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Original article

An Economic Analysis of Container Shipping through Canadian Northwest Passage*

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Abstract

Over the last 30 years the extent of sea-ice covering the North Pole has declined about 15～20% on average, and it is expected that by the end of the 21st century, vast areas of the Arctic Ocean will be ice-free during the summer season, thus, increasing the possibility of ship navigation across the Arctic Ocean.

In this paper, we have developed a model of shipping for the Northwest Passage (hereinafter NWP) in northern Canada to determine whether ice thinning will make this route more economically viable when compared with the Panama Canal. Among the 7 routes of the NWP, Route 2 and Route 3 offer better navigational conditions than the others. However, Route 3 has a depth limit of only 10m, so here we use Route 2 which is suitable for deep draft navigation to carry on our analysis. Container ships of 4,500～15,000 TEU under Hub and spoke mode, container shipping between Busan port and New York port is simulated for the Panama Canal and the NWP.

This paper considers Canada's sovereignty in matters of navigation over the waters at the Arctic Archipelago, in the form of a toll fee for passage usage. We concluded that the NWP has an advantage over the Panama Canal if it is open for free international passage, regardless of ship size. However, if it is not free, its advantages depend on its toll fee. The lower the toll fee is, the more advantages the NWP will boast.

Keywords: the Northwest Passage (NWP), the Panama Canal, Container shipping cost, Economic Analysis

* This paper is arranged according to the doctoral thesis presented to Mokpo National Maritime University in 2013.

I. Introduction

Affected by the global financial crisis, global economic growth has slowed down a lot. Meanwhile, the supply of maritime transport continues to increase due to ship size expansion. With fewer cargos, competition among shipping companies has become much fiercer. In the face of the increasing oil price, the matter of how to reduce transportation costs has become an urgent task for every shipping company.

Asia and North America are in the top 3 world trade areas. Cargoes between them are mainly shipped through the Panama Canal. In 2002, 332,000,000 PC/UMS (the Panama Canal/Universal Measurement System) tons of cargo went through the Panama Canal and out of those cargoes about 38.8% came via the Asia-Eastern USA trade route. However, the largest ship that can go through the Panama Canal is 195.1m long, 32.6m wide, and 12m craft depth. Besides, with much more usage, ships now have to wait for a longer time and are required to pay a higher transit fee to use the canal.

On the other hand, since 1970, the Arctic sea ice has been dissolving at an average rate of 74,000km^2 annually as a result of global warming. The Arctic Council anticipated that perhaps as early as 2015, an ice-free Arctic Ocean is possible for a short period in summer. Falkingham J's(2004) global climate models predicted ice free summer seasons possibly by as early as 2050 and probably ice free all year round by 2100 if the current warming trend continues.

If the Northwest Passage (NWP) is open for shipping, the route between Northeast America and Northeast Asia will be much shorter. Consequently, more attention has been given to the NWP as a potential transit route. However, the question is whether it will be more economical than moving cargo via the traditional and well-established Panama route.

In order to deal with this question, we considered the possible routes of the NWP and compared their benefit value to choose the most economical one. Also, as the sovereignty of the NWP is still uncertain, a possible toll fee for using the NWP has been talked about to give some help in making the right choice.

II. Literature review

2.1. Ice-free possibility of The NWP

In 2001, The United States Adaptive Recreation Center (USARC) declared that the arctic ice in the NWP will disappear by 2050, and ships will be able to go through this route even without an icebreaking service. Intergovernmental Panel on Climate Change (IPCC) report (2007) used 15 models to simulate the ice conditions of a typical September in the Arctic Sea. It concluded that the arctic ice has been melting at a quicker speed than the results of all the models, and that in fact, the NWP may have an ice-free summer by 2050. Also according to Corbett et al. (2010), about 2% world trade cargoes will use the NWP in 2030, and the percentage may go up to 5% by 2050.

2.2. The NWP's Economic Analysis

Saran Somanathan and Jozef Szymanski(2006) simulated container shipping from Yokohama to New York, St. Johns and Newfoundland through the NWP as opposed to using the Panama Canal to see whether ice thinning makes this route more economical. It concluded that more round trips per year can be completed for all the routes, and continued ice thinning will further reduce the shipping cost.

