Comment: The Current Challenges and Future of Logistics

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ABSTRACT

Logistics has been evolving by facing challenges and adopting innovation. This comment paper provides a better understanding about what will be logistical challenges in the future and how the future logistics industry will be reshaped by these challenges. The future logistics market is expected to offer great benefits for the society, for industry, for each logistics service provider, for all stakeholders, and ultimately for shippers. In the future, the logistics industry needs to design for additional parameters such as carbon emission reduction, reduced fuel consumption, lower traffic congestion, higher visibility on the cargo and information, enhanced collaboration, shared physical distribution, identifying sourcing issues, and increased logistics innovation.

Keywords: Logistics, logistical challenges, future logistics, future supply chains

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1. Introduction

Logistics has been evolving by facing challenges and adopting innovation. Historically, efficiency and effectiveness of transport have leaped by the advent of innovative ideas, such as Hanseatic League, steam engines, containerisation and lean thinking (DHL, 2016). From a customer's perspective, logistics quality is divided into market qualifiers and order winners (Hill, 1993). The former makes the logistics survive in the marker whilst the latter enables the logistics to win customer orders. Market qualifiers and winners are not static but ever changing; today's order winners become tomorrow's market qualifiers. For instance, door-to-door service of shipping companies was once a market winner, but now became a norm. Trace and tracking service saw the same destiny. Hence, logistics companies as well as any companies involved in logistics should be aware of the expectations from the market in order to successfully identify and adopt the order winners; this is the only way to survive in the near future. Moreover, in consideration of the accelerated pace of changes, forecasting future logistics trends and preparing for them will be a pre-requisite for maintaining a competitive advantage of a firm.

The term, logistics, was recognised as a military term before 1950s. It was concerned with maintenance, procurement and transport of military material, facilities, equipment and personnel. By that time, the enterprises were not aware of the importance of logistics and their departments of marketing, production and finance were fragmented with diverging aims (Ballou, 2007). This causes conflicts between logistics activities and firms' stance because of inertia of traditional way of business, a lack of comprehensive understanding of key cost trade-off, and focus on more important areas than logistics. After a decade later, firms start recognise the importance of logistics as a major means of reducing costs, which can be seen as another competitive advantage. The firms can benefit from converging their interests in logistics in several ways. Firstly, they reduced total costs by calculating the trade-off relationships between efficient logistics systems and other activities. Secondly, they changed the firm structure that effectively controls logistics. Thirdly, top management started recognising that logistics is final areas for reducing costs. Logistics became more integrated not just within an organisation but also with suppliers and customers.

It is evident that logistics is a drastically evolving market. Recent rise of Asia, especially China, and globalisation have changed the perception of manufacturers, retailers and investors, as they have noticed that global logistics networks are needed to underpin their effective global supply chains. Hence, the role of logistics service providers (LSPs) is getting salient. Uncertain global economy makes the LSPs attuned and responsive to macro environmental changes. The complexities and uncertainties inherent to global supply chains required LSPs to be more resilient by equipping greater visibility and flexibility within their operations. The emergence of information and communication technology (ICT) provided a solution to enabling firms to get a real-time access to the information from remote places thus to be more responsive to disturbances and disruptions in logistics. Logistics evolution has been achieved by effectively addressing logistical challenges in order to satisfy customer needs.

Recently, McKinsey (2015) revealed the megatrends that will have influences on logistics and supply chain management in the future global market. These encompass shifting growth patterns due to mega cities and new trade routes, shared transportation, the expansion of digital frontiers, the fiercer race for efficiency, rules and regulations to foster growth and competition, bigger organisations with M&A or partnerships and the increased turbulence due to interdependence and complexities. In addition to these, the new trend of industry 4.0 and smart factories are expected to change the shapes of logistics. The overwhelming amount of information to be generated by internet of things (IoT) will be both opportunities and threats to LSPs because a successful big data analysis and its application will decide a firm's sustainable advantages in the future market.

In these circumstances, it is imperative to understand what will be logistical challenges in the future and how the future logistics industry will be reshaped by these challenges. This article aims to cover these two questions in the following sections.

2. Logistical Challenges due to environmental changes

When forecasting the future, it is inevitable that many external environments or trends which cannot be controlled by a certain industry shape the industry. Hence, this article takes account for the external changes as well as internal or technical changes. The rapid changes of world may lead to the logistical challenges. Such challenges chiefly incorporate environmental concerns and sustainability, demanding customer expectations, and risk and complexity. This section aims to reveal the challenges owing to the environmental changes in the world.

• *Environmental Concerns and Sustainability*

Environmental issues and sustainability are a key consideration for future logistics, because transportation accounts for approximately 13 percent of world carbon emissions. Climate changes also will obtain urgency. A number of regulations e.g. Kyoto Protocol (Dec 1997), United Nations Climate Meeting, Bali (Dec 2007), Carbon Disclose Project, EU Directive on Renewable Energy (Jan 2008), and United Nations Framework Convention on Climate Change (Dec 2009) have attempted to address sustainability issues (GCI, 2008). Nowadays, firms have no option but to conduct in the most environmentally sustainable way possible, because legislation is rapidly driven that way. In 2007, The EU positioned a target of twenty percent green energy usage by 2020, whist developing countries attempt to meet a certain standard (e.g. China decided the target of twenty percent of its energy capacity from renewable energy by 2020) (SMI, 2016). In a logistical viewpoint, from April 2013, all transport companies in EU have to comply with the EU policy, which claims that they must incorporate carbon emissions data in their annual report (Lombard, 2016). On top of that, they should measure carbon output and uncover it to customers if necessary. Tracking carbon emission might be a relatively simple task compared to next issue. Probably, LSPs are required to document all types of negative impacts of transportation such as nitrogen oxide and noise so as to quantify the comprehensive impact of their transportation operations in the more distant future. Also, it should be noted that the customers may be attracted to the firms that are operated in an environmental-friendly responsible fashion in the future.

A recent Delphi survey reveals that experts see a notable growth in renewables, whilst they do not believe that a major energy is replaced by 2030 (SMI, 2016). Nonetheless, it is strongly argued that the world will find a solution to drive significant technological changes in this area by setting new regulations in a growing number of countries or in supra-international bodies. In the LSPs' stance, it might be likely that the reduction of carbon emissions is a bigger challenge over the next two decades than acquiring a sufficient supply of energy (SMI, 2016).

• *Demanding Customer Expectations*

LSPs suffer pressures of demanding customer expectation. In particular, customers demand on time delivery and guaranteed delivery date. This forces the LSPs to acquire higher predictability, agility, and flexibility. Furthermore, customer expectation pertaining to the visibility of logistics flows is heightened. Indeed, customers demand more accurate real-time information at their fingertips, implying that LSPs need to proactively utilise integrated ICT systems. Meeting such expectation is not an easy task to LSPs. It is attributed to a fact that the customers do not only demand aforementioned services, but also expect the same or reasonably low price. It is well known that the achieving cost and differentiation strategy at the same time is extremely tough.

Furthermore, the customers will have growing emphasis on green logistics and corporate social responsibility. More environmentally concerned consumers will prefer locally produced products, giving propagation to regionalisation of supply chains, and they would like to involve in control over the logistics process. It may be likely that this tremendously intervene or hinder the effective logistics process.

• *Increasing Risks and Complexities*

Risks and complexities also significantly reform the logistics and supply chain trends (Lee, Seo, and Dinwoodie, 2016; Kwak, Seo, and Mason, 2015) Political instability, terrorism and natural disasters cause global shippers' concern in regard to the buffering stocks against above risks. For instance, tsunami and earthquake in Japan in 2011 force automotive manufacturers to close their plants. This example typically shows that even the large enterprise (multi-national enterprise) is sometimes vulnerable to such risk. Thus, logistics managers require re-thinking redundancy built in and contingency planning. In fact, they are required to possess proper risk management capabilities to cope with the unexpected crisis. In this regard, LSPs are putting more efforts on collaboration with the shippers so as to handle the demand fluctuation via joint planning, execution and monitoring.

Oil price volatility can be regarded as another complex issue, even though recent media points out that oil prices are not likely to rise due to the over-supply from

OPEC countries and shale oil from United States. However, if the oil price becomes very expensive (e.g. four digit figure), it is likely that the proliferation of regionalisation of supply chains and production sites' relocation are unavoidable. Furthermore, the oil price may decline the growth of world economy and development, so such a slow global growth will have a negative impact on the demand for international logistics. Moreover, manufacturers will re-examine current locations of production sites in the developing countries in which the labour cost is cheap, as the current operation may be detrimental to their profits due to the high oil prices. On the other hand, should the oil price remain in the three digit figure range, global sourcing and logistics are still dominant to offer reasonable transport costs (SMI, 2016). Therefore, the LSPs will need to reduce future risks by identifying alternative use of energy or reducing their reliance only on oil. More fuel-efficient vehicles and equipment would also be beneficial to them.

3. Future Logistics

Often, it is argued that LSPs do not only have a few opportunities to differentiate their services, but also have a difficulty in power game with large shippers who keep asking lower rates. Nevertheless, there will be a room for them to differentiate themselves over rivals, at the same time pursuing lowest costs and efficient logistics operations. In the future, the LSPs may simultaneously achieve both cost and differentiation advantage by adopting following ways: (1) enhanced collaboration; (2) shared physical distribution; (3) identifying sourcing issues; and (4) logistics innovation.

3.1 Enhanced Collaboration

LSPs are required to collaborate with customers and with each other so as to shape the optimum supply chains, since a future logistics model may be based on multi-partner information sharing amongst various stakeholders such as customers, suppliers, manufacturers, retailers and LSPs. Here, information sharing amongst them is of paramount importance. Enhancing such collaboration via information sharing requires a new way of working together across the supply chains. With an emphasis of the integrated information technology (IT), the accumulated data can be used for a big data analysis, which helps the LSPs to implement an accurate forecast in customers' demands. It helps to satisfy the demanding customers' needs which are highlighted in the previous section, but also reduce the risks that are stressed in the prior section by preparing their services in peak times based on the customers' patterns.

In addition, today's LSPs are obsessed with the customer's demand with service-driven orientation. If the customer asks them to deliver goods to 'Hong Kong, tomorrow', they immediately identify air transport. However, in the near future, this aspect may be completely different from today. They may ask the customer as to why this transportation should be done by tomorrow. Instead, the logistics managers may suggest the better logistics planning, which fits with the customers' business patterns. By doing so, the customers are able to save the cost and maintain the appropriate level of stocks. Hence, the collaboration between the LSPs and customer (shippers) can be seen as a win-win strategy for the future.

3.2 Shared Physical Distribution (Shared Transport, Shared Warehouse, Shared Distribution Centre and Shared Infrastructure)

A large number of companies in developed countries have adopted the concept of shared physical distribution. Once manufacturers produce the goods, the goods are delivered to collaborative warehouse where a diverse range of the manufacturers keep the goods. Then, collaborative transport is undertaken via shared load planning and truck capacity from the collaborative warehouse to regional distribution centres (shared distribution centres). In general, the warehouse may be located in the edge of cities in the urban areas, whilst it can be found at the regional distribution centres in the rural area. Next, final delivery is taking place by consolidated deliveries using state-of-the-art equipment and vehicles. For instance, ECR Europe has initiated collaborative physical logistics with the aim of helping to lower the negative environmental impact of transport and save the cost. It can be argued that this strategy is very effective to save the fuel costs of vehicles regardless of aforementioned oil price volatility, whist it is helpful to afore-stated sustainability issue.

