Siberian winter roads on the frozen river and ponds, as public goods depending on the local environment

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Socially, transportation route has been considered as the most typical public goods to be collectively owned and managed. In the severe frozen climate of Siberia, frozen surface on the rivers, ponds and marsh are used as transportation route in winter, instead of building bridges or other kind of solid transport route. Local people use the tacit knowledge for the safety of the ice, but such tacit knowledge is not based on scientific basement, but on the empirical knowledge accumulated by try and errors. However, global warming would change the locations and periods of the usability of the service, and make the tacit local knowledge unreliable soon. This paper discuss the possible scientific and technological topics to expand the availability of the Siberian winter road system, planned to be proceed as one of the RIHN Siberia Research Project.
Keywords: Siberia, Sakha Republic, transportation, ice, cold weather

1. Road network in Yakutia in East Siberia

Siberia spreads for 2,500 km from the Arctic Ocean to the south border with China and Mongolia, and for about 8,000 km from Ural mountains to the Bering Strait. The density of transport system is very low. In the winter, the temperature falls to -50 °C and the water transportation becomes impossible because of the freezing of the big river, but the ice of one meter and thicker can support a vehicle. Then *AbtoZimniki*, the winter road in Russian, is settled on the frozen river in winter, as drawn by the broken lines on the map (figure 1).

There is national highway of 22,000 km in the Sakha Republic, and the two third of it is actually the winter road. Around Yakutsk, a winter road is used for about 6 months from early November to late April in the following year. The road paved by asphalt in Sakha is only 623 km, 3 % of the total highway length. In this area, the asphalt become soft in the summer, when the temperature exceeds +30 degrees Celsius. Heavy traffic kick out a macadam in the pavement and makes halls and cracks in the pavement. The crack are widened in winter, by the pressure of freezing water, and new cracks were made. Therefore, the asphalt pavement requires large amount of maintenance cost as well as construction cost. Recently, a vinyl sheet is inserted between the pavement and the roadbed and prevents penetration by water, but it can not be widely used because of cost problem. The remainder of 6,900 km is unpaved road in earth. It become a rough road in summer when the earth layer around 1.5m deep on the permafrost melts to be muddy.

Figure 1 is the transport network map of the Sakha Republic. In the symbol legend of the map, the first orange line is the ordinary road of year-round use, and green line of the second is a winter road. There are several marks of a ship at river harbors, many of them cannot be reachable from the capital city, Yakutsk in winter, unless you the winter roads.

2. Two types of the winter road

Even in the full season road continuously drawn in orange in figure 1, there is no bridge on the point crossing a big river, then they must use ferry service. For example, there are no bridge over the Lena river, the winter road provides much easier crossing transportation. Figure 2 shows an aero-photograph of the winter road which is crossing the main stream of the Lena river of 900 m width of a river, at about 15 km

Figure 1 Transport network of the Sakha Republic in East Siberia.

Figure 2 Aero-photograph of the Lena River, south of Yakutsk (Google Earth)

