Cost Benefit Analysis for Road Snow Removal Projects: Theory and Applications

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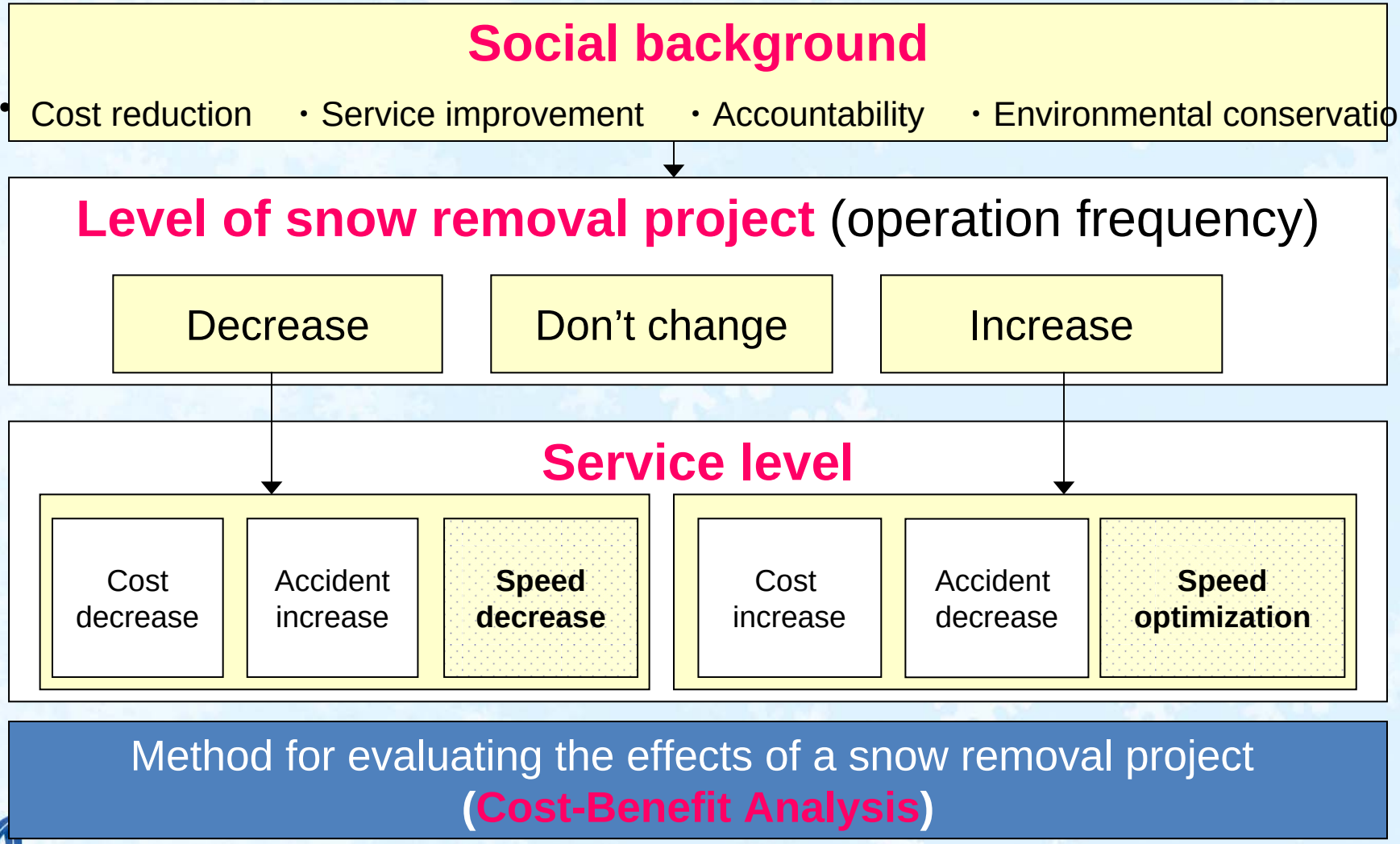
1. Introduction

