Québec 2010
AIPCR · PIARC

XIII INTERNATIONAL WINTER ROAD CONGRESS

QUÉBEC, FEBRUARY 8 TO 11, 2010

SUSTAINABLE WINTER SERVICE FOR ROAD USERS

Snowplow Deployment Management Method Considering Attributes of Region and Route

Tetsuya OGAMI

Civil Engineering Research Institute for Cold Region
JAPAN

Researcher

E-mail : oogami-t22aa@ceri.go.jp

WORLD ROAD ASSOCIATION
MONDIALE DE LA ROUTE
AIPCR PIARC

Québec

CERI
COLD REGION

Necessity of a snowplow deployment plan

Purpose of a deployment plan

= Appropriate and economical road management

If this plan fails...

Deficiency : hindrance of traffic

Excess : uneconomical

What is a snowplow deployment plan?

Deployment plan

= Estimation of the number of snowplows needed to satisfy the control level

Expressed by the concept equation below

Deployment plan

= Control level ／ Snow removal performance

Concept equation

$$\text{Deployment plan (no. of snowplows)} = \frac{\text{Control level}}{\text{Snow removal performance}}$$

Concept equation

$$\text{Deployment plan (no. of snowplows)} = \frac{\text{Control level}}{\text{Snow removal performance}}$$

What are the control levels?

$$\text{Deployment plan (no. of snowplows)} = \frac{\text{Control level}}{\text{Snow removal performance}}$$

Specifically :

- Snowfall depth, snow removal time, etc.

Control level in Hokkaido, Japan (snowfall depth)

National highways	: 5 – 10 cm
National highways (trial)	: 10 cm or more
Freeway	: 3 – 5 cm
Sapporo city roads	: 10 cm or more
Sapporo city roads (trial)	: 15 – 20 cm

Control levels are not uniform,

And may vary depending on circumstances

What is snow removal performance?

$$\text{Deployment plan (no. of snowplows)} = \frac{\text{Control level}}{\text{Snow removal performance}}$$

Snow removal performance

= Mechanical performance × Site conditions

- Engine power
- Work width
- Other

- Weather
- Road structure
- Other

In the case of fresh snow

Snow removal performance = Snow removal speed

The snow removal speed is not clearly determined !

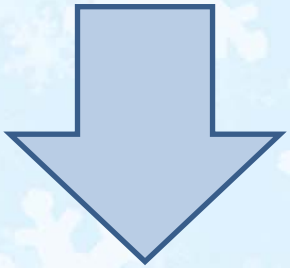
AIPCR · PIARC Québec 2010

Snow removal speeds (published values)

$$\text{Deployment plan (no. of snowplows)} = \frac{\text{Control level}}{\text{Snow removal speed}}$$