The INSROP Simulation Study has developed a model for numerical simulations of the time and costs using different ship types (25,000DWT, 40,000 DWT, 50,000DWT bulk carrier), different routes (the Northern Sea Route and the Suez Canal) and at different times of year. It concluded that the NSR is a more favourable option than the Suez Canal for a ship size of 50,000DWT.

2.3. Dispute on NWP sovereignty

Canada and the United States hold different opinions on the sovereignty of the NWP. Canada claims that the NWP, especially those in the Canadian Arctic Archipelago, are internal waters to Canada. So Canada has the right to prohibit transit. However, most maritime nations, including the United States and those of the European Union claim that the NWP is an international strait. In this case, Canada would have the right to enact fishing and environmental regulation, fiscal and smuggling laws, shipping safety laws, but would not have the right to prohibit transit.

III. Current situation of the NWP

3.1. The NWP Definition

With an area of about 14 million square kilometres, the Arctic Ocean is the smallest of the five oceans on the planet. It is enclosed by the landmasses of Russia, the USA, Canada, Greenland and Norway, with access to the Pacific Ocean through the Bering Strait and to the Atlantic Ocean predominantly through the Greenland and Barents Seas.

There are two routes connecting the Pacific Ocean and the Atlantic Ocean. That is, the Northeast Passage (hereinafter NEP) and the NWP (see in Fig. 1).

The NEP, also called the Northern Sea Route (NSR), is made up of all the marginal seas of the Eurasian Arctic, such as the Chukchi, the East Siberian, the Laptev, the Kara and the Barents Seas. The NSR makes up approximately 90% of the NEP.

The NWP runs between Greenland and Newfoundland in the Atlantic Ocean, and along the northern coast of Canada and Alaska, ending in the Bering Strait. The Bering Strait is an 85 km wide strait separating Russia and Alaska between the Arctic Ocean and the Bering Sea (part of the Pacific Ocean).

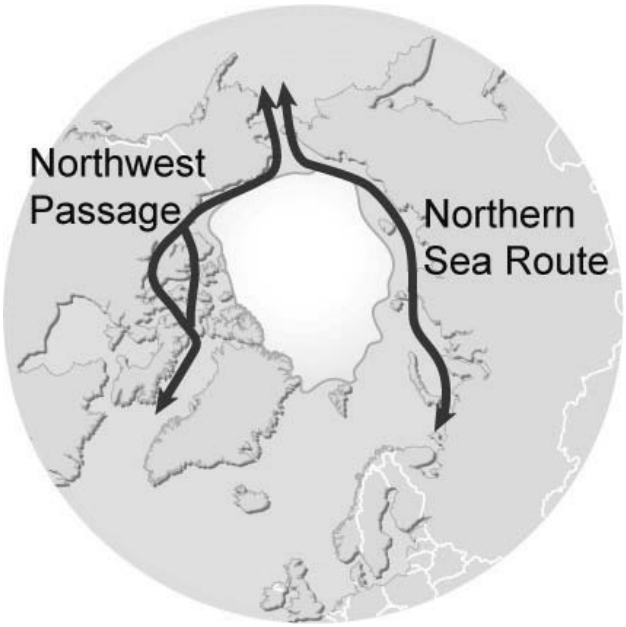

Figure 1: The North Sea Route

Source: http://eatingjellyfish.com/?tag=northwest-passage-ownership

3.2. The NWP routes

The NWP lies within the centre of the Canadian Arctic Archipelago and is in fact part of a collection of possible routes through the Canadian Arctic. In the west there are three feasible paths: The M'Clure Strait, the Prince of Wales Strait and the Peel Sound. In the East, the passage is traditionally limited to the Lancaster Sound. The Beaufort Sea region generally becomes ice free in August-September, while in most years the M'Clure Strait is prone to being blocked with Old Ice (OI)

