A Trafficability Index to Safely Operate Road Network and Vehicles during Winter

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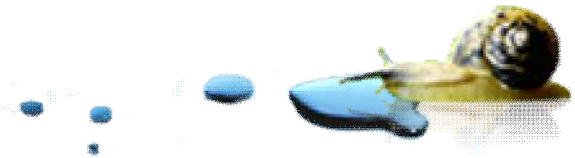

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Contents

Background and objective

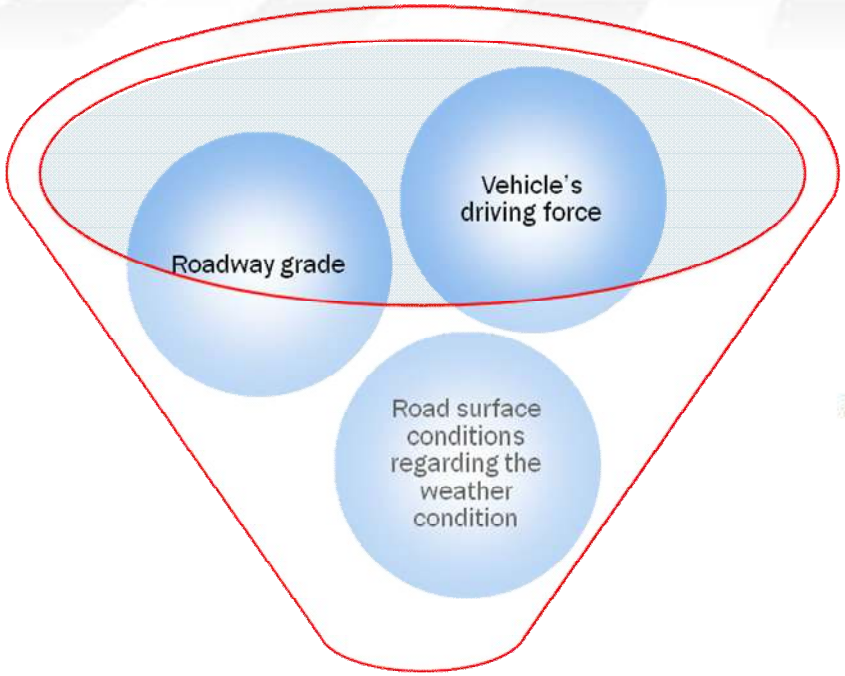
Background

- A snow fall on an uphill section of a roadway reduces the friction between the vehicle and the roadway
  - ➢ making the uphill section impossible to climb or safely descend
- Fail to climb the uphill section
  - ➢ traffic congestion or vehicle's isolation due to hampering the entry of other vehicles and snow removal vehicles

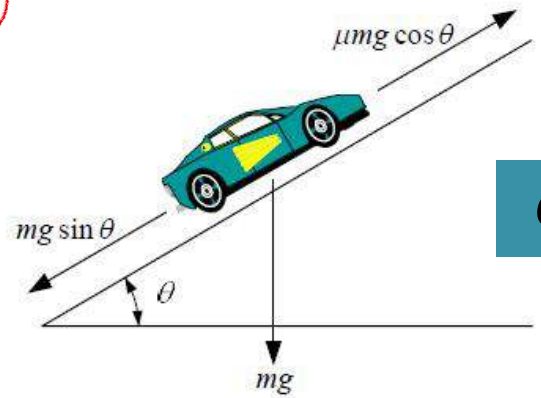
Objective

- To present a methodology for developing a trafficability index with respect to vehicle types, geometric characteristics of roadway sections, and roadway surface conditions