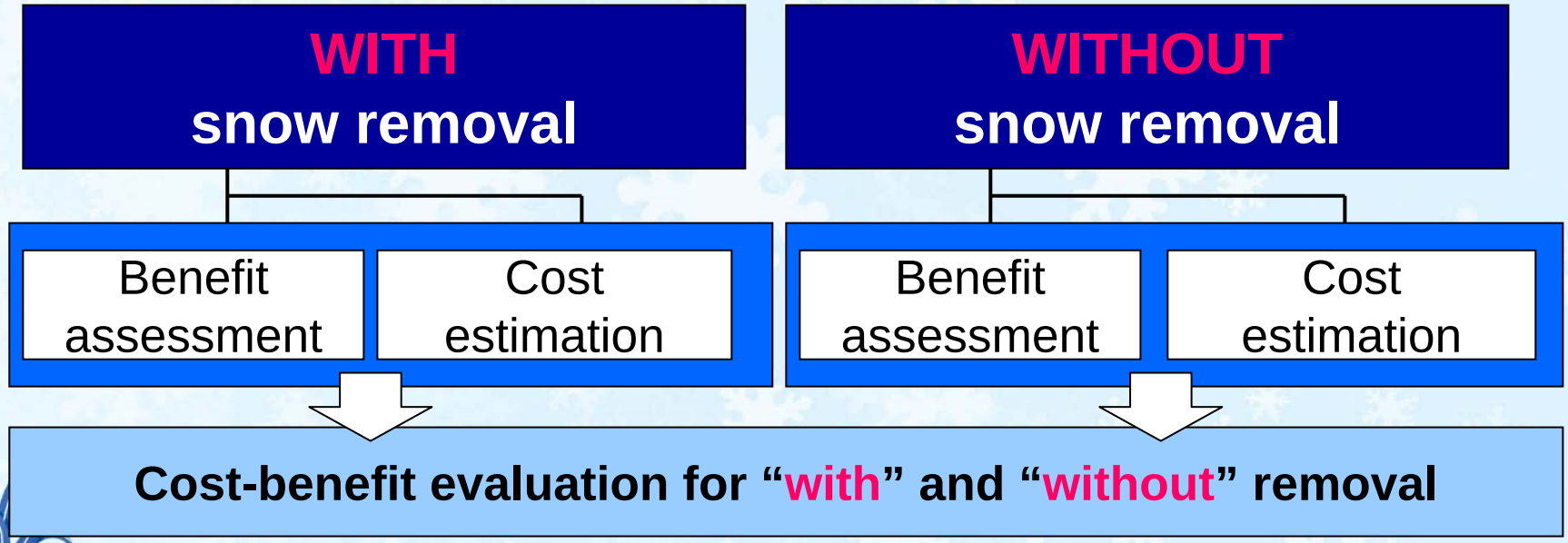


2. Study Outline

Objective

To examine whether cost-benefit analysis based on microeconomic theory is applicable for evaluating the effects of road snow removal projects by applying such analysis to collected data.

Procedure of Cost-Benefit Analysis



3. Presentation Outline

This presentation consists mainly of the formularization and assessment of benefits, analytical application to national highways, and survey results, cost estimations, and evaluation of costs and benefits.

Presentation Contents

1. **Formularization and assessment of benefits**
2. **Analytical application to a national highway, and survey results**
3. **Cost estimations**
4. **Evaluation of costs and benefits**

4. Formularization and Assessment of Benefits

The benefit is calculated as the difference in social surplus between the “with removal” scenario and the “without removal” scenario. The difference (increase) in social surplus is the sum of the increase in consumer surplus and in producer surplus.

1) Increase in consumer surplus (Δ CS)

2) Increase in producer surplus (Δ PS)

3) Benefit assessment (increase in social surplus)