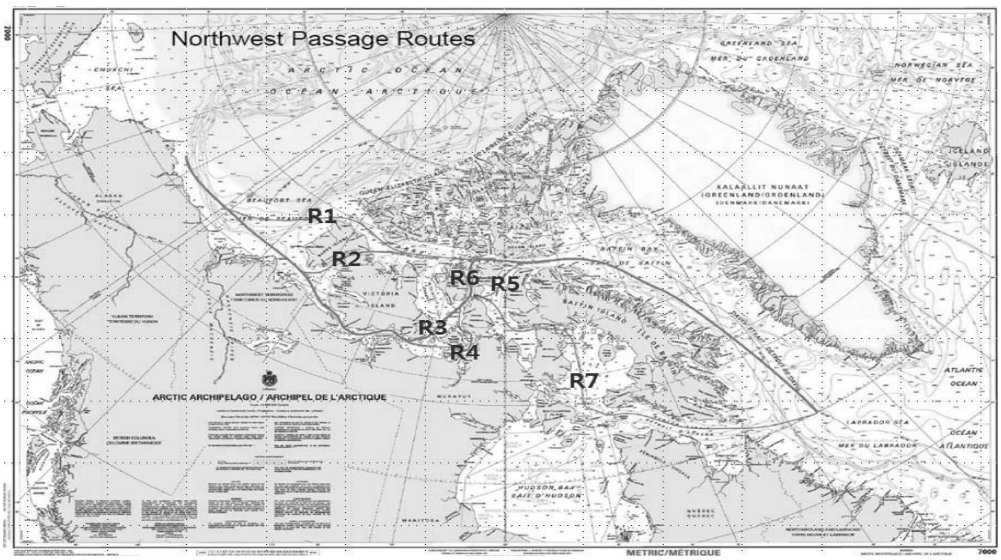

Figure 2: The NWP and Region in the Canadian Arctic

Source: download from Google

So prior to comparing the economics of Arctic transit and Panama transit, the optimal route across the Arctic sea should be determined with the consideration of transit distance, ice conditions, and water depth. Here we use the route classification about the NWP by Donat Pharand (2007) in his book named "The Arctic Waters and the Northwest Passage : A Final Revist". The routes are as shown in Figure 2.

Route 1 is the shortest one and suitable for deep draft vessels, but because of the severe ice condition in M'cClure Strait, this route is one of the most difficult ones to use. Route 2 is an easier variant of route 1, choosing the Prince of Wales Strait instead of the M'cClure Strait. This route is also suitable for deep draft vessels. Route 3 is the principal route, and usually people will consider Route 3 as the NWP. However, this route has a low depth, and only vessels with a draft less than 10m can use this route. Routes 4 ~7 share a commonality, that is, these 4 routes go through the Bellot Strait which has complex currents and is not suitable for shipping.

Table 1: Comparison of NWP Routes

Route	Advantage	Disadvantage	Business value
R1	- suitable for deep draft vessels	- severe ice condition in M'cClure Strait	×
R2	- an easier variant of route 1 - suitable for deep draft vessels		○
R3	- The principal route	- used by most vessels of draft less than 10 m	×
R4	- A variant of route 5 for small vessels if ice from McClintock Channel has blocked Victoria Strait.	- Bellot Strait: complex currents - Simpson Strait: only 6.4m deep, complex currents	×
R5	- Mainly used by eastbound vessels.	- Bellot Strait: complex currents	×
R6	- the same as R4	- the same as R4	×
R7	- Mainly used by eastbound vessels as an alternative is practicable.	- severe ice usually at the west of Fury and Hecla Strait - Bellot Strait: complex currents	×

Source: made by the authors

In summary, we think Route 2 and Route 3 have comparable value among the 7 routes. But due to the low depth, Route 3 is not suitable for international shipping, so here we choose Route 2 to analyze the NWP's economic value.

IV. Economic Model

4.1. Shipping cost model

In order to estimate whether and in which situation the NWP route is much more economical in comparison with the Panama Canal, we have modelled a shipping cost model in the shipper's position.

We suppose that there are 2 ports, Port A and Port B, and these two ports have the same handling fee and efficiency.