Traction performance



Increasing the friction coefficient results in greater the trafficability degree

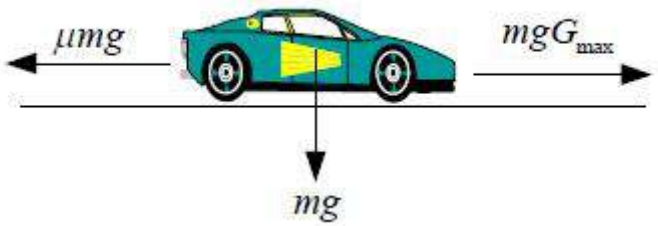


$$G_{max} = \tan(\theta_{max})$$

$$\mu mg\cos\theta_{max} = mg\sin\theta_{max} \qquad mgG_{max} = mg\mu$$

$$\mu = \tan\theta_{max} \qquad G_{max} = \mu$$

Factors associated with the possibility of a particular vehicle can pass through the particular roadway section



Previous Studies

Friction b/w the road surface and vehicle

- Measuring the stopping distance from the 1960s and early 1970s
- Braking friction and traction force of general tires, snow tires, studded tires, four-wheel-drive vehicles, four-wheel and ABS-equipped vehicles and rear-wheel and ABS-equipped vehicles in 1980 (Hayhoe and Kopac)
- In 1990, the University of Alaska performed an experiment related to vehicl e traction force both on snowy and icy roads regarding three type of tires

Type of tires	Blizzak		Studded		All-season	
Traction test	Snow	Ice	Snow	Ice	Snow	Ice
Stopping distance (40.2km/h) Starting traction (time in sec to reach 42.2 km/h)	19.5 9.6	36.5 14.4	32.3 9.1	32.3 11.9	19.3 10.5	39.1 16.7
Maximum cornering speed (15.2m radius in km/h)	27.7	22.8	25.6	21.9	27.7	22.0
Maximum starting grade (%)	16	11	16	12	15	10

Previous Studies

- In the late 1990s, Evaluated The winter traction performance of transit and paratransit vehicles
  - Tested stopping distance, starting traction, maximum hill-climbing abilit y, and degree of vehicle movement direction change occurring with sud den stops

Limits of previous studies

- Limited studies accomplished to establish the operational criteria for the road networks and vehicles with respect to the geometric characteristics of the roadways, vehicle types, and weather conditions

Average maximum friction coefficient of vehicles

- Used the maximum average friction coefficient (G_{max}) suggested by Raad and Lu
  - Was simplified to passenger car, vans, bus, and light truck
  - Value of other vehicles can be estimated by using the interpolation method

<Examples of Gmax by vehicle types on non-battered snow>

Type of vehicles	Vehicle weight	Gmax
Passenger car	1.5t	0.14
Van	4.6t	0.15
Bus	15.4t	0.16
Light truck	1.8t	0.14

Average maximum traction coefficient of vehicles

- Traction: a machine's ability to continue moving forward w/ o the wheels slip ping
- Coef. of traction: the usable force for traction divided by the weight on the ve

<Traction coefficient of universal tire by road surface conditions>

Road surface	More detailed description of the surface condition	Traction coefficient
Battered snow	Snow, battered by automobiles, which does not make the pounded layer of snow and ice	0.24~0.37
Non-battered snow	Snow, which has just fallen on the asphalt and which is not battered by the wheels of automobiles – the fir-st driving	0.15~0.42
Snow and ice, covered with the snow, which has just falle-n	Battered snow and ice, covered with the layer of snow (thickness – up to 10cm), which has just fallen and i-s not battered	0.18~0.45
Snow and ice, mixed with san-d and slush	Battered snow and ice, mixed with sand with slush, the particles of which make 3-6min in diameter	Depending on upon the quantity of slush 0.15~0.45
Snow and ice	Entire layer of snow, battered to the extent of the icy surface	0.12~0.39
Snow and ice before crossroa-ds	Snow, which at first was melted by the motors of the standing automobiles and then frozen up to the smoo-th surface	0.09~0.22
Dry asphalt in winter conditio-ns	Dry asphalt (not covered by anything) in winter conditions	0.59~0.72
Asphalt, covered with hoar-fr-ost	White cover on the asphalt, which is observed by the driver and easily recognized as hoar-frost	0.48~0.58
Smooth ice	Thick layer of frozen water, non-infringed with prickles and chains	0.054~0.19
Ice and tires with chains	Thick non-infringed layer of frozen water, infringed with the wheels, equipped with steel chains	0.12~0.18
Black ice	Thick ice layer, looking as a wet, black stretch of the road, which seems fit for traffic, and is not easily notic-ed by the driver	0.12~0.26