Benefit = Δ CS+ Δ PS

5. Increase in Consumer Surplus (Δ CS)

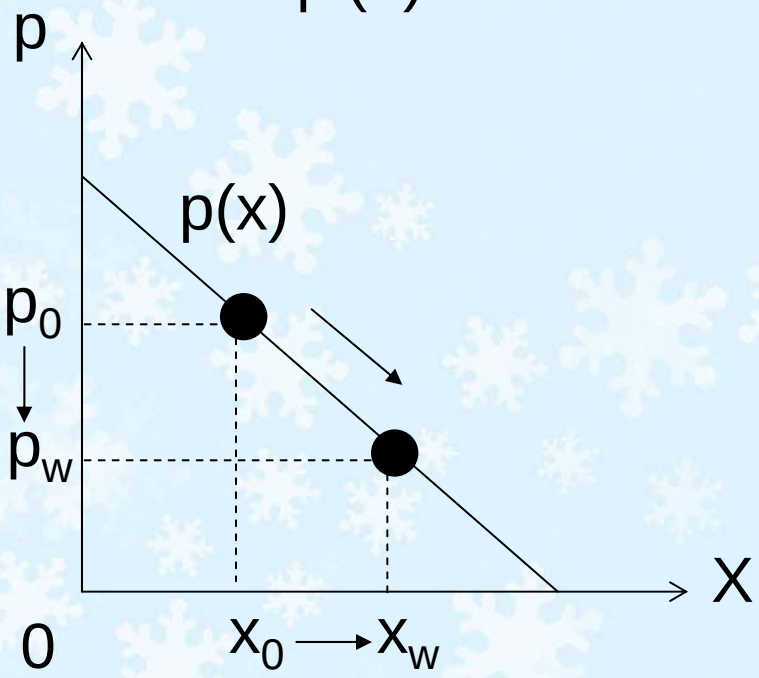
5-1 Formularization of the utility function

- The benefit is calculated based on the demand function of traffic volume.
- The demand function is derived from the utility function.
- The utility function is assumed to be quasi-linear.

$$U(z,x) = z + u(x) \rightarrow \max \qquad \text{------ Eq. (1)}$$

$$\frac{\partial u(x)}{\partial x} = p(x) \qquad \text{----- Eq. (3)}$$

U: quasi-liner utility function for consumers
Z: numéraire goods with a price of 1
x: traffic volume
P: generalized cost (monetary valuation of time)



5. Increase in Consumer Surplus (Δ CS)

5-2. Calculation of (Δ CS)

The change in consumer surplus (Δ CS) is expressed as the difference between the "with removal" utility (U_w) and the "without removal" utility (U_o).

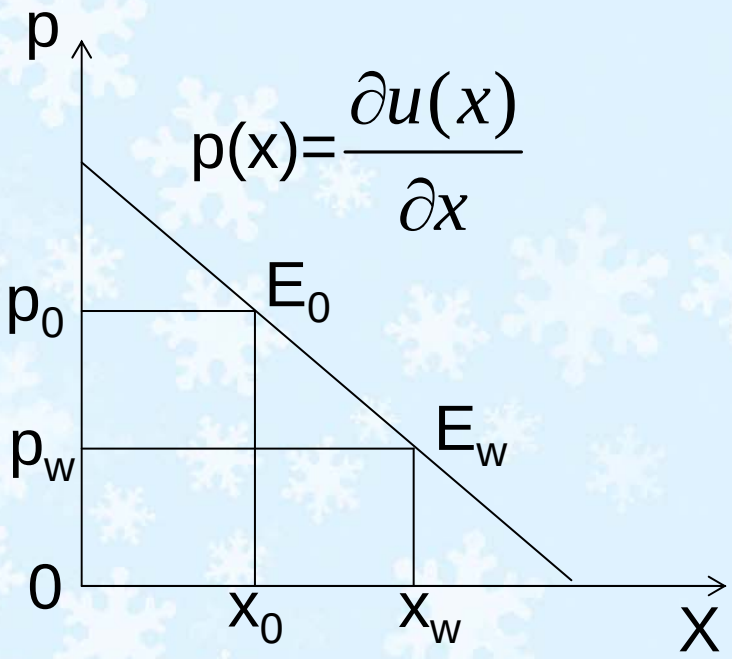
$$\Delta CS = \Delta U = U_w - U_0 \quad = U(z_w, x_w) - U(z_0, x_0)$$

$$= u(x_w) - p_w x_w - \{u(x_0) - p_0 x_0\}$$

$$= u(x_w) - u(x_0) - (p_w x_w - p_0 x_0)$$

$$= \int_{x_0}^{x_w} \frac{du(x)}{dx} dx - (p_w x_w - p_0 x_0)$$

------- Eq. (4)