Let Z denote the shipping cost of a container ship in a round way. X is the container ship size. $L(X)$ is the rental fee, (T_T) is total required time to sail the route, including the required time in open water conditions(T_O), icy conditions (T_I), harbor (T_H), and canal transit (T_C), T_O plus T_I is the navigation time (T_V). $C_{FO}(X)$ and $C_{DO}(X)$ are oil consumption of fuel oil and diesel oil separately, and both are a function of ship size. P_{FO} and P_{DO} are the price of fuel oil and diesel oil separately. $CanalToll$ is the toll fee to transit the canal. ISF is the ice breaking service fee. E^A and E^B are the harbor fees. L_O is the round trip distance in open water, and L_I is the round trip distance in icy areas. $V(X)$ is navigation speed in open water conditions, and it is a function of ship size. V_I is the navigation speed in icy conditions.

$$Z = L(X)T_T + C_{FO}(X)P_{FO}T_V + C_{DO}(X)P_{DO}T_T + CanalToll + ISF + E^A + E^B \quad (1)^1$$

s.t.

$$T_T = (T_V + T_H + T_C)/24 \quad (2)$$

$$T_V = T_O + T_I = \frac{L_O}{V(X)} + \frac{L_I}{V_I} \quad (3)$$

4.2. Relative functions

As the rental fee, oil consumption and ship speed are all related to the ship size, we use data from www.clarksons.com to monitor the relationship between these indexes and ship size. Take the rental fee as an example: firstly we put all the data in excel and made a scatter diagram, and then we used adjusted R^2 to choose the most appropriate line. The figure is as follows.

So the rental fee function is

$$L(X) = -0.001x^2 + 5.9079x + 5312.8 \quad (4)$$

Likewise, we can get the functions of fuel oil consumption, diesel oil consumption and ship speed.

$$C_{DO}(X) = -2E-07x^2 + 0.0036x + 18.841 \quad (5)$$

[1] For this equation, there is no ISF when using the ordinary route. And when using the NWP, $CanalToll$ is a supposing probable factor here. This will be talked about in detail in the next part.

$$C_{FO}(X) = 3E-06x^2 + 0.0162x + 16.507 \quad (6)$$

$$V(X) = 3.6594 \ln(x) - 7.0282 \quad (7)$$

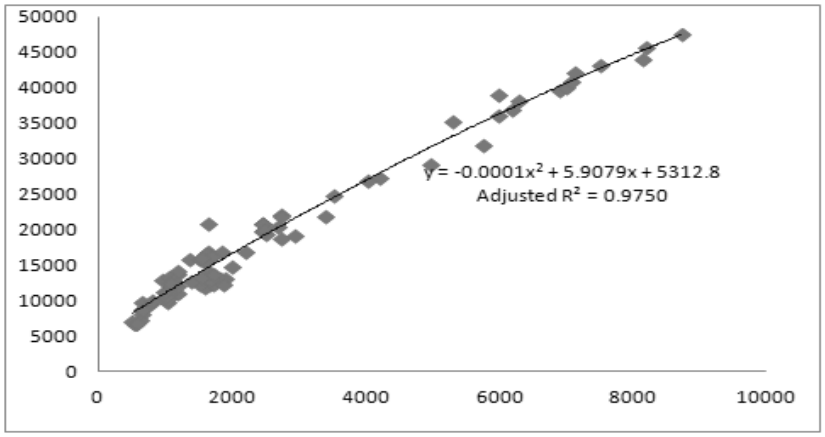

Figure 3: The relationship between L(X) and ship size

Source: Made by the authors

V. Comparison analysis between the NWP and the Panama Canal

5.1. Model data

We chose Busan port and New York port as the two points in our paper. As route 2 has enough depth, we set the ship size from 4500 to 15000 TEU. Suppose the working time in harbor is 24 hours, so in a round way, the required time in harbor is 96hours, that is $T_H = 96$h. And ship speed in icy conditions is supposed to be 10knot/h. With reference to oil price changes from June 2012 to May 2013, we set the fuel oil price and diesel oil price to be \$640/mt and \$960/mt respectively.