3.3 Identifying Sourcing Issues

In some developed counties, people pursue the sustainable local supplies wherever possible in order to reduce the sourcing distances. In other words, they are more likely to make more sustainable purchase decisions. This issue is related to sustainability which is described in the previous section. The LSPs will need to understand the customers' sourcing preference in the future. This may include their main customers (manufacturers or shippers) and final customers of goods in order to quickly respond to the changes of transport demands. If the LSPs comprehensively understand this phenomenon in advance, they are more likely to invest their assets such as distribution centres, warehouses, and facilities for value-added services (e.g. packing and labelling) in the right place at the right time.

In addition, as LSPs' future strategy, they should rigorously observe how the manufacturers' sourcing strategies are evolving over times, because this may significantly affect the demands for transportation and transport geography. No matter what strategies the manufacturers use for sourcing, it is apparent that lowering costs and enhancing efficiency by re-examining the location of production sites will be a major issue to remain competitive in the future. Therefore, identifying their behaviours in advance or in the right time can provide LSPs with a source of competitiveness.

3.4 Logistics Innovation

The salience of technology to LSPs cannot be overstated. For future LSPs, the pathway to profitability may lie with logistics innovation, which can be categorised into process innovation and technology innovation (Kwak, Seo, and Mason, 2015; Seo, Dinwoodie, and Kwak, 2014). These two innovation approaches can minimise the errors and differentiate the logistical capability, improving customer satisfaction. Small upfront investment onto these innovation can provide integrated additional services during warehouse management, consolidation, distribution, and handling and receiving of goods.

Technology innovation aims to enhance the integrated information system, real-time tracking technology and innovative logistics equipment across global supply chins so that it provides cutting-edge and real-time information, reduced inventory cost and high quality logistics services. It is a key variable and the means of differentiation for logistics intermediaries. The application of contemporary technologies such as GPS, RFID and ERP can effectively support risk management in global logistics practices. In the future, the range of usage of further advanced technologies such as Real-Time Locating Service (RTLS), Optical Character Reader (OCR), and Global Navigation Satellite System (GNSS) would be enlarged. Technology innovation plays an important role in exploiting economies of scale in purchasing, logistics and central distribution centres. Technology innovation helps firms to heighten labour and capital productivity and offer real-time visibility regarding the flow of cargoes and information and sales data so that firms can enhance inventory management, enlarge value proposition for final customers, and obtain an ability to rapidly respond to abnormal circumstances. Numerous technology innovations derived from technological experimentation, whilst the greater efforts aiming at improving customer value result in process (service) innovation such as agile and responsive processes against changes and creative service in the global supply chains. In addition, via the technology innovation, the LSPs may conduct big data analysis combining with logistical data. The data are accumulated by integrating the information via RFID or Electronic On-Board Recorder (EOBR) equipped in the trailer, truck, vessels and so on. As a result, they can apply such analysis into the logistics planning, performance measurement and risk management. Big data may simultaneously provide the LSPs, shippers and manufacturers with competitiveness, since they can control their human resources and assets with higher visibility, which is derived from the big data analysis. Besides, they are able to make effective strategies by grasping the customers' patterns and quickly respond to the changes of supply and demand.

Process innovation is concerned with the effective re-design and re-engineering of the logistics system. Wagner (2008, p. 222) noted that "a process innovation is the implementation of new of improved techniques, methods and procedures with the goal to continually improve the quality of a service or reduce the cost of providing a service". In terms of process innovation, by understanding how the LSPs in the supply chains transfers innovation as well as knowledge, meaningful process innovations and ultimate value for better services can be stimulated. It focuses on operational issues and processes that enhance management practices, networking, distribution, procurement and so on.

4. Concluding Remarks

The future logistics market is expected to offer great benefits for the society, for industry, for each LSP, for all stakeholders, and ultimately for shippers. Current logistics managers primarily aim to lower logistics costs, enhance logistics performance, and yield sound financial figures. Some LSPs may consider themselves as low-cost logistics providers, where the customers select them due to primarily cheap rates, whilst other LSPs put their position into innovative logistics providers equipped with cutting-edge technology to provide highly sophisticated real-time control of the cargoes' flows. In the future, the logistics industry should design for additional parameters such as carbon emission reduction, reduced fuel consumption, lower traffic congestion, higher visibility on the cargo and information, enhanced collaboration, shared physical distribution, identifying sourcing issues, and increased logistics innovation. The influence of such parameters are getting more important in the coming years than today. Logistics managers may need to plan the strategies based on the priority to these parameters. Consumer demand and awareness for these new parameters to employ new practices might be another source of competitive advantage. Furthermore, it should be noted that using a big data analysis based on accumulated data through the integrated IT system amongst various stakeholders is of paramount importance. By doing so, the LSPs are able to set a feasible and accurate plan so that they can reduce the risks involved and respond to expected demand in advance. It is also a core determinant factor to satisfy their customers by having robustness and resilience in response to any upcoming unexpected events.

The logistics managers should possess the insights into the development of future logistics that effectively responds to and satisfy tomorrow's customers in a sustainable and green way. They must not only pursue the efficiency, but also understand the potential of logistics innovation and collaboration. Finally, it should be noted that to effectively prepare the future logistics, logistics industry has to consider how to attract more trained and intelligent staff. It is important to appropriately train and develop the staff's capability to absorb, diffuse, and apply such logistics innovation into the real logistics operations. On top of that, the government may able to encourage intelligent young generations to enter the logistics industry by setting a decent logistical training programme. It does not only include basic knowledge regarding logistics but also help them to deal with aforementioned future logistical trends in advance in order to heighten the competitiveness of the logistics industry.

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Parametric identification of the mathematical model of marine moving object using the apparatus of variational calculus

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ABSTRACT

Quantitative discrepancy between the vessel motion parameters (when her propulsion system is used) obtained by means of simulation and those obtained in natural conditions raises the problem of the ship mathematical model efficiency when it is based on the results of model tests in experimental tanks (Hoffman A.D., 1988), in a wind tunnel and in automated control systems. Therefore, the problem of the parametric identification of the vessel mathematical model is very important (Moiseev, 1979), (Udin and Pashentsev, 2006). In this article the authors propose one of the approaches to solving this problem with the help of the mathematical apparatus of the variational calculus.

Keywords: marine mobile unit steering, the mathematical model of the vessel, parametric identification, variation calculus

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1. Introduction

The development of an adequate mathematical model of a marine mobile unit (MMU), for example, of a vessel – is an imperative condition for creating intelligent control systems of its movement in the water (Sobolev, 1976).

There is a common structure of the MMU mathematical model, which is made with regard to the known principles of the hydrodynamic theory, and there are a number of its varieties defined by features of the applied problems to be solved.

When a certain MMU mathematical model structure is chosen or formed on the basis of the objective of the applied problem to be solved, it is necessary to define model parameters.

On the first stage of solving an applied research problem or MMU steering problems its model parameters are defined with the help of results of numerous model experiments carried out in experimental tanks, rotative installations and wind tunnels. Taking into account the fact that experiments are carried out on models of one MMU type, but later as a rule these results are used to determine parameters of other MMU types, it is possible to assume low adequacy of the model developed this way. In this case the use of the mathematical model for solving an applied research problem or any other practical problem connected with the assessment of a MMU movement dynamics in real sea conditions becomes pointless.

Moreover, taking into account that the model experiment, for example, in the experimental tank, cannot fully cover all possible real variants of MMU state, the model parameters based on the results of the model experiment on the one hand and the parameters corresponding to the certain current state of a unit being modeled on the other hand will be markedly different.

Of course, it will reduce the quality of results of the applied model research conducted with the use of the MMU mathematical model as well as when using this model for solving the problems of this unit steerage.

2. The main principles of parametrical identification

For the above stated reasons it follows that the most important problem to be solved when planning, for example, model experiments both of research and applied type is the problem of parametrical identification of the MMU mathematical model, i.e. their values should be brought into line with the values corresponding to the current state of the given unit. It is particularly important if the MMU mathematical model is used in the adaptive control system, which is typical for modern intelligent control systems.

Sea trials, during which kinematic parameters of the MMU movement and the type of their changes are determined, should be considered the main source of data for its mathematical model parameters identification. Identification of the parameters of the mathematical model can take place continuously during MMU movement, not interrupting its principal activity, so that the obtained (identified) parameters of its model could immediately be used in the unit steering system and for predicting current and next MMU maneuvers. It is obvious that in this case the safety, the quality, and the efficiency of MMU steering will substantially increase.

Traditionally, the MMU mathematical model, for example, of a vessel is given in the form of differential equations of motion, and its parameters are the coefficients in the right-hand sides of these equations. Usually these factors enter into the right-side of equations linearly, although more complex variants of entering can be considered.

The problem of the parametric identification is usually defined as a problem of minimization of some functional in an integral form. If the set of unit state variables is designated by vector X = {Xi}, and the set of parameters of the MMU mathematical model is designated by vector C = {Ck}, the condition of the functional minimum will look as follows:

$$\min\{\int f(X, dX/dt, d^2X/dt^2, \overline{C}, t)dt\},\ \ \overline{C} \in D \qquad (1)$$

where D is some closed variation area of model C parameters, and the integrand function can depend on both the state vector X and on its first dX/dt and second d2X/dt2 derivatives.

The concrete form of this function primarily depends on our ability to measure kinematic and dynamic parameters of MMU motion. Theoretically, when observing MMU motion we would like to measure 6 variables characterizing its movement – three linear accelerations W = {w1, w2, w3} and three angular accelerations E = {e1, e2, e3}. By measuring these parameters we would be able to evaluate the kinematic characteristics of the six-dimensional motion: linear V = (u1, u2, u3) and angular speeds W = {w1, w2, w3}. In this case it is essential that all these characteristics are determined by integration (- not by numerical differentiation of the measured variables) which greatly increases the accuracy of final results.

However, such a statement is only an idea, because the problem of fitting ordinary vessels with six-dimensional accelerometers and appropriate processing equipment hasn't been solved yet in required amount. That is why instead of the general problem (1) some particular problems of this type are to be solved depending on the dynamic and kinematic parameters of MMU motion which we can measure directly with the help of appropriate sensors. For example, if we measure kinematic parameters of MMU movement: speed V; x, y coordinates; and heading K; then the functional (1) can be represented in a form of a define integral within interval (0, tf):

min{Φ = ò[a1(X-Xэ)2+a2(Y-Yэ)2+a3(V-Vэ)2+a4(K-Kэ)2]dt} = min{Φ=òFdt}, (2)

where Xэ, Yэ, Vэ, Kэ are the values of kinematic parameters measured during MMU movement,

X, Y, V, K are the values of kinematic parameters of MMU movement which are determined in accordance with the chosen mathematical model, and therefore they are dependent on the parameters vector of the MMU mathematical model C,

A ={a1, a2, a3, a4} - weight normalization vector, components of which define for us the significance of this or that kinematic parameter of MMU movement and reduce inhomogeneous summands of the integrand to a uniform dimension.

Problem (2) can easily be represented in a discrete form by replacing integral (2) by its discrete analog – the sum of integrand at points tk - the moments at which the kinematic parameters of motion linear speed Vkэ, drift angle bkэ and angular speed wkэ are measured. After that the problem can be solved quite traditionally by method of the least squares: the partial derivatives of the function being minimized with respect to the required parameters are set equal to zero. Now we have a so-called system of normal algebraic equations in accordance with the number of parameters being determined:

$$\partial\Phi/\partial Cj = 0 \quad j=1,\ 2,\ldots,\ m \tag{3}$$

If the parameters themselves were included into the model linearly the obtained normal system is also linear and can be solved from a formal point of view without any apparent difficulties.