6. Increase in Producer Surplus （ΔPS)

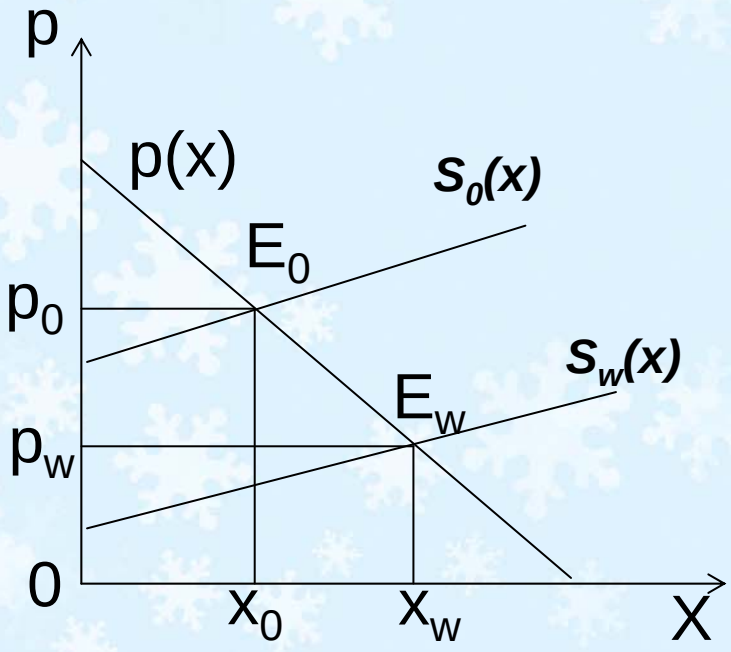
$S_w(x)$ stands for the social marginal cost function of road use with snow removal, and $S_o(x)$ stands for that without snow removal.

$$\Delta PS = \left\{p_w x_w - \int_0^{x_w} s_w(x)dx\right\} - \left\{p_0 x_0 - \int_0^{x_0} s_0(x)dx\right\}$$

$$= (p_w x_w - p_0 x_0) - \left\{\int_0^{x_w} s_w(x)dx - \int_0^{x_0} s_0(x)dx\right\}$$

$$= (\Delta PQ) - (\Delta SC)$$

------ Eq. (7)



7. Benefit (Increase in Social Surplus)

For the benefit, which is defined as the increase in social surplus (Δ CS + Δ PS), Eq. (8) can be obtained.

$$\Delta B = \Delta CS + \Delta PS$$

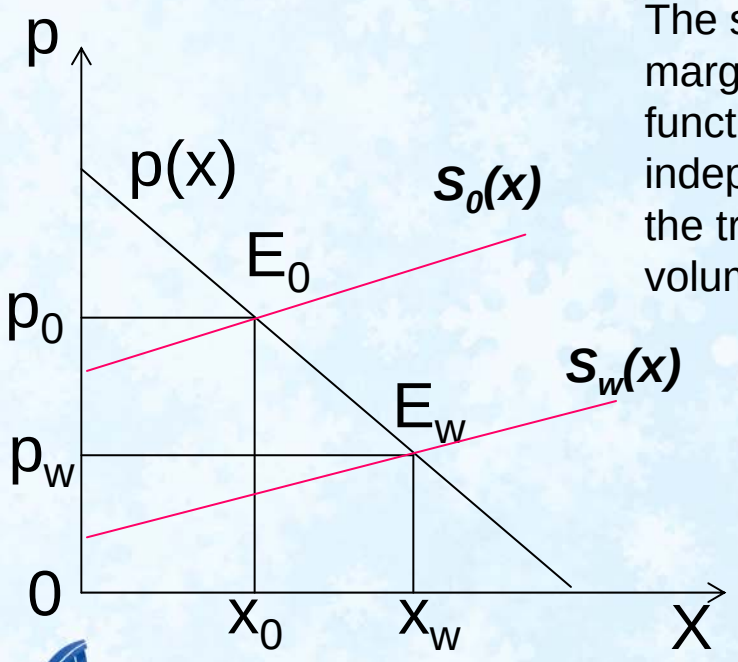
$$= (\Delta GCS - \Delta PQ) + (\Delta PQ - \Delta SC)$$

