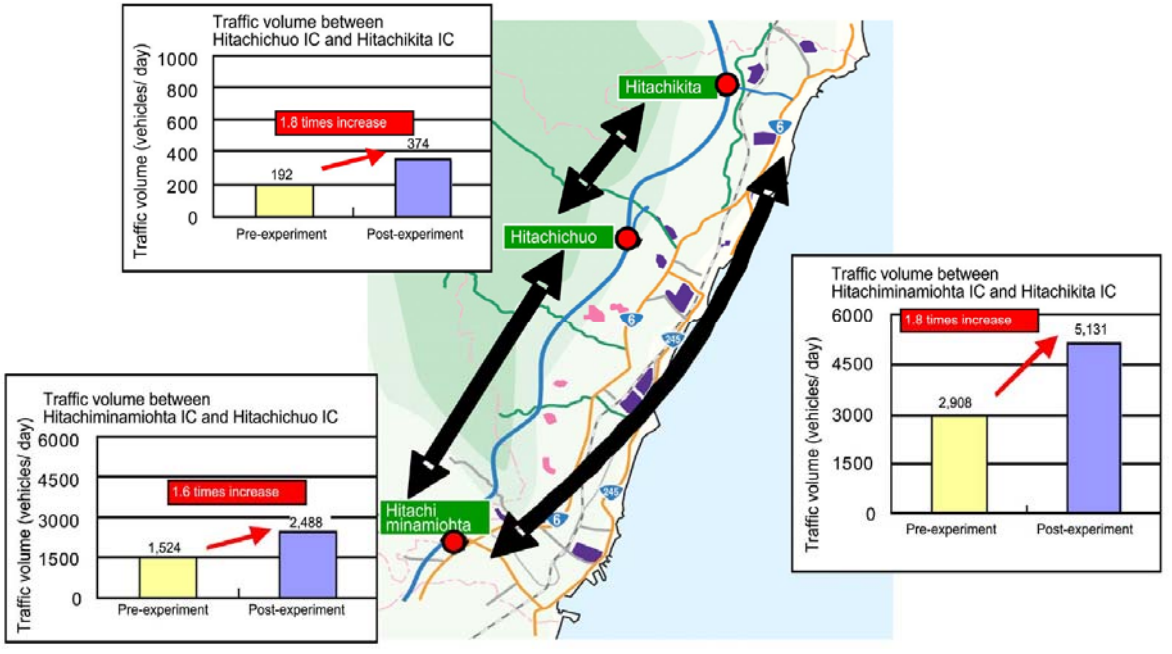
- Greatly improve the consumer welfare for transportation users
- Recover significant portion of revenue supposed to be lost for lowering toll rate



# 6. Experimental Outcome of Flexible Tolling

## Effect of the discounting of toll roads in Hitachi city

- Discount rate of toll is approximately 50%.
- Traffic volume on the segments became around 170% in weekdays.




*Hitachi city (Effect on Tolled Expressway)*

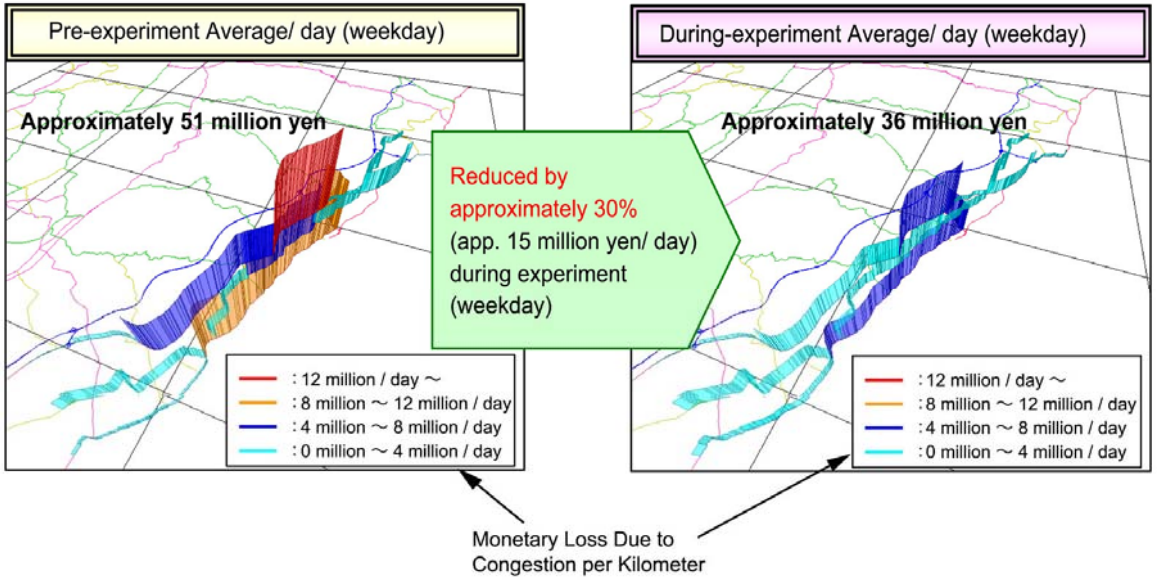
# 6. Experimental Outcome of Flexible Tolling

## Effect of the discounting of toll roads in Hitachi city

The loss of revenue is about 600 thousands yen per day,

Travel time cost from congestion has decreased by 15 million yen per day.