Trafficable slope

<Summary of Gmax for vehicle types and road surface conditions>

Road surface condition i	$G_{max(i,j)}$ for vehicle type j			
	Passenger car	Van	Bus	Light truck
Battered snow	0.24	0.257	0.274	0.24
Non-battered snow	0.15	0.161	0.171	0.15
Snow and ice, covered with the snow, which has just fallen	0.18	0.193	0.206	0.18
Snow and ice, mixed with sand & Slush	0.15	0.161	0.171	0.15
Snow and ice	0.12	0.129	0.137	0.12
Snow and ice before crossroads	0.09	0.096	0.103	0.09
Dry asphalt in winter conditions	0.59	0.632	0.674	0.59
Asphalt, covered with hoar-frost	0.48	0.514	0.549	0.48
Smooth ice	0.054	0.058	0.062	0.054
Ice and tires with chains	0.12	0.129	0.137	0.12
Black ice	0.12	0.129	0.137	0.12

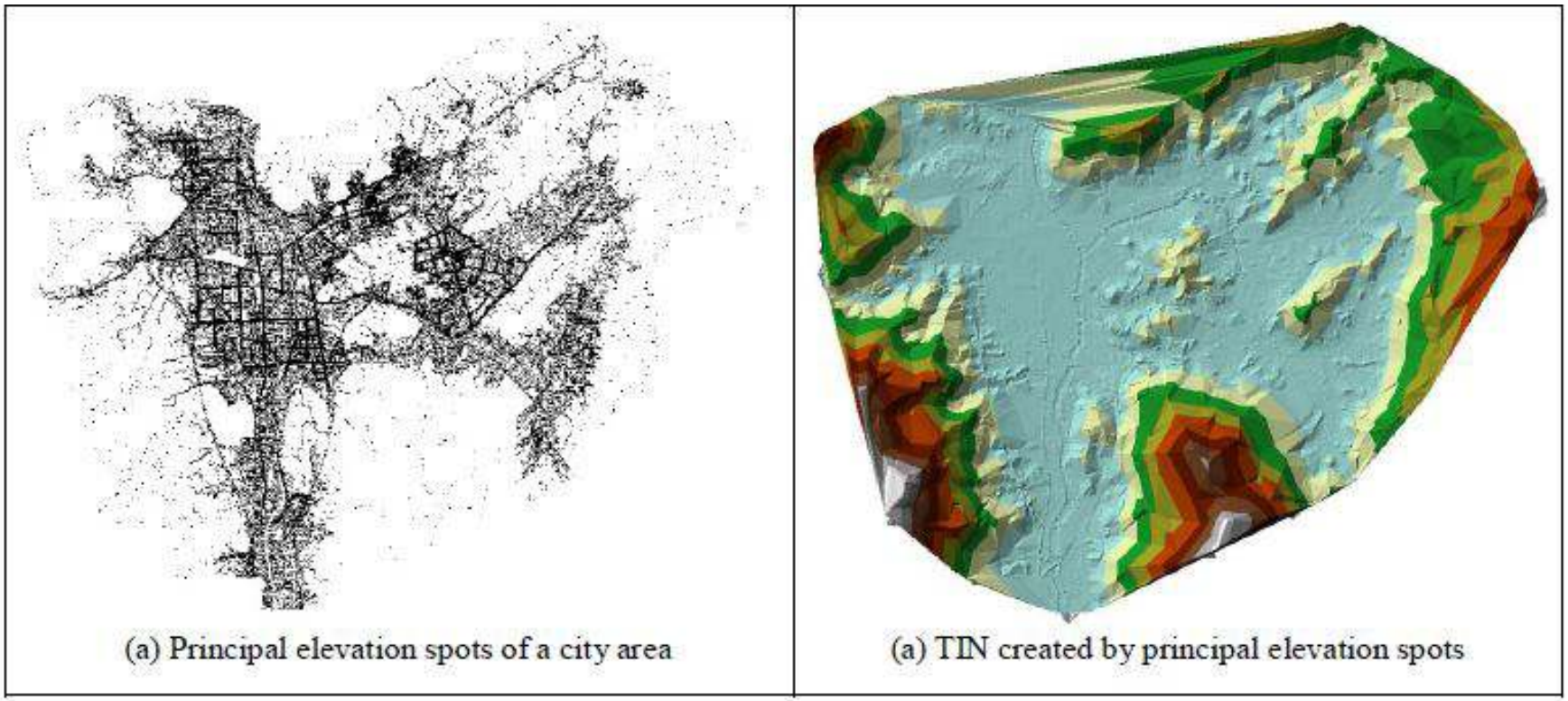
Trafficable slope

<Degree of maximum slope for vehicle types and road surface conditions>

Road surface condition i	Maximum slope for vehicle type j in degree			
	Passenger car	Van	Bus	Light truck
Battered snow	13.50	14.42	15.34	13.50
Non-battered snow	8.53	9.13	9.73	8.53
Snow and ice, covered with the snow, which has just fallen	10.20	10.92	11.62	10.20
Snow and ice, mixed with sand & Slush	8.53	9.13	9.73	8.53
Snow and ice	6.84	7.33	7.81	6.84
Snow and ice before crossroads	5.14	5.51	5.87	5.14
Dry asphalt in winter conditions	30.54	32.30	33.99	30.54
Asphalt, covered with hoar-frost	25.64	27.22	28.75	25.64
Smooth ice	3.09	3.31	3.53	3.09
Ice and tires with chains	6.84	7.33	7.81	6.84
Black ice	6.84	7.33	7.81	6.84