$$= \Delta GCS - \Delta SC \qquad \text{------ Eq. (8)}$$

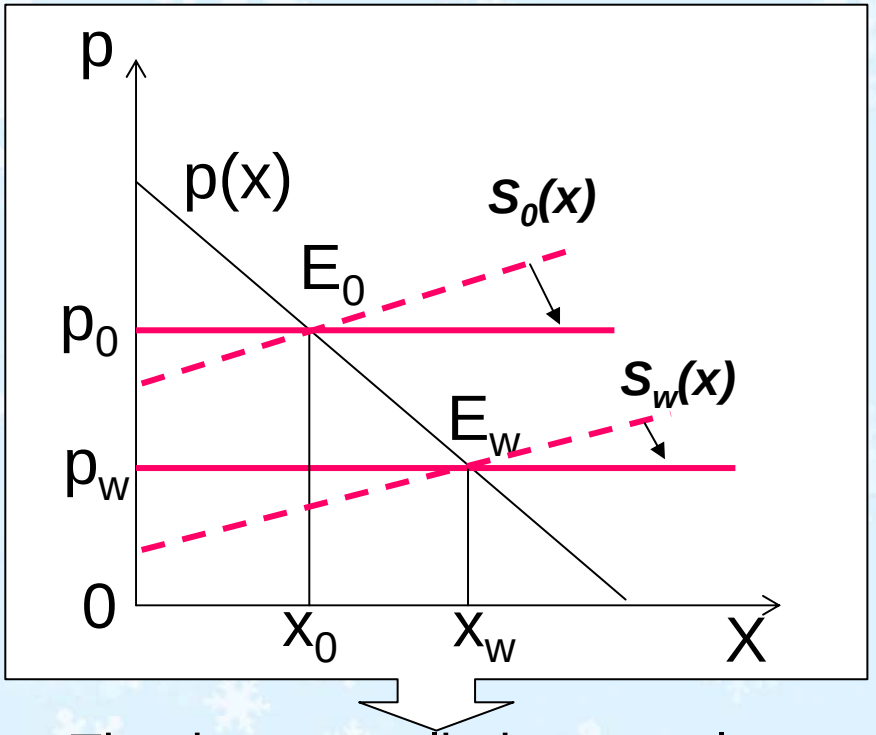
8. Benefit (Increase in Social Surplus)

8-1 Proposition of the cost function

If both of the social marginal cost functions by road use, $S_w(x)$ *and* $S_o(x)$, remain constant regardless of the change in traffic volume (x), then they plot as horizontal.



The social marginal cost function is independent of the traffic volume.