Despite the apparent simplicity of the problem stated this way its solution is confronted by a number of difficulties. Unobservability, i.e. impossibility to measure directly some kinematic parameters such as b, dw/dt, dV/dt makes it necessary to calculate them by means of differentiation one way or another. It significantly reduces accuracy of the final results. In addition, the matrix of the linear problem of the form (3) is ill-conditioned, and even small errors in the initial data lead to significant errors in determining the outcome parameters of the MMU mathematical model C (Udin et al, 2009), (Udin, Gololobov and Stepahno, 2009). Thus, two factors – the low accuracy of the initial information and the ill-conditioned matrix of the system (3) virtually put this problem into a class of ill-posed problems, the results of which are dangerous to trust. Therefore, getting back to the problem formulated by dependence (2) we will try to find acceptable approaches to solving it in other ways.

3. Variational approach

One of the approaches to solving problem (2) is the possibility of using the apparatus of variational calculus. Variational calculus formulates the necessary condition that function X is an extremal of the functional (2) in the form of the Euler-Lagrange equation (Elsgolts, 1969):

$$\frac{\partial F}{\partial X}-\frac{d}{dt}\left(\frac{\partial F}{\partial X'}\right)=0 \tag{4}$$

As X is a multidimensional vector, then the partial derivatives are implied by derivatives with respect to this vector components, i.e. formally equation (4) transforms into a system of scalar differential equations with respect to a number of components of vector X. To obtain the solution of equation (4), we are to define boundary conditions at the ends of the integration interval:

$$X(0) = X0,\ X(tf) = Xf \tag{5}$$

Often due to the character of the problem the boundary condition on the right end of the integral tf is not defined and so it is replaced by so-called natural boundary condition:

$$F(tf) = 0,\ \frac{\partial F}{\partial X'}(tf) = 0$$

These two conditions are sufficient to solve the Euler-Lagrange equation – the second-order differential equation. Solving it we can find the parameters of the vessel mathematical model which are included in the solution found, and thereby we can complete the parametric identification of the model. Let us consider as an example two particular problems of the above stated procedure of identification.

Consider the example of two private tasks such identification procedure. This will be the simplest tasks with a small number of identified options to show the possibility of the proposed approach. The more complex issue of generalized model Nomoto with 6-s parameters fixed by us (Nomoto et al, 1957) and is in the stage of publishing.

4. Problem 1: Vessel acceleration

In this case the differential equations defining the linear motion of the vessel are of the form:

$$\begin{aligned} \frac{d\upsilon}{dt} &= C0 \times T_e - C1 \times \upsilon^2; \\ \frac{dx}{dt} &= \upsilon, \end{aligned} \tag{6}$$

where Te - the propulsive thrust.

Here we use a two-parameter mathematical model of the vessel, which contains the parameters C0 and C1, the values of which have an uncertainty, for example, due to errors in the value of the added mass of the ship and not only.

We will minimize the following functional:

$$\mathbf{min}\{\int[\alpha(X-X^{э})^2 + (V-V^{э})^2]dt\} = \mathbf{min}\{\int Fdt\}, \tag{7}$$

i.e. we will make the mathematical model (6), which describes the dynamics of vessel acceleration, be maximum adequate to longitudinal movement experimental data (in this case it doesn't matter which movement is considered) and to the linear speed of the vessel. Factor a = (1/tf)2 will be chosen as a weight factor, it makes the summands in equation (7) homogenous and equally important for us. Euler-Lagrange equation in this case is as follows:

$$\frac{\partial F}{\partial X}-\frac{d}{dt}(\frac{\partial F}{\partial X'})=\frac{\partial F}{\partial X}-\frac{d}{dt}(\frac{\partial F}{\partial V})=2\alpha(X-X^{э})-\frac{d}{dt}(2(V-V^{э}))=0,$$

as a result we have :

$$\alpha(x-x^{э})-\frac{d\upsilon}{dt}+\frac{d\upsilon^{э}}{dt}=0 \qquad (8)$$

Taking into consideration that dV/dt = d^2X/dt^2 we obtain the differential equation of the second order in the distance x:

$$\frac{d^2X}{dt^2}-\alpha X=-\alpha X^{э}+\frac{dV^{э}}{dt}=\varphi(t) \qquad (9)$$

It's a simple equation and can be written down as follows:

$$X(t)=D1(t)e^{t/tf} + D2(t)e^{-t/tf}$$

where coefficients D1(t) and D2(t) are determined by method of variation of constants in the form of integrals:

$$D1(t)=\int_0^{tf}\varphi(t)e^{-t/tf}dt \qquad D2(t)=\int_0^{tf}\varphi(t)e^{t/tf}dt \qquad (10)$$

However in our case we can obtain an algebraic equation in the vessel speed V.

For this purpose we should substitute the value of the speed derivative from equation (6) into equation (9), differentiate the obtained equation with respect to time, and again substitute the value of the speed derivative into it, i.e.:

$$\alpha(V-X'^{э})-C0*Pe'+2C1*V*(C0*Pe-C1*V^2)+\frac{dV^{э}}{dt}=0$$

As a result of these actions we will have an exponential equation of the third order in ship's speed V:

$$2C1^2V^3-V(\alpha+2C0*C1*Pe)+\alpha X'^{э}-V''^{э}+C0*Pe'=0 \qquad (11)$$

It is an incomplete third-order equation and its solution can be written down in the form of the Cardano formula:

$$V=\sqrt[3]{-q/2+\sqrt{q^2/4-p^3/27}}+\sqrt[3]{-q/2-\sqrt{q^2/4-p^3/27}}$$

where (12)

$$q=(\alpha+2C0*C1*Pe)/2C1^2 \quad p=(\alpha X'^{э}-V''^{э}+C0*Pe')/2C1^2$$

Thus we get the problem solution, i.e. the equation of the extremals of functional (7) is found. However, our main goal is the mathematical model identification, that is, the definition of its parameters C0 and C1 in the first equation of system (6). Solution in the form (11) allows doing it by setting appropriate boundary conditions. At the initial time of movement the vessel speed and the travel have zero values: X(0)=0, V(0)=0.

At the final moment of the motion we can use the natural boundary condition, which can be represented by the equation u(tf) = ufэ.

Substituting the boundary values of variables x and u in equation (11), we obtain

$$C0=\left[\left(\upsilon''^{э}-\alpha x'^{э}\right)/T_e'\right]_{t=0};$$

$$C1^2*2\upsilon_f^{э^3}-C1*2C0T_{ef}+\alpha x_f'^{э}-\upsilon_f''^{э}+C0*T_{ef}'-\upsilon_f^{э}\alpha=0. \quad (13)$$

In the first equation (13) both variables representing the nature of the motion of the vessel, are taken at the initial time t = 0, in the second – at the final time t = tf, that is indexed by the subscript f. In the particular case, when at the final time the process becomes steady, the second equation (13) is greatly simplified by zero derivatives of the variables representing the character of motion, which leads to more simple equation

$$C1=C0\times T_{ef}/\upsilon_f^2.$$

5. Numerical solution

Let's consider a numerical example of how to use this method for solving a specific practical problem. The results of solution of the vessel movement problem will be taken as conditional experimental data in accordance with the dependence:

$$\frac{d\upsilon}{dt}=B0\times T_e-B1\times\upsilon^{2,1}$$

where (6) C0= 0.3, C1 = 0.58, and the power of speed in the conventional law describing the hydrodynamic resistance to the ship movement is deliberately taken to be equal to 2,1. In this case, it is assumed that propulsive thrust Te increases linearly, and then remains constant. We obtain the problem solution in MathCad system, its fragments are given below as Figure 1, Figure 2, Figure 3.

Figure 1. The example of obtaining experimental data by means of solving a problem with the given parameters (acceleration).

$$C0 := 0.3 \qquad C1 := 0.58 \qquad Pe(t) := \begin{cases} 5\dfrac{t}{3} & \text{if } t < 3 \\ 5 & \text{if } t \geq 3 \end{cases} \qquad x := \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$$D(t,x) := \begin{bmatrix} C0 \cdot Pe(t) - C1 \cdot \left(x^{2.1}\right)_0 \\ x_0 \end{bmatrix}$$

$$n := 100 \qquad m := 10 \qquad k := 0..n$$

$$Z := \text{rkfixed}(x, 0, m, n, D)$$

$$V := Z^{\langle 1 \rangle} \qquad X := Z^{\langle 2 \rangle} \qquad T := Z^{\langle 0 \rangle}$$

Thus we determine the parameters being identified by means of formulas (13). The derivatives of the variables characterizing the movement of the vessel are found using finite differences, as shown in one of the fragments of Figure 2. This solution gives the identified values of the model parameters:

Figure 2. The identification of model parameters by means of formula (13).

$$dt := \frac{m}{n}$$

$$Pes0 := \frac{Pe(dt) - Pe(0)}{dt} \qquad Xs0 := \frac{X_1 - X_0}{dt} \qquad Vs0 := \frac{V_1 - V_0}{dt}$$

$$Vss0 := \frac{(-2V)_1 + V_2 + V_0}{dt^2} \qquad Vssf := \frac{(-2V)_{n-1} + V_{n-2} + V_n}{dt^2} \qquad Xsf := \frac{X_{n-1} - X_n}{-dt}$$

$$CC0 := \frac{Vss0 - Xs0}{Pes0}$$

$$Pef := Pe(m) \qquad Vf := V_n$$

$$CC1 := \frac{CC0 \cdot Pef}{Vf^2}$$

C0 = 0.299, C1 = 0.606. This is a very good result, because the actual values were 0.3 and 0.58. The first value is almost exact, the second has 4.5 % error.

Then we solve the problem which directly describes our unit movement with the help of a model, the parameters in which have the identified values B0 = 0.3, B0 = 0.606, and the resistance is proportional to the second power of speed in accordance with the conventional hydrodynamic theory postulates.

The aim of this solution is to calculate the value of the functional which appears to be equal to J = 0.837. The relevant fragment of the solution is given in Fig.3

Figure 3. The calculation of the functional with the identified parameters (J = 0.837).

$$y := \begin{pmatrix} 0 \\ 0 \end{pmatrix} \qquad DD(t,y) := \begin{bmatrix} B0 \cdot Pe(t) - B1 \cdot \left(y^2\right)_0 \\ y_0 \end{bmatrix}$$

$$ZZ := rkfixed(x, 0, m, n, DD)$$

$$VV := ZZ^{\langle 1 \rangle} \qquad XX := ZZ^{\langle 2 \rangle}$$

The calculation of the functional

$$J := \sum_{k=0}^{n} \left[\left(VV_k - V_k\right)^2 + \frac{\left(XX_k - X_k\right)^2}{tf^2} \right]$$

6. Problem 2: vessel circulation

In this case the differential equations which govern the curvilinear motion have the following form:

$$d\omega/dt = -\omega/\tau_1 + K^{\delta}{}_{\omega}\delta(t)$$
$$dK/dt = \delta(t), \qquad (14)$$

where d(t) is the rudder angle , K - the ship's speed, w - the angular speed of the vessel.

The first equation of this system is called Nomoto equation (Sobolev, 1976), (Elsgolts, 1969) and is widely used for studying the yawing process.

Similarly to the previous example here we also use the two-parameter mathematical model of the vessel containing the parameters t1 and Kdw, which are called the main inertia constant and the variable characterizing the vessel's initial turning qualities (Sobolev, 1976).