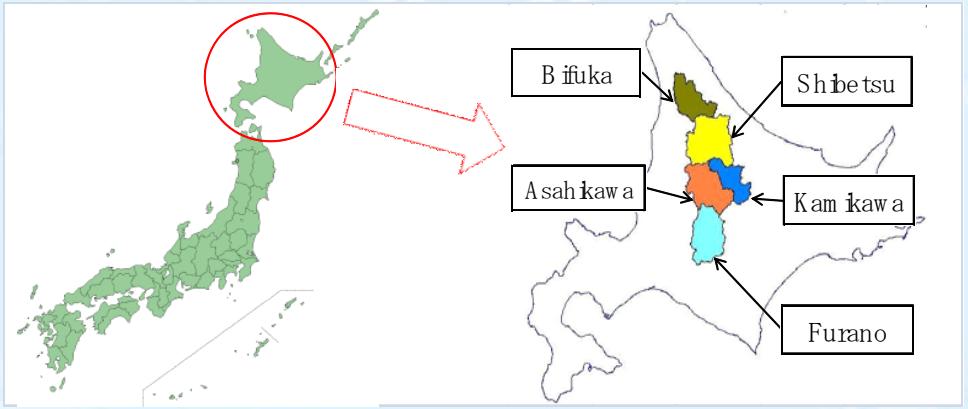
Published snow removal speeds

- Speeds vary by source
- Only uniform values are presented

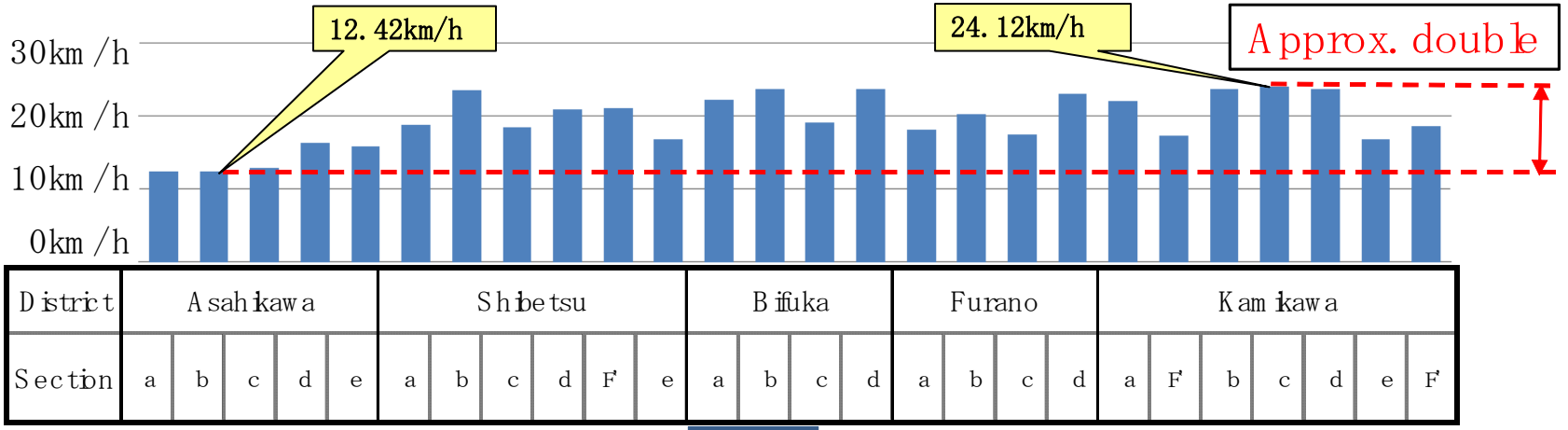


Differences in site conditions are not reflected

Snow removal speeds (actual values)



Average snow removal speeds



The causes of differences in speed have not been identified

Study policy

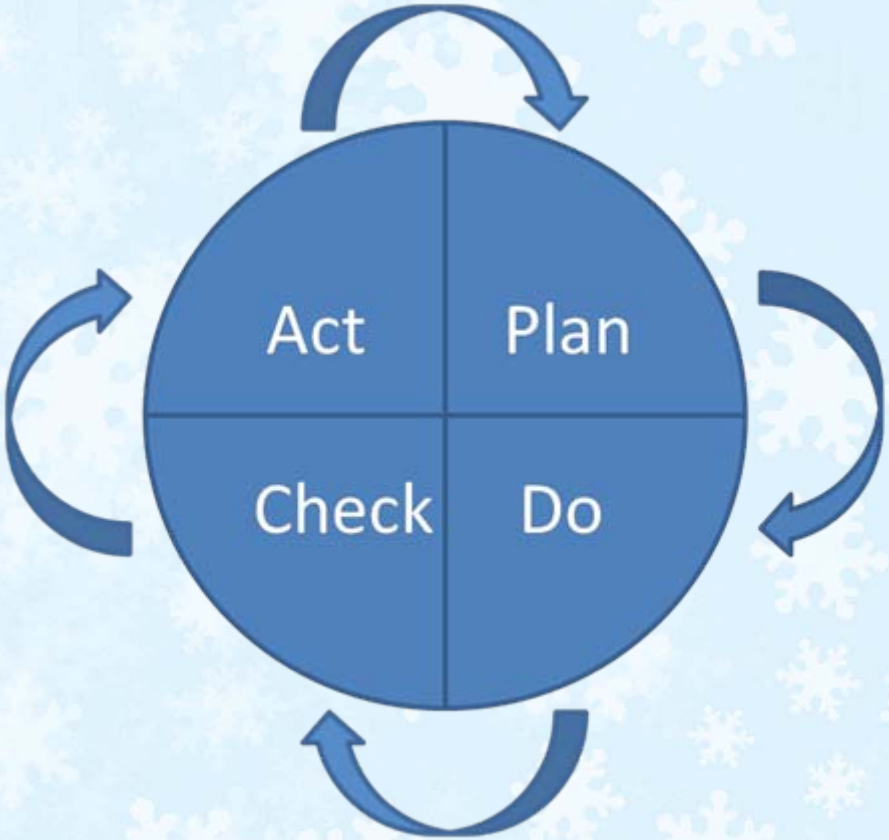
Deployment plan (no. of snowplows) = Control level / Snow removal speed