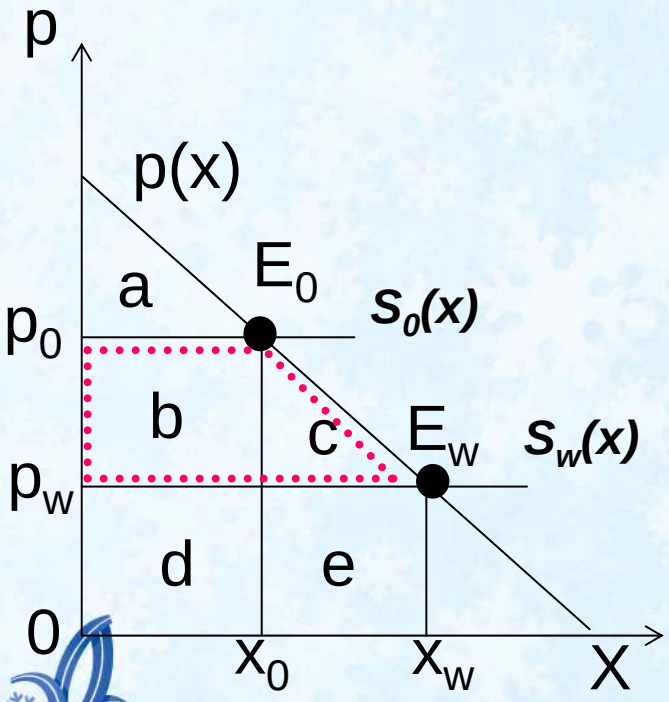


The theory applied to actual road management

8. Benefit (Increase in Social Surplus)

8-2 Benefit assessment

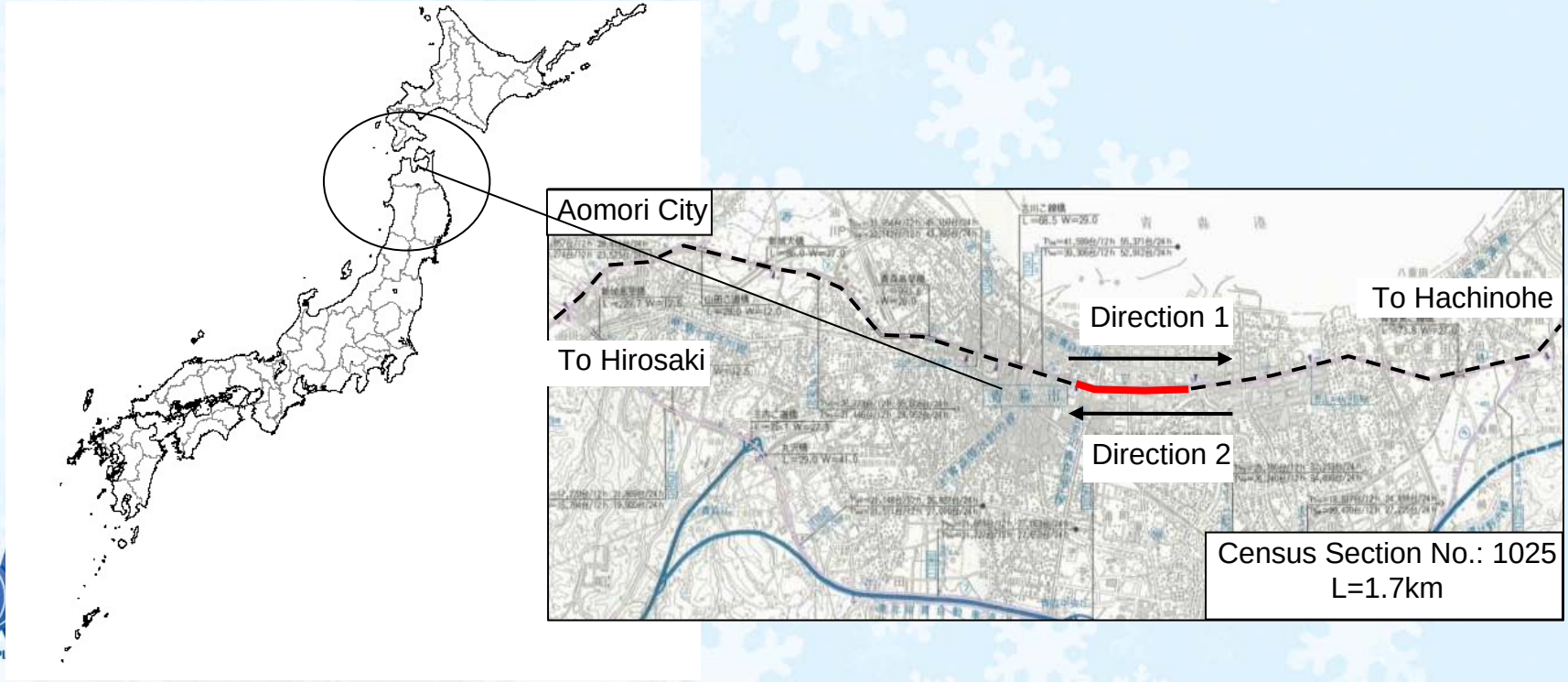
(b+c) represents the benefit as the change in social surplus.



			Snow Removal		[1]-[2]
			With [1]	Without [2]	
GCS	CS		a+b+c	a	b+c
	PS	PQ	d+e	b+d	-b+e
		-SC	-d-e	-b-d	b-e
B			a+b+c	a	b+c