Let's minimize the following functional:

$$\mathbf{min}\{\int[\alpha(K-K^{\text{э}})^2 + (\omega-\omega^{\text{э}})^2]dt\} = \mathbf{min}\{\int F dt\}, \qquad (15)$$

i.e. again we want the mathematical model to be maximum adequate to experimental data on the heading K and angular speed w. The known to us multiplier a = (1/tf)2 will be chosen as a weight factor. It makes the summands of the equation (15) homogenous and equivalent. Euler-Lagrange equation in this case is as follows:

$$\frac{\partial F}{\partial X}-\frac{d}{dt}(\frac{\partial F}{\partial X'})=\frac{\partial F}{\partial K}-\frac{d}{dt}(\frac{\partial F}{\partial \omega})=2\alpha(K-X^{э})-\frac{d}{dt}(2(\omega-\omega^{э}))=0\ ,$$

finally it will look like this:

$$\alpha(K-K^{э})-\frac{d\omega}{dt}+\frac{d\omega^{э}}{dt}=0 \qquad (16)$$

Taking into account that dw/dt = d2K/dt2 we obtain the differential equation of the second order for the extremal with respect to the vessel heading K:

$$\frac{d^2K}{dt^2}-\alpha K=\alpha K^{э}+\frac{d\omega^{э}}{dt}=\psi(t) \qquad (17)$$

Principle of solving equations of this type is given above (10), the general form of the solution is given in the form of the dependence of the following type:

$$K(t)=E1(t)\times e^{t/t_f}+E2(t)\times e^{-t/t_f}\ ,$$

where coefficients E1(t) and E2(t) are determined by the method of variation of constants in integral forms:

$$E1(t)=\int_0^{tf}\psi(t)e^{-t/tf}dt \qquad E2(t)=\int_0^{tf}\psi(t)e^{t/tf}dt \qquad (18)$$

However in our case we can obtain algebraic equation in the vessel angular speed w. Let's substitute the value of the derivative of angular speed from equation (14) in equation (16), differentiate the obtained equation with respect to time and again substitute the value of the derivative of the angular speed into it. We will obtain the linear equation in w:

$$\omega(\alpha-1/\tau_1^2)=\alpha K'^{э}-K_\omega^\delta\delta/\tau_1+K_\omega^\delta\delta'-\omega''^{э}\ ,$$

from which we can easily find the angular speed

$$\omega=(\alpha K'^{э}-K_\omega^\delta\delta/\tau_1+K_\omega^\delta\delta'-\omega''^{э})/(\alpha-1/\tau_1^2) \qquad (19)$$

Now it is possible to identify the parameters of the mathematical model represented by the system of equations (14), using the initial condition at the left end of the interval w(0) = 0 and the natural boundary condition at the right end w(tf) = wfэ. Taking into consideration these conditions we will obtain a system of two algebraic equations from which we can find the parameters:

$$K_\omega^\delta = (\omega''^э(0) - K'^э(0)/t_f^2)/\delta'(0)$$
$$\omega_f/\tau^2{}_1 - K_\omega^\delta \delta_f/\tau_1 + (K_f'^э/t_f^2 - \omega_f/t_f^2 + K_\omega^\delta \delta_f' - \omega_f''^э) = 0 \qquad (20)$$

If we assume the stationarity of the final state of the vessel, then from the second equation (20) we can find the second parameter being identified

$$1/\tau_1 = K_\omega^\delta \delta_f / \omega_f \qquad (21)$$

7. Numerical solution

Let's consider a computational example of using this approach in the same way it has been done for the problem of vessel acceleration. As experimental data we take the results of solving the problem of the ship's initial state during circulation with the change of angular speed by law:

$$d\omega/dt = - B0\ \omega^{1.1} + B1\ \delta(t),$$

in which the parameters C0= 1.6, C1 = 0.56, and the power in the law of resistance is deliberately chosen not equal to1.0 but to1.1 for experimental data distortion. Rudder angle increases linearly up to 0.5 rad, then remains constant. Fragments of calculation in MathCad are shown on Figure 4, Figure 5, Figure 6.

Figure 4. The way of obtaining experimental data by solving the problem with the given parameters (circulation).

$C0 := 1.6 \qquad C1 := 0.56 \qquad DelR(t) := \begin{cases} .5\dfrac{t}{60} & \text{if } t < 60 \\ 0.5 & \text{if } t \ge 60 \end{cases}$

$$D(t,x) := \begin{bmatrix} C0 \cdot DelR(t) - C1 \cdot \left(x^{1.1}\right)_0 \\ x_0 \end{bmatrix} \qquad x := \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$n := 1000 \qquad m := 100$

$Z := rkfixed(x, 0, m, n, D) \qquad k := 0..\ n - 2$

$OM := Z^{\langle 1 \rangle} \qquad K := Z^{\langle 2 \rangle} \qquad T := Z^{\langle 0 \rangle}$

Directly identifiable parameters are obtained with the help of formulas from groups (20), (21). Besides that, the derivatives of movement characteristics are obtained by means of finite differences as it is shown in Fig.5. This solution gives the identified values of the model parameters: C0 = 1.562, C1 = 0.565. Again the result is good, because the actual values were 1.6 and 0.565. Both values have the error of not more than 2%.

Figure 5. Identification of model parameters by the formulas (19), (20).

$$tf := m$$

$$DelRs0 := \frac{DelR(dt) - DelR(0)}{dt} \qquad Ks0 := \frac{K_1 - K_0}{dt}$$

$$OMs0 := \frac{OM_1 - OM_0}{dt} \qquad OMss0 := \frac{(-2OM)_1 + OM_2 + OM_0}{dt^2} \qquad OMf := OM_n$$

$$CC0 := \frac{OMss0 - \frac{Ks0}{tf^2}}{DelRs0}$$

$$Ksf := \frac{K_{n-1} - K_n}{-dt} \qquad OMssf := \frac{(-2OM)_{n-1} + OM_{n-2} + OM_n}{dt^2}$$

$$DelRsf := \frac{DelR(tf - dt) - DelR(tf)}{dt} \qquad DelRf := DelR(tf)$$

$$CC1 := \frac{(CC0 \cdot DelRf)}{OMf}$$

Now let's solve the problem which describes the circulation of a unit with the help of a model, in which the parameters have the identified values B0 = 1.562, B1 = 0.565, and the damping is proportional to the first power of the angular speed. The aim of solving this problem is to calculate the value of the functional which is equal to J = 1.073. The appropriate fragment of this calculation is shown in Fig 6.

Figure 6. The calculation of the functional with the identified parameters (J = 1.073).

$$B0 := 1.6 \qquad B1 := 0.56 \qquad y := \begin{pmatrix} 0 \\ 0 \end{pmatrix}$$

$$DD(t, y) := \begin{bmatrix} B0 \cdot DelR(t) - B1 \cdot (y)_0 \\ y_0 \end{bmatrix}$$

$$ZZ := rkfixed(x, 0, m, n, DD)$$

$$OMM := ZZ^{\langle 1 \rangle} \qquad KK := ZZ^{\langle 2 \rangle}$$

The calculation of the functional

$$J := \sum_{k=0}^{n} \left[(OMM_k - OM_k)^2 + \frac{(KK_k - K_k)^2}{tf^2} \right]$$

8. Conclusion

In this article we proposed and described variational approach to solving problems of parametric identification of ship mathematical models for different purposes. On the basis of the article materials we can make a conclusion that for models with a small number of parameters (mathematical models with few parameters), this approach provides sufficiently accurate results and can be used to approximate compound motions by a set of simple motions, models of which are easily identified. Its application to models with a large number of parameters requires further research, which is being carried out by the authors of this article.

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Inside the pond: an analysis of Northeast Asia's long-term maritime dynamics

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ABSTRACT

The analysis of historical vessel movements is proposed in this paper to compare recent Northeast Asian port and maritime dynamics with previous development stages back to the late nineteenth century. The changing distribution of vessel calls at and between Northeast Asian ports reveals important shifts of maritime connectivity over time, from the emergence of Japan as the dominant player in the region to a present-day more complex pattern with Hong Kong, Busan, and Shanghai as the major hubs. The analysis also underlines the uneven importance of domestic, intraregional, and extraregional flows as well as the existence of localized, peripheral subnetworks including small and medium-sized ports.

Keywords: historical geography, maritime network, Northeast Asia, port system, vessel movements

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1. Introduction

Despite its potential role as a gateway for the Europe-Asia land bridge, Northeast Asia[1] remains, more than ever, a maritime region where sea transport is the principal mean of cargo distribution domestically and internationally. While the region's history is well-known and subject to numerous scholarly works, especially in the field of trade, logistics, and transportation (see Gipouloux, 2011; Rimmer, 2007, 2014), the precise evolution of its port system and maritime network is less (Ducruet, 2015a). Scholars proposing a long-term perspective on port development put much emphasis on one specific port or country, such as China (see a review by Wang and Ducruet, 2013), while region-wide analyses mainly focused on container flows in the recent period only (Ducruet et al., 2010). The network approach combined with a historical perspective can provide new answers to fundamental questions about network growth dynamics in general and port system evolution in particular, as well as novel views about the uneven impacts of technological change and diffusion. Such an approach proved particularly helpful to understand regional integration processes in light of changing maritime connectivity patterns, for instance in North Africa (Mohamed-Chérif and Ducruet, 2014) and Southern Africa (Fraser et al., 2014).

It is the goal of this paper to go back in time and investigate what has been the form and mechanism of transformation of the maritime network in Northeast Asia. One possibility is to verify how much geography and technology have mattered in the centrality shifts among Northeast Asian ports. Centrality in this paper is understood from the perspective of graph theory, or network science, where ports are defined as nodes in a network made of inter-port vessel movements. Thus, port centrality refers to various local, port-level measures such as the number of links of each port (i.e. degree centrality) or the number of shortest paths on which each port is situated (i.e. betweenness centrality). Another originality of this paper is to make use of a largely untapped source of information, namely the vessel movement historical database published by Lloyd's List called the Shipping Index, to map and analyse maritime flows and networks. One publication was extracted in table format every five years or so between 1890 and 2008, which details the last known inter-port movement of each vessel at the time of the publication around March-April. As the time coverage is very partial, such a source may not fully reflect yearly port dynamics, but rather, provide a rough picture of past trends. Further efforts are being done to extract more systematically this source with the goal of constituting more complete time series of traffic data (Ducruet, 2015b). An originality of the study is that it encompasses the whole fleet of vessels whereas most former works on Asian ports focused on container traffics in the recent period.

The remainders of this paper are organized as follows. The second section examines the results of data extraction from the statistical source and explores the long-term evolution of maritime traffics to highlight main fluctuations. In a third section, we particularly focus on the topological and geographic structure of the network to shed

1) In this paper, Northeast Asia is referred to as a region including China, Japan, Taiwan, Far-East Russia, and the Korean Peninsula.

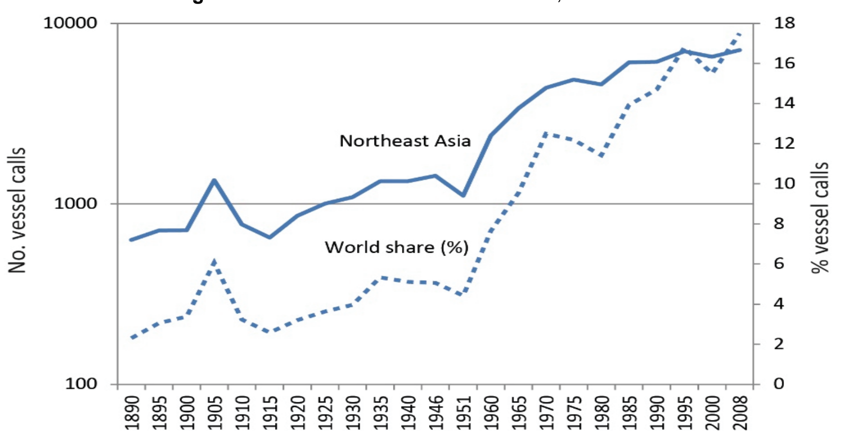
more light on which ports increased their roles in the Northeast Asian maritime network at the expense of others. Lastly we discuss the main results and their implication for current and future Northeast Asian port development.