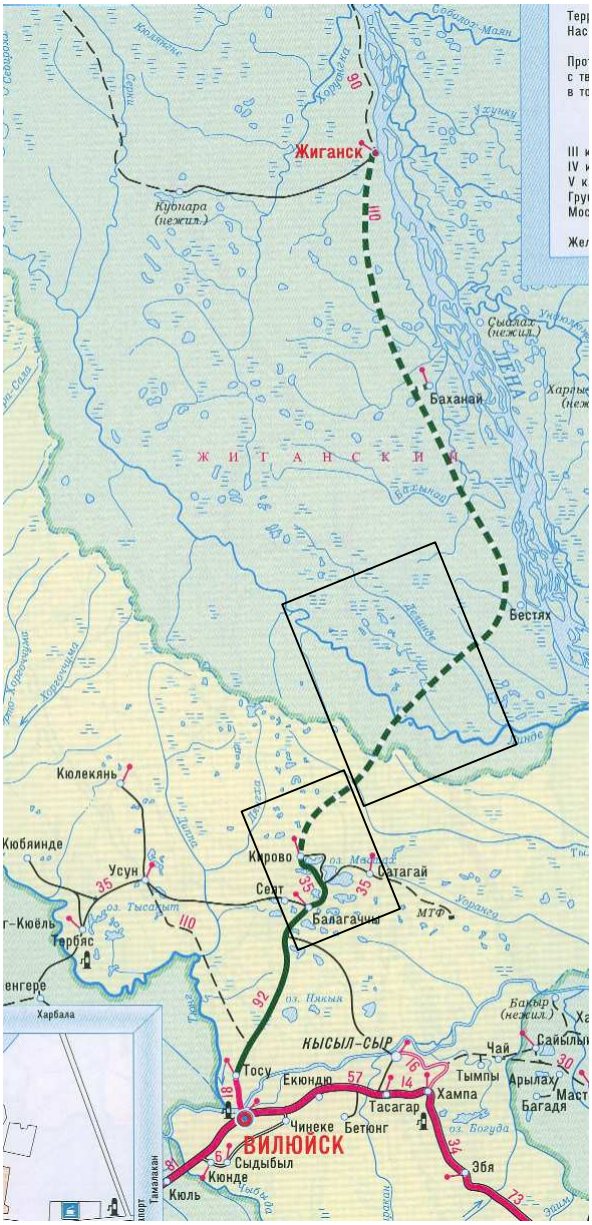

Figure 3 A road map near Zigansk, downstream of the Lena River

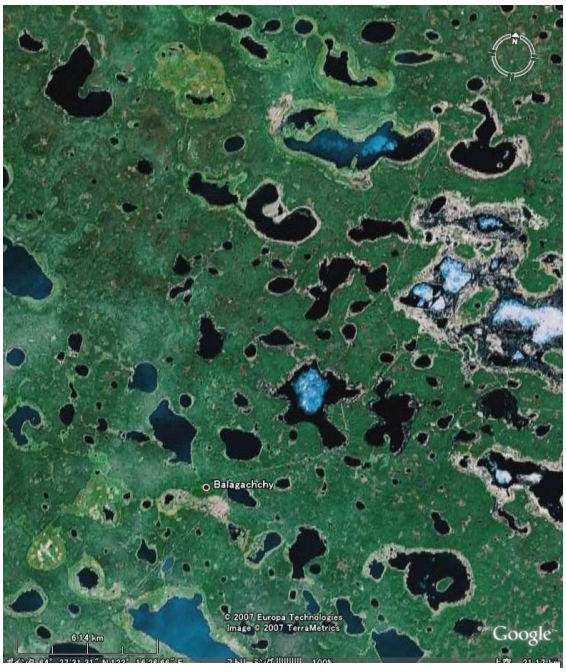

Figure 4 Ponds of alass (Google Earth)

Figure 5 Meandering river, Linde (Google Earth)

upper stream (south) from Yakutsk. In winter, the snow on the ice surface was removed, then the crossing route is shown blackly in the photo.

Figure 3 showed an example of another type of the winter road -- inland penetrating road. The map shows a road section heading to Zigansk by the Lena river, about 600 km downstream (north) from Yakutsk. The road on can be set straight only in winter, because many obstacles are there in summer, as shown by Figure 4. There are many shallow ponds centered in hollows, named *alass*. This thermal karst is very unique geographical feature in taiga forest on the ground of permafrost. Once tall trees are fallen down due to wild fire or other reasons, increased sun beam stimulate the melting of permafrost layer, and weaker sustaining power for trees. Further falling down of trees makes a spot of stronger sun shine and stimulates the melting of the permafrost, and results in a hollow with small pond. Furthermore, there are very complicatedly meandering small rivers like Figure 5, it is not easy to pass in the summer.

3. The public goods dependent on the climate

As above mentioned, in the Sakha republic, year around service of the ordinal road transportation is difficult and the winter road system plays a big role. Before the Soviet Union collapses in 1991, necessary living goods and

essential foods were lift by helicopters to the settlements and villages under the responsibility of the federal government. Such money-consuming way becomes impossible after the federation collapse, then the existence of small rural villages now strongly depends on the winter road system.

The winter road system around Yakutsk were available for six months, from November to April. But for particular purpose, the season for transportation is limited more shortly. For example, the maintenance of the electric power-transmission wire in rural area must be scheduled in winter, considering the transportation of materials and construction vehicles. Furthermore, they can not set field work between December and February, when the temperature becomes less than –40 degrees, if considering the risk to the workers' life in case of breakdown of vehicles in rural area. As a result, the electric power company *Sakha Power* plans all maintenance work in the three months; November, March and April. Another example is road construction work. They carry pavement material such as macadam beforehand through the winter road, but the asphalting pavement work must be waited until the temperature to exceed +5 degrees Celsius.