Falkingham et al. (2001) caution that potential marine hazards may still arise because of the rapid rate at which sea ice is dissolving due to warmer climates. This gives way to the increased likelihood of hull-penetrating, high-latitude multiyear ice(MYI) flowing into the NWP shipping lanes. He pointed out two possible chokepoints, one is in the Viscount Melville Sound and the other one is in the M'Clure Strait. In this paper, we define that the ice-shipping service should be used from the eastern end of the Parry Channel to the eastern end of the Prince of Wales Strait. The distance between them is 576nm according to Google Earth's "Ruler" function.

Table 2: Distance between Busan port and New York port

(unit : nautical mile)

Distance	The Panama Canal	The NWP(Route 2)	
Busan-New York	10,129	Open water distance	Ice condition distance
		7034	576

Source: Made by the authors

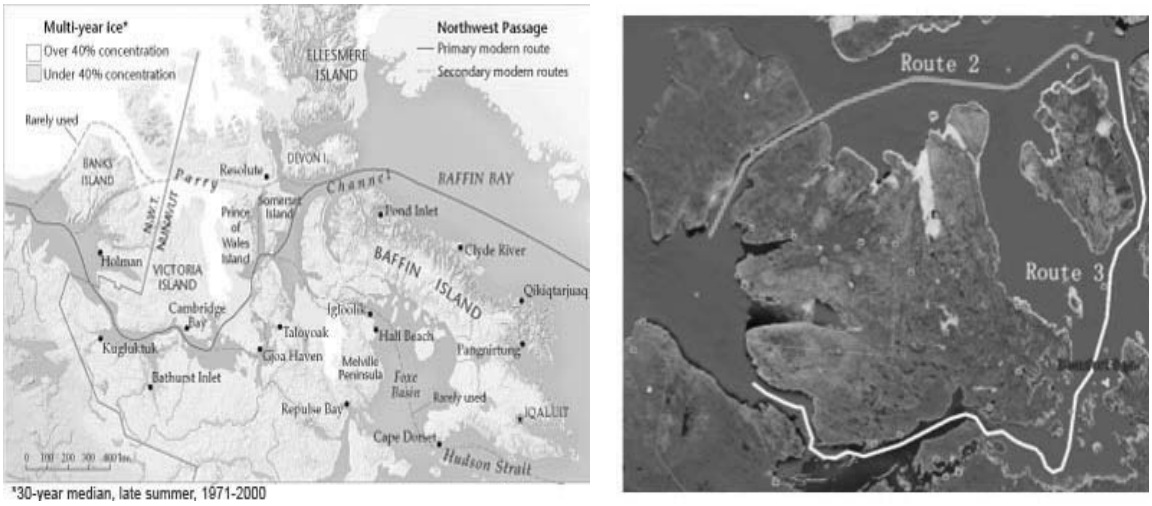

Figure 4: Parry Channel from Macnab(2004), left, and the distance using ice shipping service, right

Source: the left one is from Google and the right one is made in the google earth

According to Ragner(2000), icebreaking service fees on the NSR do not depend on the number of days of icebreaker support, and could be as low as $5US per long ton while still covering operating costs. This is also used in this model. As '1 TEU =21 Long ton' is satisfied, when using the icebreaking service, the container ship with the size X should pay $105X$ one time.

$CanalToll$ is the fee paid by ships to use the Canal. In general, tolls are determined by the ship measurement parameters. Now the Panama Canal basic fee is $74 per TEU, and a $8 is added for full containers. As we suppose that container ships will be always full, the Panama Canal fee is to be 82X.

$$Z_{PC} = L(X)\frac{1}{24}[\frac{20258}{V(X)}+144]+C_{FO}(X)\cdot 640\cdot\frac{20258}{24V(X)}+C_{DO}(X)\cdot 960\cdot\frac{1}{24}[\frac{20258}{V(X)}+144]+82X+E^A+E^B \quad (8)$$

$$Z_{NWP} = L(X)\frac{1}{24}[\frac{20258}{V(X)}+144]+C_{FO}(X)\cdot 640\cdot\frac{20258}{24V(X)}+C_{DO}(X)\cdot 960\cdot\frac{1}{24}[\frac{20258}{V(X)}+144]+CannalToll_{NWP}+105X+E^A+E^B \quad (9)$$

5.2. Situation analysis

There is a conflict about who owns the NWP. The key point in this conflict resolves around the Lancaster Sound, which lies in the eastern entrance to the NWP.