Slope of roadway segment

<CAD drawing data and TIN based on principal elevation spots of a city>

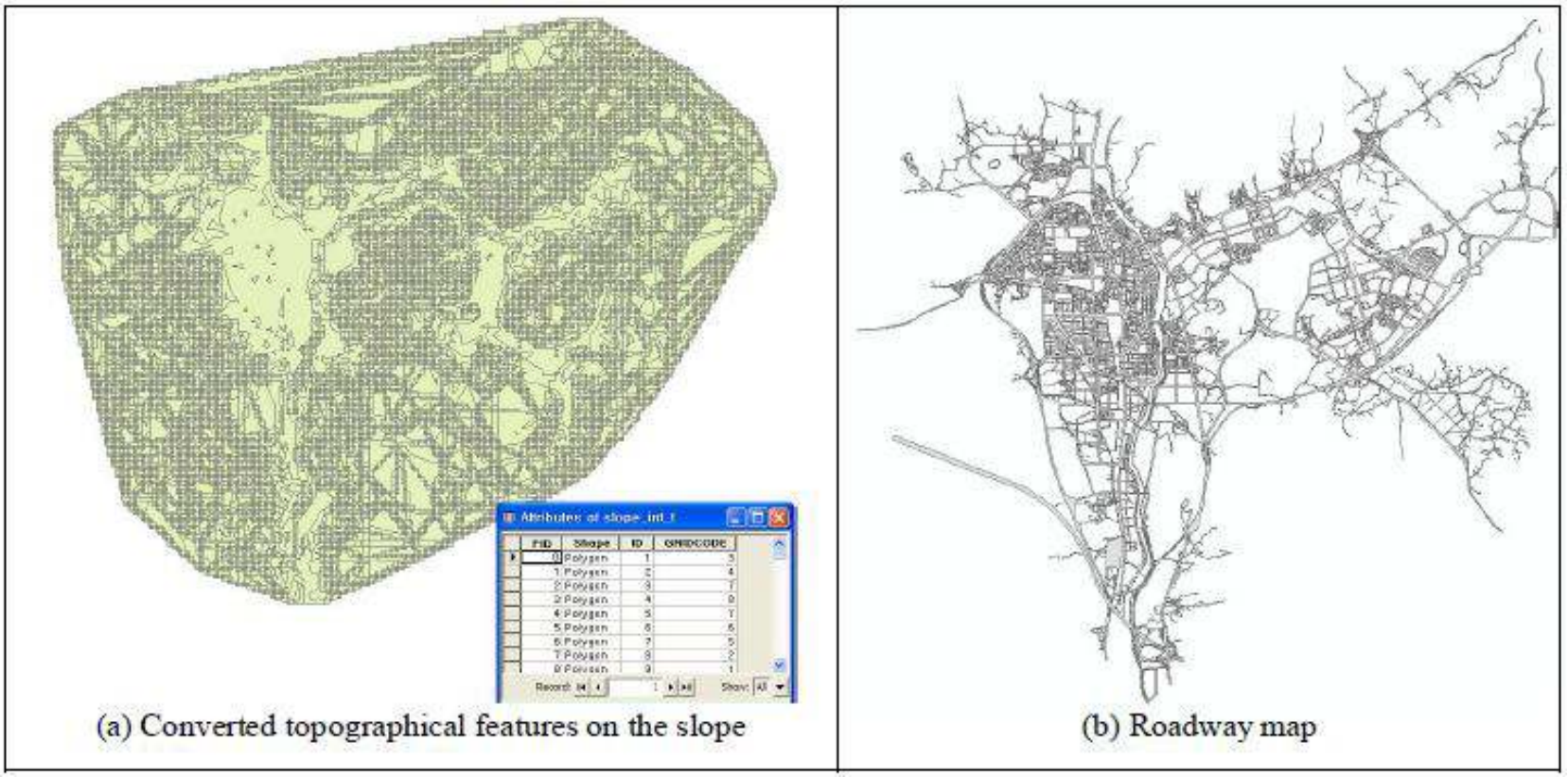


(a) Principal elevation spots of a city area

(a) TIN created by principal elevation spots

Slope of roadway segment

<Topographical features on the slope and roadway network of a city area>

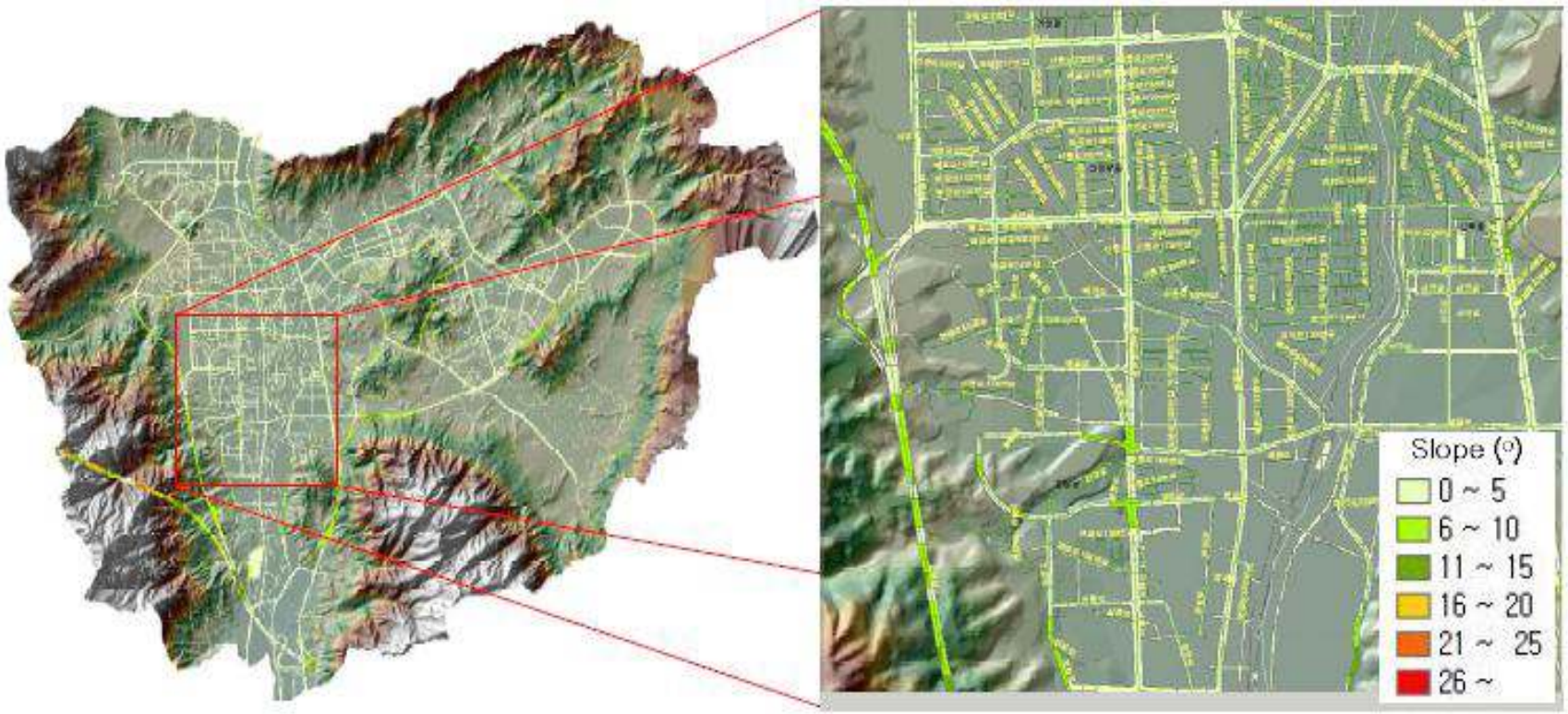


(a) Converted topographical features on the slope

(b) Roadway map

Slope of roadway segment

<Roadway slope map with small segments>



Trafficable index

- To deliver the trafficable slope as traffic information in real-time or in advance based on weather forecasts, use 'trafficability index' which includes the concept of the probability for decision making

$$TI_{ijk} = 1 - \frac{\tan(\theta_k)}{G_{\max(i,j)}}$$

$$if\ TI_{ijk} \le 0$$

The travel of the associated vehicle on the road segment k is impossible

$$if\ 0 < TI_{ijk} < 1$$

The travel is probabilistically possible

$$if\ TI_{ijk} = 1$$

The travel is possible

Concluding Remarks

- Presented a procedure to develop a trafficability index as a countermeasure of the safe driving and safe traffic operation in winter
- The presented parameter values can be constructed through the field test and the presented procedures
- Useful to determine whether or not the Road Administration and the road management officials close the associated roadway section when snowfall event occurs
- Drivers can detour their initially planned route or prepare special equipment when delivered such an index as traffic information

4. CONCLUSIONS

Proposed policy with this results

- Be expected to be used by drivers who are planning winter vacations in the nationwide road networks
- Be expected to be minimized by evading snowfall-expected sections where travel is impossible and by modifying their travel schedule for the case of the logistics industries

Limitation

- Only focused on the trafficability in uphill sections
  - ➢ Need a future research about the diagnosis on the issues associated with the loss in braking ability in downhill sections
- Need an in-depth study considering braking ability and performance of a vehicle

Thanks! Any Questions?