2. Traffic evolution and distribution

Counting the number of vessel calls for the whole of Northeast Asia is a fruitful exercise to estimate the region's changing importance in world trade (Figure 1). Until the 1950s, total Northeast Asian maritime traffic had increased within reasonable limits, oscillating around 4-5% share of world traffic on average. The trend has been marked by certain shocks such as the sudden increase of 1905, probably caused by trade support to the Russo-Japanese War, the decline due to the First World War (1915) and following the Second World War (1951), the rise of the 1930s and 1940s being explained by the effects of Japan's colonial rule in East Asia and the European presence in China (Gipouloux, 2011).

Subsequently, the share of Northeast Asia in world maritime traffic rapidly increased from 7.7% in 1960 to 17.5% in 2008. Such an evolution can illustrate only partly the overall shift of economic and maritime activity from the Atlantic to the Pacific (Ducruet, 2015b), backed by the independence of formerly colonial countries and the transformation of Hong Kong, Taiwan, and South Korea into newly industrialized countries from the 1960s onwards, with an export-led development strategy. The period 1980-1995 is marked by the effects of China's Open Door Policy following a similar economic model.

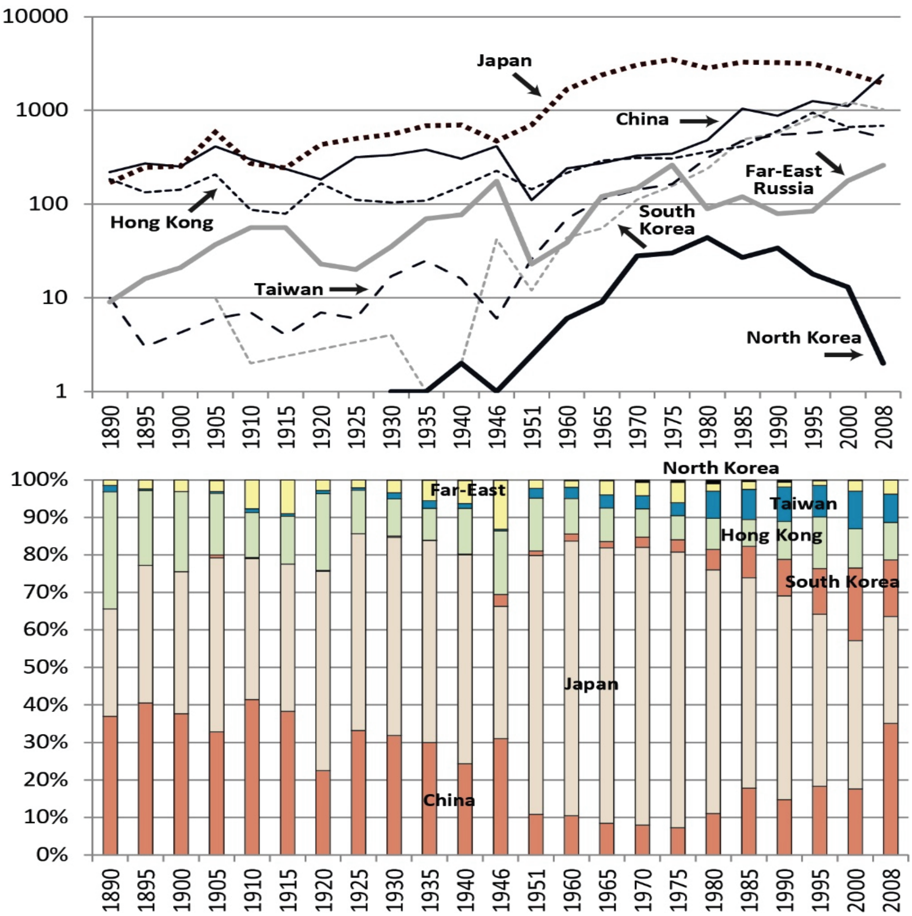
Figure 1. Maritime traffic of Northeast Asia, 1890-2008



Source: own elaboration based on Lloyd's Shipping Index

Another aspect of changing traffic dynamics is obtained by looking at the distribution of vessel calls per country in absolute and relative values (Figure 2). Japan has always been the region's dominant traffic concentration, except in 1890-1895, in 1910, and in 2008 when it ranked second after China. Although Japan's evolution is in line with the Northeast Asian trend, it underwent stabilization and slowdown since the 1980s, compared with the much faster growth of Taiwan, South Korea, China, and Hong Kong. Far East Russia went through wide traffic fluctuations along the period, with also a slowdown since the 1980s but compensated by a recent revival. North Korea, which traffic is recorded since the 1930s only (at that time being part of a unified yet occupied Korea), experienced rapid growth up to the 1980s and rapid decline since then, as explore more specifically in previous research (Ducruet et al., 2009a), such a trend being caused by combined geopolitical and economic factors.

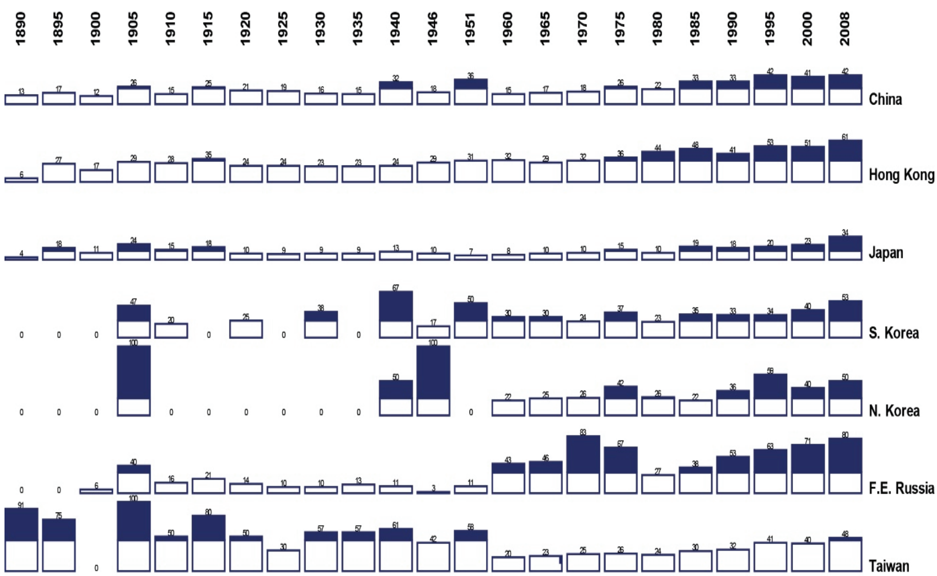
Figure 2. Evolution of maritime traffic by Northeast Asian country, 1890-2008



Source: own elaboration based on Lloyd's Shipping Index

Such evolutions clearly confirm the influence of historical changes on traffic evolution and distribution among Northeast Asian countries. In addition, such countries have been more or less focusing on Northeast Asia itself as the origin or destination of their maritime linkages. Measuring the share of intraregional flows (Figure 3) provides interesting information on the region's importance by country; it corresponds to the share of intraregional vessel movements in the total excluding domestic movements. For most countries, intraregional traffic increased rapidly in the second half of the period, i.e. following the Second World War and alongside new industrial developments. Such a trend may suggest a dynamic of regional integration. As the region's oldest industrial country, Japan had long been the most outward-looking economy through its long-distance connexions with North America, Oceania, and Europe. Due to the technological gaps with world shipping standards, Chinese ports connected principally the world network via Hong Kong in the early days of the 1978 reform, while Hong Kong itself became more and more a hub and gateway for Mainland China (Wang, 1998). From manufacturing centres serving external (global) interests, South Korea and Taiwan became increasingly embedded in regional economic networks (Lee and Rodrigue, 2006), but still with a higher proportion of long-distance linkages in their total maritime activity. Comparatively, North Korea and Far East Russia had become more local since the 1990s already, suffering from the difficult restructuring of their trade networks following the collapse of the Soviet Union.

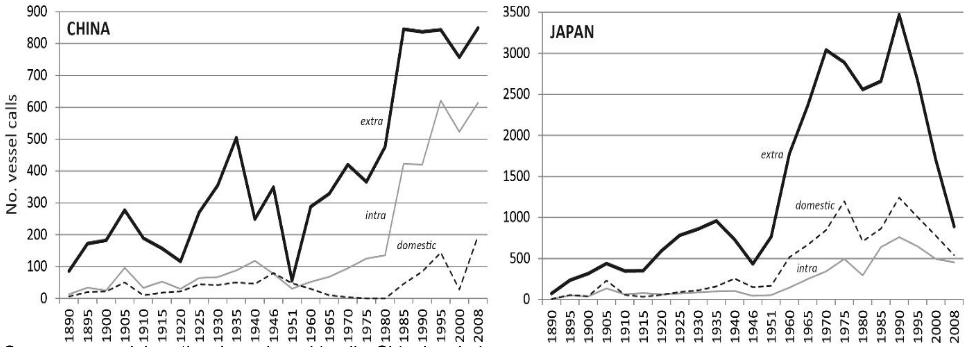
Figure 3: Share of intraregional traffic by Northeast Asian country, 1890-2008



Source: own elaboration based on Lloyd's Shipping Index
N.B. the size expresses the share of interregional traffic (%) in total traffic, and the dark blue colour applies to values over the country's average over the period

A zoom on China and Japan is provided to better understand their particularities (Figure 4). In both cases, the amount of extraregional maritime flows always surpassed intraregional and domestic flows. Both countries went through drastic decline around 1950 for different reasons: a major political change in China with the proclamation of the People's Republic (1949) and the war effects on Japan's economy in general. Nevertheless, long-distance maritime trade resumed rather rapidly in both cases, but while China continued to grow up to 2008, Japan went through drastic decline since 1990. This latter trend can be explained by the fact that our analysis considers vessel calls instead of vessel tonnage. Fewer vessel calls may hide increasing vessel size and therefore growing trade, especially in a context of growing ship sizes in container shipping. Such a bias was compensated for China due to the continued growth of vessel calls, notwithstanding a drop in 2000 for similar reasons. Another interesting difference between the two countries is the much higher importance of domestic (coastal) shipping for Japan than for China, as it always surpassed intraregional flows.

Figure 4. Contrasted evolutions: China and Japan, 1890-2008



Source: own elaboration based on Lloyd's Shipping Index

Last but not least, it is possible to measure the respective traffic of sailing and steamer vessels by country and on the level of the whole region compared with world average (Table 1). The share of steamer vessels in total traffic is a good indicator of the successful technological transition in port and shipping operations. As such, Northeast Asia as a whole had always been more advanced than world average, with a 20-30% higher share of steamer vessel traffic all over the period 1890-1925; subsequently sailing vessels became almost non-existent except in Europe and the West Indies. Japan and Russia had been faster to adopt innovations due to their earlier industrialisation (Japan) and strong focus on heavy industries and shipbuilding (Russia). Analyzing the extent to which steamer traffic has also varied among Northeast Asian ports would go beyond the aim and scope of this study. Therefore, next section concentrates on total traffic to measure network dynamics and port evolutions.