The Canadian government, in accordance with the provisions of UNCLOS (United Nations Convention on the Law of the Sea), claims that part of the NWP, especially the part that lies in the Canadian Arctic Archipelago, is to be their territorial waters or internal waters. They claim that they have sovereignty and jurisdiction over that area by drawing straight baselines around the outer edges of the archipelago. This gives them full control over what is called "transit passage and innocent passage" and requires that all vessels, aircraft and persons on board comply with Canadian domestic law.

Figure 5: the area with sovereignty conflict

Source: http://eatingjellyfish.com/?tag=northwest-passage-ownership

On the other hand, the U.S. and other countries dispute this claim and argue that the NWP is an international strait and a transit passage should be permitted. This means that Canada would still have certain jurisdiction over the waters in matters such as fishing and environmental regulations as well as over laws intended for the safety of shipping, but the Canadian government would not be able to hinder ships or to close the passage.

5.2.1. *The NWP is open for international passage*

If the NWP is open for international passage as the U.S. claims it should be, transit passage is possible in the Canadian Arctic Archipelago. $CanalToll$ of the NWP will not exist and is considered to be zero. Therefore, difference for the shipping cost of a container ship between the NWP and the Panama Canal can be written as the following equation (10).

$$\Delta Z = Z_{PC} - Z_{NWP} = \frac{1}{24}[\frac{6190}{V(X)} - 115.2] \cdot [L(X) + 640C_{FO}(X) + 960C_{DO}(X)] - 23X \quad (10)$$

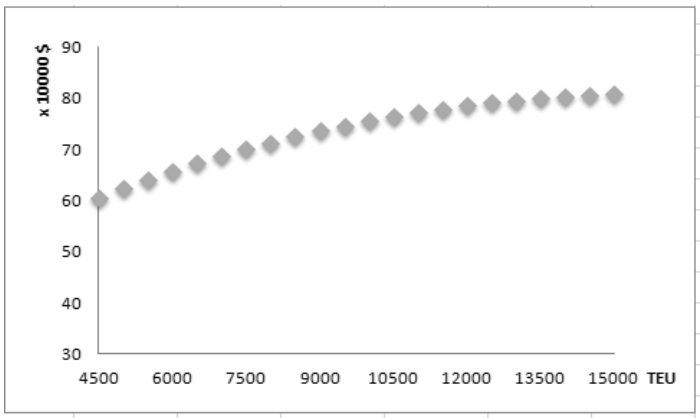

Figure 6: △Z's result when the NWP is open for international passage

Source: Made by the authors

With regard to this situation, the NWP is a far more advantageous route than the Panama Canal, by at least 600,000 dollars. With the increase in ship size, this advantage becomes even more apparent. So it is not difficult to see that in the pursuit of larger container ships, the NWP will attract more shipping companies' attention.

5.2.2. *The NWP is open subject to a toll free within Canada*

If the NWP is subject to be toll free only within Canada, and the Canadian government poses the same Canal transit fee as the Panama Canal, difference for the shipping cost of a container ship between the NWP and the Panama Canal will be like equation (11).

$$\Delta Z = Z_{PC} - Z_{NWP} = \frac{1}{24}[\frac{6190}{V(X)} - 115.2] \cdot [L(X) + 640C_{FO}(X) + 960C_{DO}(X)] - 105X \quad (11)$$

We can see that with the increase of container ship size, the NWP's advantage becomes smaller. Especially for the ships larger than 9,000TEU, the Panama Canal becomes more economical than the NWP. In other words, if Canada wants to put taxes on the NWP in the same way as the Panama Canal in order to get more transit incomes, considering the severe icy conditions in the North Sea, ship companies may instead choose to use the traditional route.