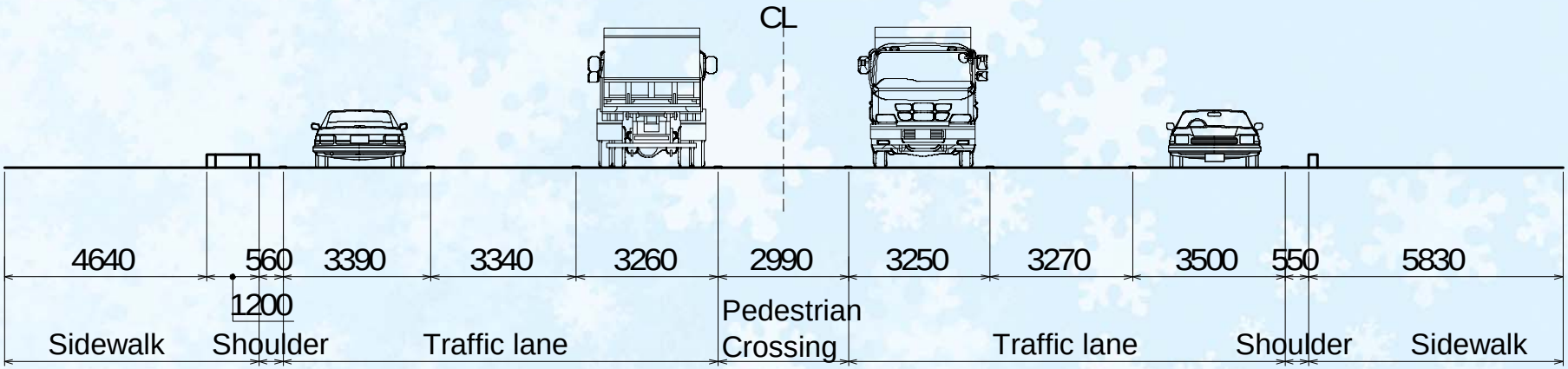
9. Analysis of a National Highway (surveyed area: Aomori)

The survey area is a section of Natl. Rte. 4 in downtown Aomori City, Aomori Prefecture. The city is in one of the snowiest regions in Japan. It had 444 cm of snowfall last year.



10. Analysis of a National Highway (surveyed road section)

The section is 1.7 km with 6 traffic lanes.



11. Before and After Snow Hauling

Before

After

12. Survey Results

The snow hauling operations shortened the travel time by **108 hours** and increased the 12-hour traffic volume by **1250 vehicles** for both directions combined.

		2009/1/28, without-CASE			2009/1/29, with-CASE		
		Travel time (s)	Travel speed (km/h)	Traffic volume (vehicles)	Travel time (s)	Travel speed (km/h)	Traffic volume (vehicles)
Vehicle type	Direction	p_0		x_0	p_w		x_w
Passenger car	1	303	20.2	12,525	265	23.1	12,882
	2	395	15.5	11,811	325	18.8	12,433
Bus	1	303	20.2	591	265	23.1	608
	2	395	15.5	494	325	18.8	521
All four types	1	303	20.2	16,296	265	23.1	16,762
	2	395	15.5	15,098	325	18.8	15,885

Total 698(s) → **Δ 108(s)** → **Total 590(s)**

Total 31,394 vehicles → **+1,250 vehicles** → **Total 32,547 vehicles**

Traffic volume: 12-h traffic volume
All four types: passenger cars, buses, small freight vehicles, and mid-sized freight vehicles

13. Cost Estimation

The cost of snow hauling per day is estimated as **1.27 mil. yen** for this section.

Cost breakdown of snow hauling

Cost	Remarks
Labor	Rotary snow plow operators
	Truck drivers
	Traffic flagmen
Other	Fuel, etc.

=1.273 mil. yen/day

14. Cost and Benefit

Travel times and traffic volumes figured out for the “with” and “without” snow removal scenarios

Vehicle type	Dire-ction	Consumer surplus (10,000 yen)
Passen-ger car	1	32.3
	2	56.7
Bus	1	14.2
	2	22.2
Mid-sized freight	1	3.5
	2	5.5
Small freight	1	8.5
	2	14.1

Vehicle type	Time value (yen / min. / vehicles)
Passenger car	40.10
Bus	374.27
Regular-sized freight vehicle	64.18
Small-sized freight vehicle	47.91

Benefit (B)

1.568 mil. yen

B/C

1.23

Cost (C)

1.273 mil. yen/day

15. Conclusion

1. The applicability of cost-benefit analysis based on microeconomic theory to evaluate the effects of road snow removal projects was examined by using data collected from a national highway.
2. The method was found to be feasible for evaluating snow hauling projects.
3. The cost-effectiveness of snow hauling was verified.

Thank you.

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