Table 1. Share (%) of steamer vessels in total maritime traffic, 1890-1925

	1890	1895	1900	1905	1910	1915	1920	1925
China	56.2	67.6	77.8	88.4	99.3	99.2	98.9	99.4
Hong Kong	48.6	61.9	70.6	88.9	95.4	98.7	100.0	100.0
Japan	58.2	78.5	74.7	95.5	97.4	97.9	98.6	100.0
South Korea	-	-	-	100.0	100.0	-	-	-
North Korea	-	-	-	100.0	-	-	-	-
Russia	70.0	82.4	90.5	97.6	98.3	100.0	96.0	100.0
Taiwan	10.0	33.3	-	100.0	85.7	100.0	100.0	100.0
Northeast Asia	53.9	70.7	75.5	92.2	97.9	98.7	98.9	99.8
World	36.6	45.6	59.3	71.2	82.1	87.3	88.9	97.2

3. Network structure and port hierarchy

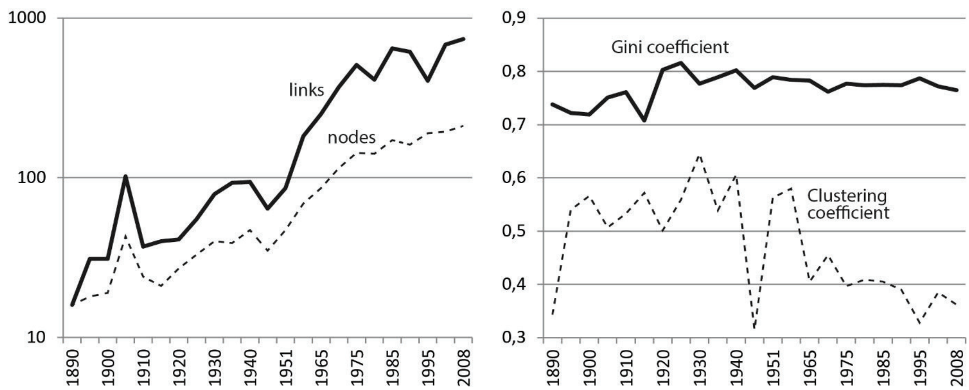
3.1 Overall topology

The Northeast Asian maritime network is made of all inter-port vessel movements for each year under study. The overlap of these movements provided a port-to-port matrix, weighted by the number of movements. Appendix 1 is provided as a benchmark upon which network analysis results can be confronted as it simply represents the port hierarchy based on the number of vessel calls, but without the representation of their linkages.

In terms of network size (Figure 5), the observed evolution confirms the aforementioned traffic evolution based on vessel calls. Yet, the number of links increased faster than the number of nodes (ports) in the network, especially since 1960. This confirms our earlier finding that intraregional flows gained in importance during that second half of the study period. More links imply increased regional connectivity and hence, more probability for regional ports to permit smooth cargo distribution within the area. However, while the concentration ratio of vessel calls among ports did not witness any substantial change over time (Gini coefficient), the clustering coefficient went through rapid decline since 1960. This measure is one key indicator of network structure (Ducruet and Lugo, 2012) as it tells us how much nodes' neighbours are also connected to each other. Higher values indicate harmonious or homogenous connectivity among ports, while lower values and especially decreasing values suggest the emergence of a hub-and-spokes structure, i.e. a rather heterogeneous connectivity with few large ports and many small ports, and a centralization of links at hub locations.

Thus, what had appeared as a possible sign of regional integration (i.e. growing intraregional flows) might in fact be explained by growing transhipment and transit trade among neighbouring country ports. Economic development since the 1960s not only created more opportunities for freight distribution, but also it exacerbated competition and specialisation among Northeast Asian ports.

Figure 5. Network size and connectivity, 1890-2008



Source: own elaboration based on Lloyd's Shipping Index

3.2 Hub ports and subcomponents

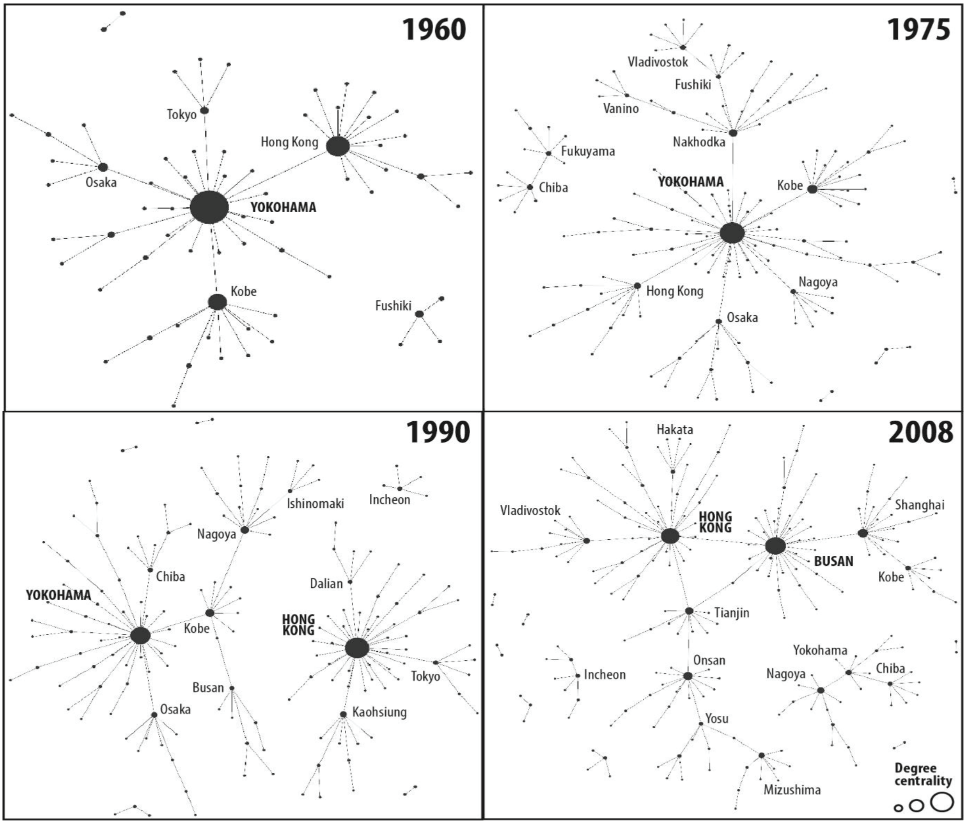
A look at the evolution of inter-port flows reveals interesting trends which were not visible only by looking at the volume of port calls. Table 2 provides the ranking of the top five ports by year, and the discussion is based on the evolving shape of the network and its principal hubs and components that emerge over time, but which were not all visualized for the sake of space (see Figure 6 for a look at four key years between 1960 and 2008). In 1890, Hong Kong and Xiamen are the two main hubs of the region, with the first centralizing Japanese flows and the second mostly Chinese and Taiwanese flows. But these two hubs centralize two unconnected components. It can be suggested that the fragmented network echoes earlier findings on the dominant core-periphery pattern, which lowers the probability for local, intraregional linkages to exist.

Table 2. Network centrality ranking of Northeast Asian ports, 1890-2008

Year	Port centrality ranking					
	1	2	3	4	5	6
1890	Hong Kong	Xiamen	Kobe	Fuzhou	Tainan	-
1895	Hong Kong	Shanghai	Yokohama	Kobe	Nagasaki	Shimonoseki
1900	Shanghai	Hong Kong	Yokohama	Nagasaki	Moji	Kobe
1905	Kobe	Hong Kong	Shanghai	Yokohama	Nagasaki	Shantou
1910	Shanghai	Kobe	Yokohama	Vladivostok	Moji	Hong Kong
1915	Hong Kong	Yokohama	Shanghai	Vladivostok	Kobe	Nagasaki
1920	Hong Kong	Yokohama	Shanghai	Kobe	Vladivostok	Qinhuangdao
1925	Yokohama	Shanghai	Hong Kong	Kobe	Dalian	Vladivostok
1930	Yokohama	Hong Kong	Shanghai	Dalian	Kobe	Keelung
1935	Yokohama	Hong Kong	Shanghai	Dalian	Kobe	Vladivostok
1940	Yokohama	Kobe	Hong Kong	Shanghai	Osaka	Dalian
1946	Shanghai	Yokohama	Hong Kong	Yokosuka	Qingdao	Qinhuangdao
1951	Hong Kong	Yokohama	Kobe	Osaka	Shanghai	Fuzhou
1960	Yokohama	Hong Kong	Kobe	Osaka	Moji	Nagoya
1965	Yokohama	Moji	Osaka	Hong Kong	Kobe	Yawata
1970	Yokohama	Hong Kong	Kobe	Vladivostok	Osaka	Nagoya
1975	Yokohama	Kobe	Osaka	Nakhodka	Nagoya	Chiba
1980	Yokohama	Hong Kong	Osaka	Kobe	Nagoya	Chiba
1985	Yokohama	Kobe	Hong Kong	Nagoya	Chiba	Osaka
1990	Hong Kong	Yokohama	Nagoya	Kobe	Osaka	Chiba
1995	Hong Kong	Yokohama	Tokyo	Busan	Ulsan	Nagoya
2000	Busan	Hong Kong	Nagoya	Kobe	Ulsan	Chiba
2008	Busan	Hong Kong	Shanghai	Nagoya	Onsan	Tianjin

Source: own elaboration based on Lloyd's Shipping Index

Figure 6. Hubs and subcomponents in the Northeast Asian maritime network, 1960-2008



Source: own elaboration based on Lloyd's Shipping Index

In 1895 however, there is only one tightly connected system with Hong Kong as the main hub followed by Kobe and Shanghai. Transversal linkages occur among Chinese ports (domestic, coastal shipping) but their majority remains at the periphery of the system, as terminal nodes (spokes). In 1900, the pattern is similar but Shanghai became the dominant hub (16 links) before Hong Kong (8) and Kobe (4), with its links equally distributed towards Japanese and Chinese ports. Due to the Russo-Japanese War (1904-1905), Dalian disappeared from the network in 1905, causing high growth at Yantai, another Chinese port situated just across the Bohai Rim in Shandong province. Interestingly, Busan and Incheon emerge in the network but mostly connected to Japanese ports, probably as a reflection of Japan's presence in Korea at the time (naval bases). High growth is also felt at Vladivostok in such context, connected with the main hubs (Shanghai, Hong Kong), as the main connexion port for the Russian Baltic fleet coming for the Battle of Tsushima. Military operations have without any doubt altered commercial routes and ports.

The situation had resumed by 1910, going back to the one in 1900 with Shanghai as the main hub (11 links) followed by Kobe (10), Yokohama (9), Vladivostok (6), and Hong Kong (6). The system remains stable in 1915 with a polycentric structure centred upon Shanghai, Hong Kong, Yokohama, and Vladivostok with comparable degree centrality. These hubs have no particular geographic specialization as they all connect a balanced number of Chinese and Japanese ports. In 1920 however, major hub ports connect each other while being bound to a specific country: Shanghai and China, Hong Kong and Taiwan, South China, Japan, and Yokohama and Kobe with mostly Japan. Vladivostok, a second-order hub port, connected all countries except Hong Kong. To be noted is Incheon, Korea's only port in the network at the time, with only one link to Moji in Japan. Indeed since 1910 officially, Korea belongs to the Japanese Empire and Incheon served as a major gateway port towards Seoul and the rest of the peninsula. No major change affected the network in 1925. In 1930, Yokohama became a much bigger hub with 30 links, followed by Hong Kong (17) and Shanghai (13). This reflects Japan's growth based on industrialisation, trade, and conquest. Interestingly, Busan and Incheon only connect Shanghai. The overwhelming dominance of Yokohama and other Japanese ports continues in 1935, especially given the occupation of parts of China by Japan, until 1945. This dominance is well reflected in the geographic homogeneity of the network where important hubs are fully connected with Japan and do not exhibit anymore specialization on a proximate range. It is still the case in 1940, with the notable difference that Japan is represented by three major hubs (Yokohama, Kobe, Osaka) instead of only one and still dominate Shanghai and Hong Kong, which rank far below. Incheon connects only Shanghai, but Busan connects only Niigata (Japan).