Establishment of standard snow removal speeds suitable for the attributes of individual regions and routes

- Development of efficient and economical deployment plans
- Equalization of snow removal service levels
- Quantitative evaluation of snow removal work efficiency

Study policy

Continuous improvements in snow removal efficiency are enabled through ongoing study



Tasks for the establishment of standard snow removal speeds

- Extraction of factors (attributes of regions/routes)

  → What factors affect snow removal speeds?

- Examination of basic data

  → How can extracted factors be evaluated quantitatively?

- Analysis of correlation between speeds and factors

  → How can multiple extracted factors be analyzed?

Extraction of factors

Possible factors affecting snow removal speeds

Factor affecting speed			
Roadside conditions	DID length	Weather	95% snowfall intensity
	Length of other urban areas		Snow quality (dry snow)
	Length of flat areas		Snow quality (sugar snow)
	Length of mountainous areas	Road structure	Double-lane length
	LR (left-to-right) length of continuity of private houses		Multiple-lane length
Traffic	Nighttime traffic volume		Added/climbing lane length
Specific factors	Snow-flowing gutter length		No. of roadway width change points
	No. of roadside stations		Sharp curve R < 150
	No. of chain attachment/removal sites		Length of slopes with a gradient of 5% or greater
	No. of tunnels in the mountainous area		Median strip length
	No. of unsignalized intersections		Sidewalk length
	No. of return points		Bridges
			LR (left-to-right) length of guard fences
			No. of bus stops
			No. of signalized intersections

Examination of basic data

Examination principles

→ Quantitative counting

→ Continuous study

Data used

Telemeters, Road traffic census results,
Road management databases,
Maintenance and management ledgers, etc.

Analysis of correlation between speeds and factors

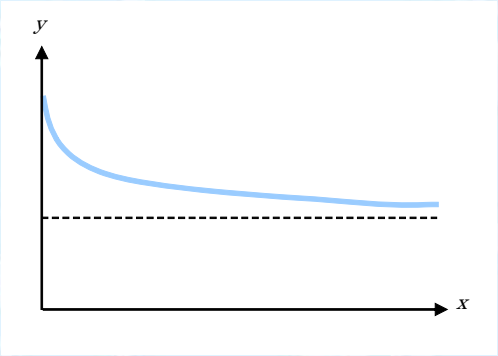
Multiple regression analysis of a log-linear model

- Multiple regression analysis is a technique that focuses on one among multiple variables to ascertain how it is affected by the other explanatory variables