⇨ 25 times the loss of revenue

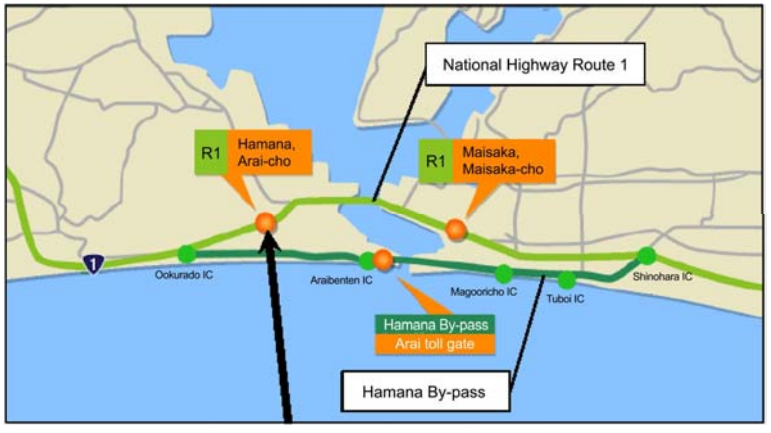



*Hitachi city (Effect on Non-Tolled Roads)*

*Changes in Monetary Loss Due to Congestion*

# 6. Experimental Outcome of Flexible Tolling

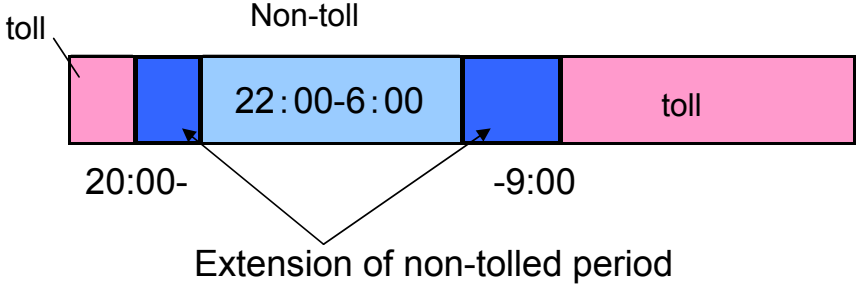
## Improvement of the living environment: at Hamana Bypass




*Hamana Bypass (Description)*

Experiment:

- For four daytime-tolled Bypasses.

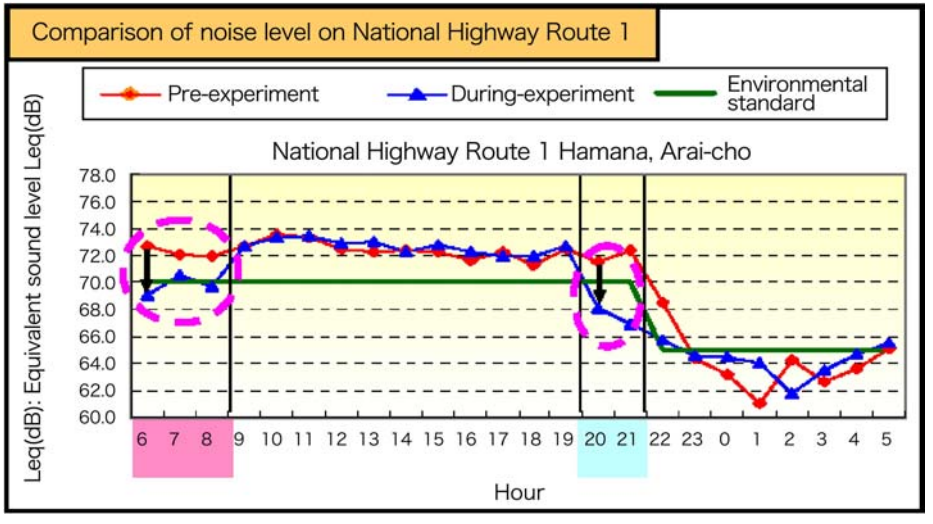



<u>During the newly introduced free periods</u>

- Traffic volume of Hamana Bypass increased by 60% (3,500 vehicles per day).
- Traffic volume of paralleled non-tolled national highway decreased by 30% (1,800 vehicles per day).

# 6. Experimental Outcome of Flexible Tolling

## Decreased noise level for non-tolled national highway




*Hamana Bypass (Effect)*

Decreasing tolls on these bypasses

Along the non-tolled national highways:

- Lower noise level than environmental standards all day
- Less air pollution due to particle matters and nitrogen oxide

# 6. Experimental Outcome of Flexible Tolling

Suggestion from the various experiments

Consideration of flexible tolling on roads is necessary.

Loss from rigid construction cost based pricing on toll roads may be quite large.

We should:

- accumulate more examples of the experiment
- draw more general characteristics and outcomes of flexible tolling
- utilize the theoretical analysis based on the practical data to show the social benefit of flexible tolling.

## What's Next?

- Prohibition of Use National Funds to support Japanese Highway Corporations.

- Privatization of Public Road Corporations.