A major change occurred by 1946, after the Second World War, as seen with the reduced centrality of Japanese ports. Yokohama, despite its decline, still occupies a strong position with 12 links, just after Shanghai (14) and even before Hong Kong (11), but it connects mostly smaller ports, while Kobe and Osaka had vanished. The network goes back to previous stages where Shanghai and Hong Kong primarily connected Chinese and Taiwanese ports. In 1951 however, Shanghai's decline illustrates the effects of China's major political change a few years earlier (1949) to such an extent that it connects only Chinese ports in the region as well as Hong Kong, which is the dominant hub (22 links) followed by Yokohama (20) and Kobe (13), while Incheon and Busan connect only Japan. The decline of Japanese ports had been nothing but temporary, as their dominance resumed as early as in 1960. Shanghai and Dalian connect mostly Chinese ports and stand apart of the system, while Incheon and Busan show contrasted behaviour: as the main gateway to Seoul, the first connects the large Japanese hubs while the second only connects secondary East Sea ports such as Nakhodka, Fushiki, Otaru, and Muroran. A subaltern network of peripheral ports emerges, composed of Niigata, Fushiki, Vanino, and Tsuruga, to which are added Chongjin (North Korea), Akita, Vladivostok, and Naoetsu in 1965, still standing apart from the core system centralized by Yokohama, which has maintained its dominance in similar ways than in 1960. It is a rather monocentric network polarized by one highly dominant node (Yokohama) and a few second-order hubs. In 1970, the peripheral subnetwork centred upon Vladivostok and Niigata had gained more importance with the inclusion of 13 ports of which Tokyo, Shimonoseki, and other Japanese ports. This subnetwork became integrated in the main system in 1975, with Nakhodka as the main secondary hub connected to Yokohama, still the dominant node.

A major break occurs in 1980 with an evolution towards a bipolar network structure based on the high centrality of Hong Kong and Yokohama in relatively equal terms. Although Japanese ports continue to dominate the port hierarchy, Hong Kong attracted a wide number of ports under its dominance, mostly Chinese, Taiwanese, Korean, but also Russian, thereby completely transforming the regional pattern. Incheon stands apart with a small subnetwork including only Korean ports (Gunsan, Mokpo, Yosu) and Nagasaki. The high centrality of Yokohama and its secondary hubs (Nagoya, Osaka, and Kobe) is in fact dominantly a domestic shipping system organised around major urban concentrations, with the exception of Nakhodka, a Russian port but centralizing only smaller and relatively peripheral Japanese ports. This trend continues in 1985 as Hong Kong and Yokohama dominate two distinct networks. The one with Hong Kong includes most Chinese ports but a growing number of Japanese ports. A new feature is the role of Shanghai as a subordinate hub of Hong Kong, as well as Kaohsiung (Taiwan) and Tokyo. Incheon still stands apart from the system and includes mainly Korean ports in its small subnetwork (Yosu, Samchok, Ulsan, Gunsan, Donghae) and Naoshima in Japan. The Japanese hubs remain mostly of domestic influence, alongside Nakhodka and a few Chinese ports.

As the Chinese economy grows and Japan stabilizes, the subcomponent of Hong Kong had become even larger than the one of Yokohama by 1990 in terms of the number of included ports. As in the previous years, Busan emerges as a secondary hub and connects Kobe, while Incheon still stands apart in a small subnetwork composed of Ulsan, Gwangyang, Qinhuangdao, and Shimonoseki. The large component of Yokohama now only possesses Kobe, Nagoya, and Osaka as second-order hubs, reflecting upon Japan's shrinking influence in the network. In 1995 this evolution reaches a peak with Hong Kong as the main hub of the whole integrated system. Yokohama now appears as a secondary hub with only Nagoya and Kobe under its direct influence. All other secondary hub primarily connect Hong Kong, such as Tokyo, Nakhodka, Kaohsiung, but also Incheon, Busan, and Shanghai to a lesser extent. Incheon appears more as a local, domestic hub while Busan is more specialized on Japanese and Russian transhipment.

A major change occurred in 2000 with Busan becoming the major hub of the whole system. However, the latter system had split amongst two main components: one with Busan and Hong Kong as main nodes (with Osaka and Shanghai as secondary hubs) and the second dominantly Japanese with Chiba, Nagoya, Yokohama, and Kobe as central nodes. Nakhodka stands apart at the centre of a Far-East subgroup. In the last year under study (2008), the aforementioned dynamics are prolonged as seen with a huge component centred upon Busan and Hong Kong including several Korean (Onsan, Yosu), Chinese (Shanghai, Tianjin), and Russian (Vladivostok) secondary hubs. Comparatively, a much smaller component including Yokohama, Nagoya, and Chiba lies at the periphery, as well as another small group centred upon Incheon and mostly dominating Chinese Yellow Sea ports.

4. Conclusion

The ambition of this paper was not to question the history of Asia and its ports, but rather, to offer a new perspective on their long-term evolution. This was made possible using a largely untapped data source, the Lloyd's Shipping Index, which allowed for the first time to provide a region-wide analysis based on one single measurement unit, the vessel call. Thus, despite the drawbacks of such an approach (e.g. missing information on more local traffics such as junk vessels, unrecorded ship movements, calls instead of vessel tonnage capacity, etc.), Northeast Asian countries and ports could have been compared in a relatively objective manner in terms of their ability to absorb a number of political, economic, and technological changes and transitions in the last 120 years.

Main results are satisfactory is a sense that they convey a general snapshot of the Northeast Asian port system at regular points in time since 1890, without too much discrepancy compared with existing knowledge. The major traffic concentrations and hubs could have been well identified as well as their geographic specialization and the precise turning points where port hierarchies have shifted within the region. While traffic concentration in general has been somewhat stable over the period, we observed a growing centralization of inter-port links. This occurred at the advantage of Japanese hub ports, which superseded China and Hong Kong as the region's pivotal hub. In the 1990s, Hong Kong and South Korea became the leading hubs as part of a more polycentric system, relegating Japan at the periphery. As compared with previous research using similar methods, what became clear is the prominence of transhipment hub ports, such as Busan, backed by ambitious port policies and investment. This major shift toward Busan port could both confirm the spatial characteristics of modern transhipment hubs (Fleming and Hayuth, 1994), such as the route and service optimality required by increasingly global transport actors, and local dynamics stemming from the Kobe earthquake in 1995. In particular, these results could confirm the more recent emergence of South Korea as the leading maritime hub in Northeast Asia, based on the sole analysis of liner shipping networks (Ducruet et al., 2009b), notwithstanding more local dynamics such as the growing importance of local/regional hub ports like Incheon but also Onsan and Yeosu.

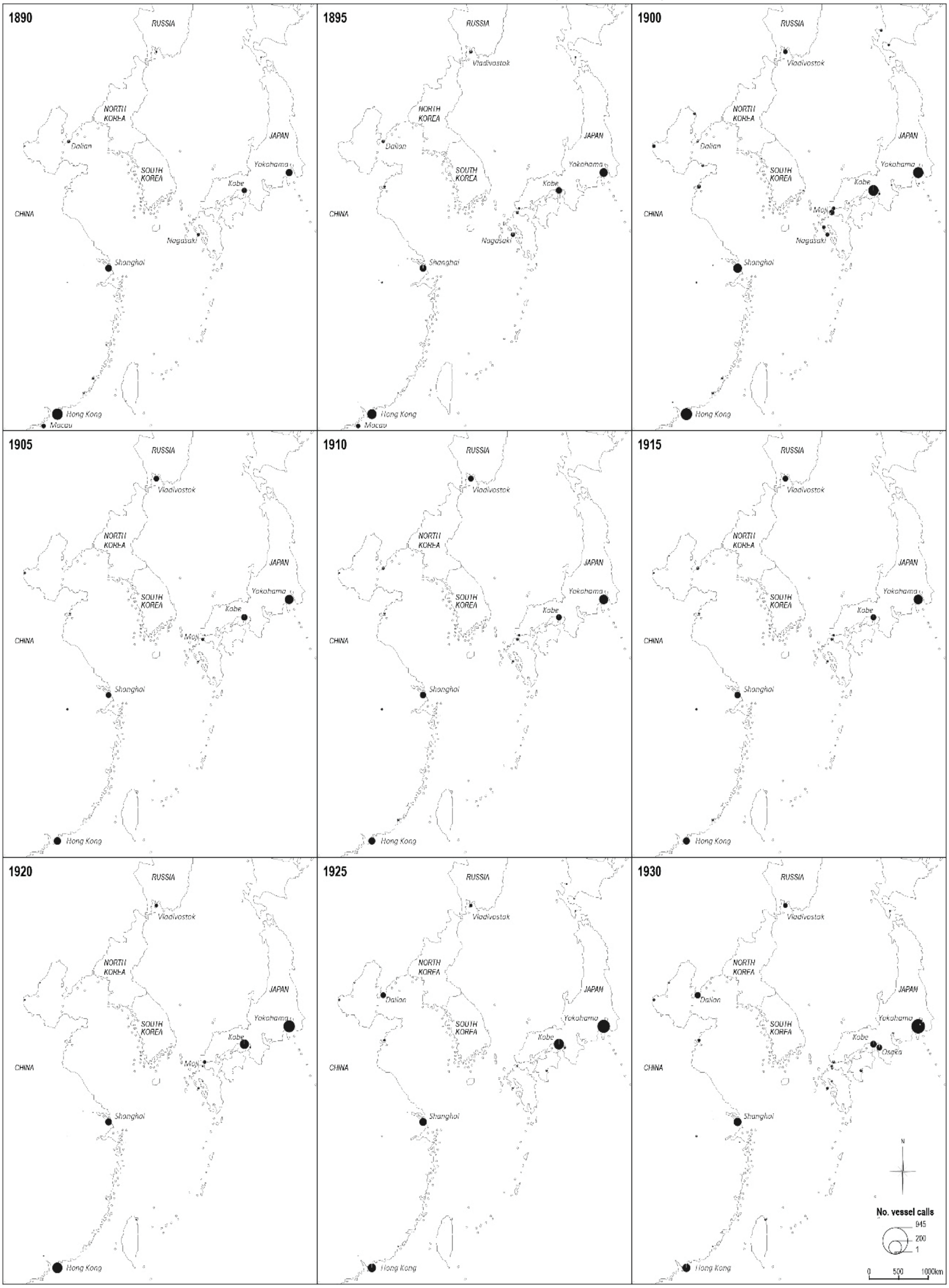
Many aspects motivate further research in such directions. For instance, the likely reinforcement of the Arctic Sea Route may in the coming years or so modify profoundly the current trends. As Northeast Asia is not a closed system, the study should be extended to East Asia or the Asia-Pacific to grasp port dynamics in a more comprehensive way, without naming the possibility to analyse in detail how Northeast Asian ports have evolved at the global scale in the world maritime network. A better understanding of past and current port dynamics at multiple scales shall provide novel views on the way future trends can be defined and anticipated. This would necessitate to expand the time coverage of the current study to include the post-2008 period.