→ Suitable for cases such as snow removal speeds that involve multiple factors

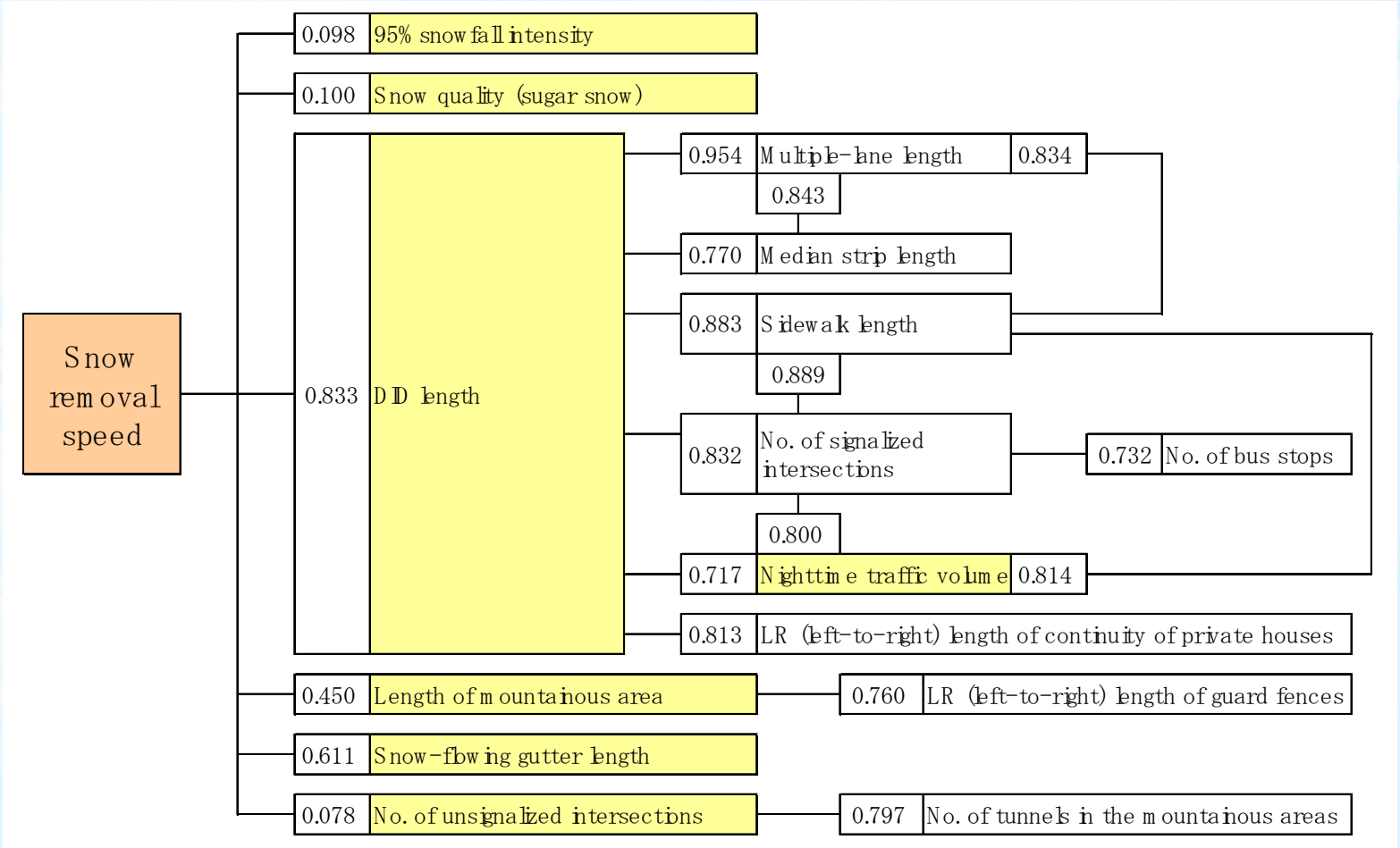
■Model equation for standard snow removal speeds

$$y = \exp\left(\sum_{i}^{n} a_i x_i + b \right)$$



Analysis of correlation between speeds and factors

Correlation among factors affecting snow removal speeds



Determination of standard snow removal speeds

Calculation formula for standard snow removal speeds

(Asahikawa Development and Construction Department)

$$y = \exp(-0.009\,x_1 - 0.214\,x_2 - 0.704\,x_3 + 0.162\,x_4 - 2.047\,x_5 - 0.110\,x_6 - 0.158\,x_7 + 3.128)$$

- y : Standard snow removal speed
- X_1 : Snowfall intensity
- X_2 : Snow quality (sugar snow)
- X_3 : DID length
- X_4 : Length of mountainous area
- X_5 : Nighttime traffic volume
- X_6 : Snow-flowing gutter length
- X_7 : No. of unsignalized intersections

Multiple correlation coefficient = 0.865

(sufficient accuracy was ensured)

Comparison of standard and actual snow removal speeds (reference values)