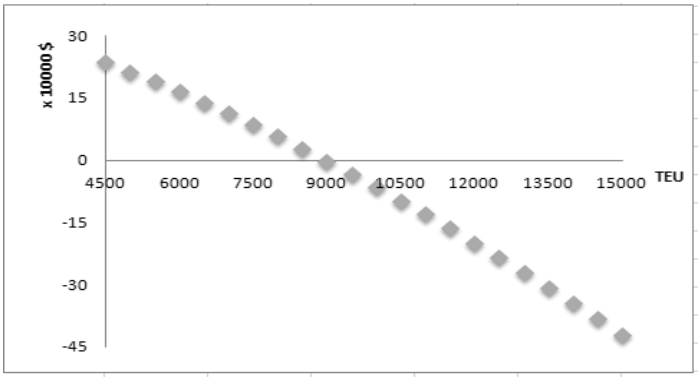

Figure 7: △Z's result when the NWP is not open for international passage

Source: Made by the authors

So if the NWP is open and toll free only within Canada, how should the Canadian government set the toll fee for the transit ships? Here we let the relation of toll fee between the NWP and the Panama Canal is as follows:

$$\text{Cannal}Toll_{NWP} = \lambda \text{Cannal}Toll_{PC} = \lambda \cdot 82X \quad (0<\lambda<1) \quad (12)$$

λ is between 0 and 1, when $\lambda = 0$, it means Canada will not put any toll fee on this route, and when $\lambda = 1$, it means Canada will put the same toll fee as the Panama Canal.

So the Equation can be written as follows,

$$\Delta Z = Z_{PC} - Z_{NWP} = \frac{1}{24}[\frac{6190}{V(X)} - 115.2] \cdot [L(X) + 640C_{FO}(X) + 960C_{DO}(X)] + 82(1-\lambda) - 105X \quad (13)$$

With the smaller 'λ', the NWP is far more economical than the Panama Canal. Therefore, in order to attract more shipping companies' interest, the Canadian government should set its transit fee to be at least 40% lower than the Panama Canal.

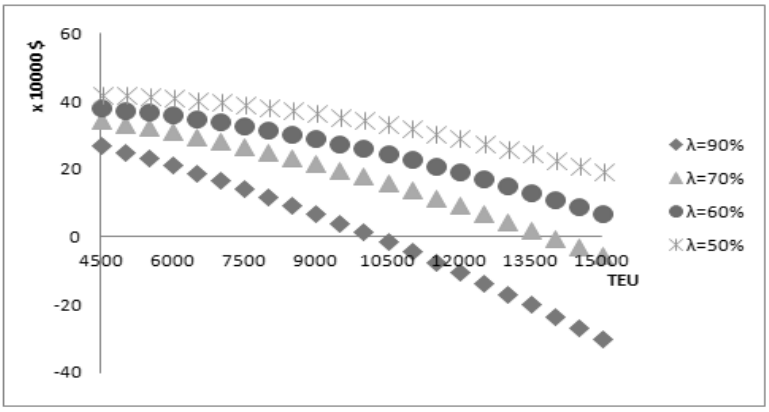

Figure 8: △Z's result with changes in the NWP toll fee

Source: Made by the authors

VI. Conclusions

Ice cover in the Arctic is expected to continue diminishing throughout the 21st century. This trend may lead to a longer navigation season and improved accessibility for ships. This paper has used a model based approach to consider the expanded ship traffic as a result of continued global warming.

Based on the comparison of 7 NWP routes, Route 2 is chosen to simulate container shipping between the NWP and the Panama Canal with different ship sizes and different transit fee situations in NWP. The results show that whether the NWP is favourable depends a lot on its transit fee. If the NWP becomes internationally toll free, it is of course far more economical when compared with the traditional Panama Canal. But if the route turns out to be free only within Canada, the government should think carefully when setting the transit fee. Especially in the very beginning, with regard to infrastructure building and also where to get investment is a big undertaking prior to talk about the NWP's development.

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