The winter road system have been used based on the empirical and local, rather than based on scientific knowledge. Officially, the special commission composed of the specialists from the Department of Transportation, Police, Road construction, Water navigation, as well as Emergency Department, decides the officially permitted dates of use, based on whether the measured thickness of ice is larger than one meter or not. In these years, the official opening date for vehicles under one ton is fixed on December 20th, and for heavier vehicle on January 1st, and two or three days suspension are sometime ordered. However in reality, many vehicles begin to use much earlier than those dates.

In the spring, many users are found by early May, after the formal ending date in April, and dropping accidents from the broken ice are frequently occur.

Many transportation planning textbooks begin with defining the three essential component of transportation; transported content, vehicle, and traffic route. Among these, the transported content indicates the goods to be transported and the human to want to make move. Historically, the needs of goods transportation strongly depend on the season, especially in case of agricultural and natural products. On the other hand, the sailboat which used the wind of the nature for vehicle of large-volume freight transportation, then the availability of vehicles were also strongly limited by seasonal climates. For example, the *Kitamae* coastal shipment in 17-19 centuries in Japan was dependent of the seasonal winds only available in the limited months.

As for the winter road system of Siberia, traffic route, the third element is strongly limited by the climate conditions. Therefore, transportation planning must be designed to meet the seasonal limitations of the three transportation elements. However, regrettably, the modern traffic planning theory does not concern such a seasonal change, rather calculates the average traffic. It is because the theory has been developed with the needs to solve the daily congestion problem in urban planning, where seasonal variation is not so important compared to the capacity shortage. They try to build so large scaled facilities as not to be affected by natural conditions. Once the facilities are completed, the prepared capacity are tried to be used up. In other words, the time where there is little demand, they discount the shipping fare and gather cargo. That system is considered as efficient one from the economic point of view, but not always so from the ecological and environmental point of view. They consume much energy and expense the natural environment in order to transport the goods, not necessary at first.

4. Possible effects of global warming

Siberia is one of the areas which are strongly influenced in the global warming. For example, the rise of the average temperature from 1975 to 2000 is 0.5 degrees in Celsius in the world average, but 2.5 degrees in Yakutsk. Expectation of the average temperature rise in Siberia in the report of 4th of IPCC reaches 1.5 degrees in 25 years, and century rise becomes 5-6. Winter precipitation is considered to increase, while decreases in summer.

Rivers may still freeze up under such climate changes, but the time of the freeze and the melting may strongly change.

As stated before, there are several works depending on the winter road system, which can be done only the limited time in the severe climate in Siberia. Global warming in the future may change the time of the freezing and melting of the ice on river, then requires the adjustments of work and life schedule of the people. The local empirical knowledge concerning on the winter road will loose the applicability soon. We must provide an alternative knowledge and technology based on more explicit and scientific knowledge.

5. Research Issue and the RIHN Project

Here we suggest some of the technologies to be developed for the winter road system in the year of global warming.

Firstly, development of transportation planning technology is required, which includes a middle-term meteorological expectation of melting dates in spring, based on the precipitation and temperature measurement in autumn. Another technology is expectation of the freezing date based on the rainfall in summer and river flows in autumn. Those methods must the model of the outflow and the heat exchange based on the hydrology and the statistical knowledge.

Second topic of scientific guidance concerns on the place of the river crossing. The safety of the ice road is much depend on the river flow. Wider place gives slower flow in autumn, then more stable ice grows. In spring, such wider places get the smaller variation of water level by increased flow due to the melted water from south upstream area. As a result, ice in such a wider place are kept more stable also in spring, then the most desirable place of the ice bridge is not always same as the best iron bridging, that is narrow place. In order to build the technology to find the better location of crossing, studies of the physical process of freezing and melting, as well as the flow dynamics must be collaborated.

Thirdly, the measurement of the thickness of ice is very important technology. The radar measurement technology is promising to give the short term alerting or limiting the passage of heavy vehicles, connected with the mechanical assessment of the strength of ice.

In 2008, a new research project of five years entitled as Global Warming and the Human-Nature dimension in Siberia – The social adaptation to the changes of the terrestrial ecosystem with an emphasis on the water environment – at Research Institute for Humanity and Nature, Kyoto. This interdisciplinary project gathers researchers having both the natural and human science perspectives. You may agree that the winter road system in Siberia is the problem which perfectly match to the purpose of the RIHN project. That is why my research on the winter road system is included as one of research topics of the Group 3 in the RIHN project.

However, the present information about the system is very limited; what I have been written is gathered by the interview in autumn 2007, which is supported by the pre-research for the RIHN project. Another research trip in May 2009, just after this symposium is expected to be a good occasion to gather several information and data, including the video movie of the traffic. I sincerely want to have another occasion when I can display further findings in near future.