District	Section	Actual snow removal speed (km/h)	Standard snow removal speed (km/h)	Difference (km/h)	Percentage (%)
Asahikawa	a	12.45	12.33	-0.12	101
	b	12.42	12.79	0.37	97
	c	12.99	12.83	-0.16	101
	d	16.32	15.27	-1.05	107
	e	15.83	17.95	2.12	88
Shibetsu	a	18.80	19.75	0.95	95
	b	23.58	22.10	-1.48	107
	c	18.53	17.79	-0.74	104
	d	20.95	19.25	-1.70	109
	e	16.94	18.75	1.81	90
Bifuka	a	22.31	21.70	-0.61	103
	b	23.71	24.14	0.43	98
	c	19.22	21.45	2.23	90
	d	23.83	24.00	0.17	99
Furano	a	18.25	18.74	0.49	97
	b	20.39	21.65	1.26	94
	c	17.50	17.42	-0.08	100
	d	23.07	22.76	-0.31	101
Kamikawa	a	22.15	19.80	-2.35	112
	b	23.76	22.34	-1.42	106
	c	24.12	20.87	-3.25	116
	d	23.74	25.18	1.44	94
	e	16.92	19.58	2.66	86

Actual snow removal speed/standard snow removal speed > 1.1 = Section where efficient snow removal is conducted

Actual snow removal speed/standard snow removal speed < 0.9 = Section where inefficient snow removal is conducted

AIPCR · PIARC Québec 2010

Case study

Making of section reorganization plan based on the standard snow removal speed

- $\Sigma s = Cl / Si$

  Σs : Allowable snow removal time (h)

  Cl : Allowable maximum snowfall depth (cm)

  Si : Snowfall intensity (cm/h)

- $\Sigma e = \Sigma s \times y$

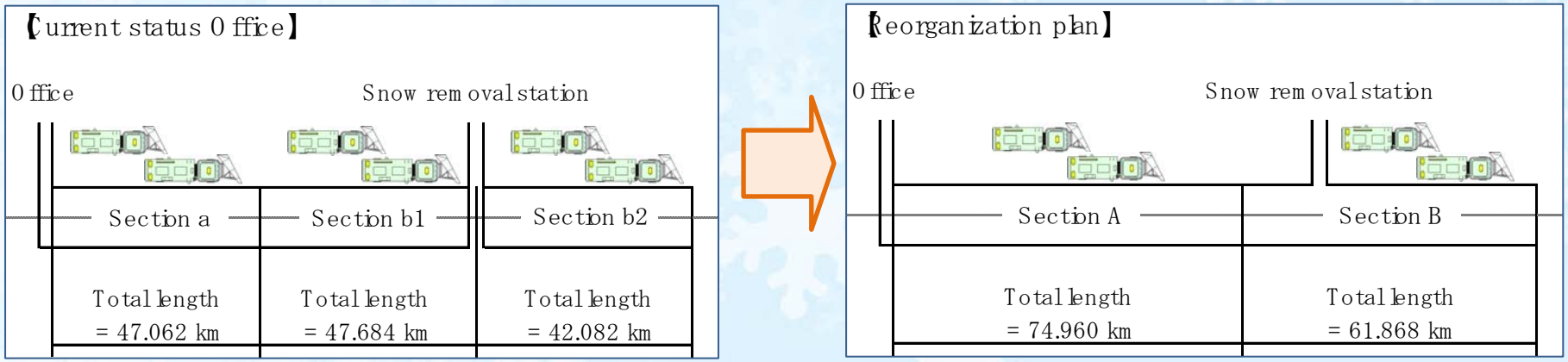
  Σe : Permissible limit length (km)

  Σs : Allowable snow removal time (h)

  y : Standard snow removal speed (km/h)

Case study

Example



- Within the allowable snow removal time for all sections
- Reduction of three sections and six snowplows

Achievement of service level improvement and reduced costs

Conclusion

Study results

- Factors involving site conditions and the degree of their effect on snow removal speeds were measured quantitatively.
- A method of determining standard snow removal speeds suitable for the attributes of individual regions and routes was established.
- The validity of these standard snow removal speeds was confirmed, as it was possible to evaluate work efficiency and perform case studies for efficient and economical deployment plans.

Future plans

- Expansion of study areas and verification of mechanical performance
- Consideration of this management method's application to the spreading of antifreeze agents, etc.

Thank you for your attention.

Québec 2010
AIPCR · PIARC