Acknowledgements

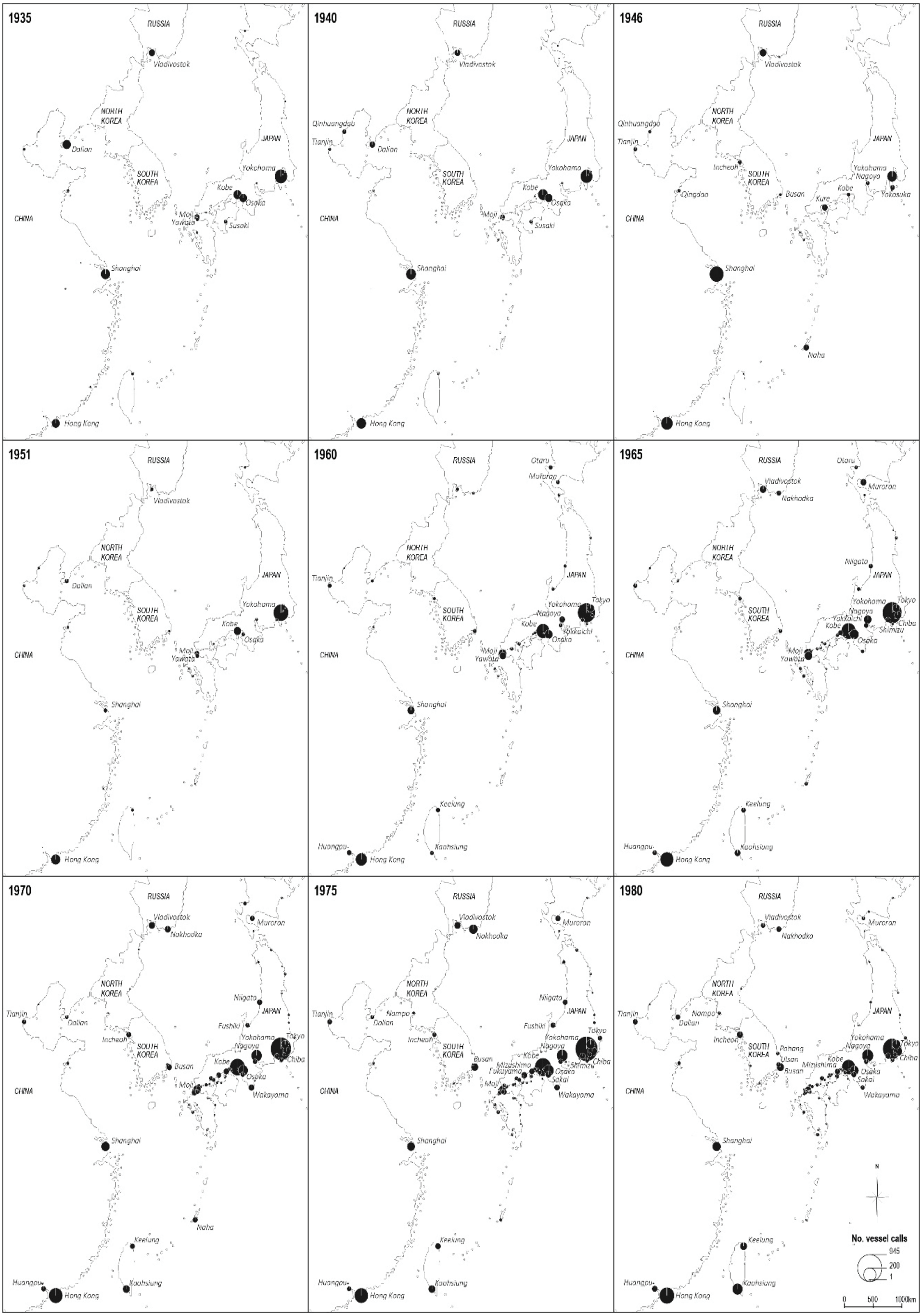
The research leading to these results has received funding from the European Research Council under the European Union's Seventh Framework Programme (FP/2007-2013) / ERC Grant Agreement n. [313847] “World Seastems”.

Appendix 1a: Northeast Asian port hierarchy, 1890-1930

Source: own elaboration based on Lloyd’s Shipping Index

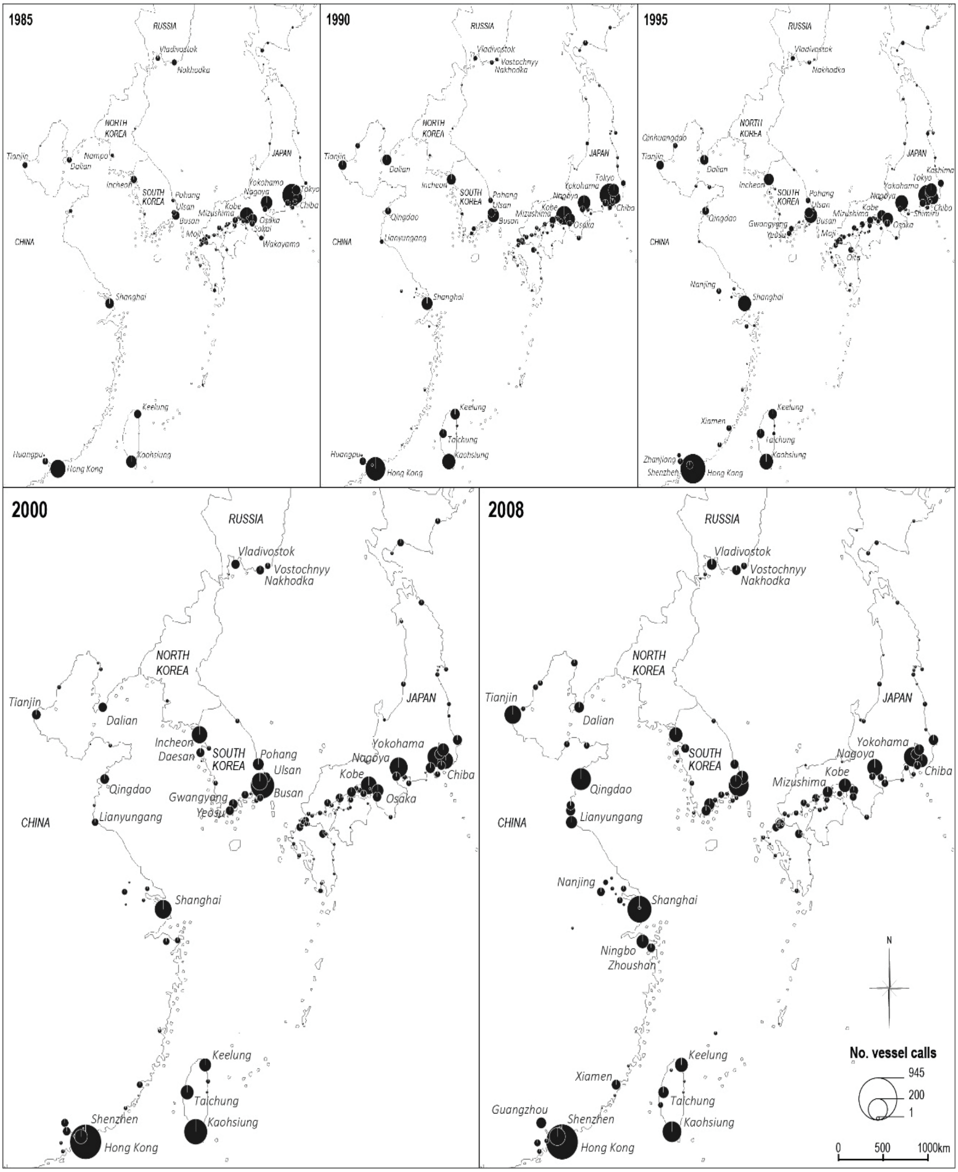


Appendix 1b: Northeast Asian port hierarchy, 1935-1980
Source: own elaboration based on Lloyd's Shipping Index



Appendix 1c: Northeast Asian port hierarchy, 1985-2008

Source: own elaboration based on Lloyd's Shipping Index



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Possible Business Models Using the NSR: South Korea's Perspective

Sung-woo Lee[*], Yun-hee Hwang[**]

ABSTRACT

The new era of Northern Sea Route (NSR) is changing the global logistics environment. In response to this phenomenon, this study explores possible ways for South Korea to use the NSR commercialization. The study highlights trade of wood pellets and promotion of cruise industry as promising two business models which enable to accelerate the NSR commercialization. The findings in this study for removing risks and barriers related to the models can be summarized as follows. First, a closer examination of ports and their related infrastructure along the coasts of the Arctic Ocean is required. Second, target and demand for the logistics infrastructure required should be identified. Third, enormous investments into the construction of ports and related logistics infrastructures are required. Fourth, transport·logistics network should be connected as a whole. Fifth, in order to maximize benefits and profits, business models relevant to NSR require considerable effort for further development. The South Korean government and the local governments should establish strategies by which business models can be utilized more effectively.

Keywords: Northern Sea Route (NSR), Arctic shipping, Business model, Commercialization

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1. Introduction

After experiencing the Cold War between the US and USSR following World War II, the definition of globalization has become widespread throughout the world. The globalization has brought a huge change in the logistics field such as containerization and intermodalism which are the basis for the movements of goods. The globalization has rapidly spread through the transportation revolution and stimulating growth of global trade which has achieved a rapid growth from 1.5 times to global GDP to 3 times. Going through the process of adaptation and proliferation for many decades since the first emergence of containerization, the world maritime container transport network has become reality by spreading it from Europe and US to Asia and the third countries.[1] The remarkable aspect is that the field of maritime transport has grown very fast, handling more than 80% of international trade. Due to the sustainable growth of the international trade by utilizing maritime transport, the functions of ports and the back-up logistics facilities have developed with incredible speed and as the size expands, the spatial structure of port back-up areas of main countries are changing.[2] However, although the port back-up areas network connected to maritime transportation has changed dramatically, maritime transportation connected to ocean has remained the same in terms of its geographic spatial aspect since the 20th century. Since the Atlantic Ocean and the Pacific Ocean have connected by the commercial revolution by discovering the sea routes from Europe to Asia using the route for the Cape of Good Hope which was discovered in 16^{th} century and, by opening of Suez Canal in 19^{th} and Panama Canal in 20^{th} century, no particular changes have been made in the shipping routes.

While not much change has been made in terms of transportation geography, the new commercial revolution has broken out recently in the field of sea transport. Thawing of the ice in the Arctic region due to the global warming has provided the shortcut between Europe and Asia. The emergence of the Northern Sea Route (here in after referred to NSR), bringing a new form of trade between Asia and Europe, makes it possible to bring the center of the world economy to Asia.[3] In this respect, East Asian countries such as South Korea, China and Japan are taking their profound interests in the NSR. Based on this environmental change, it is required to examine the necessary requisites in order to use NSR from the perspectives of East Asian countries.

Therefore, this study explores to find the elements required and actions which are to be taken in order for the East Asian countries to make economical use of the NSR. The research proposes the possibility of commercializing NSR from the perspectives of South Korea to expand the role in Northeast Asia in a new NSR era.

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1) Rodrigue, J.P., Notteboom, T., "Foreland-based regionalization: Integrating intermediate hubs with port hinterlands", Research in Transportation Economics, Volume 27(1), 2010, p. 20.

2) Lee, S.W., Ducruet, C., "A Tale of Asia's world ports: the spatial evolution in global hub port cities", Geoforum Volume 39(1), 2008, p. 163.

3) Lee, S.W., "The Change in the port logistics system in East Asia and the commercialization of the Northern Sea Route", KMI press: Seoul, 2014, p. 77.

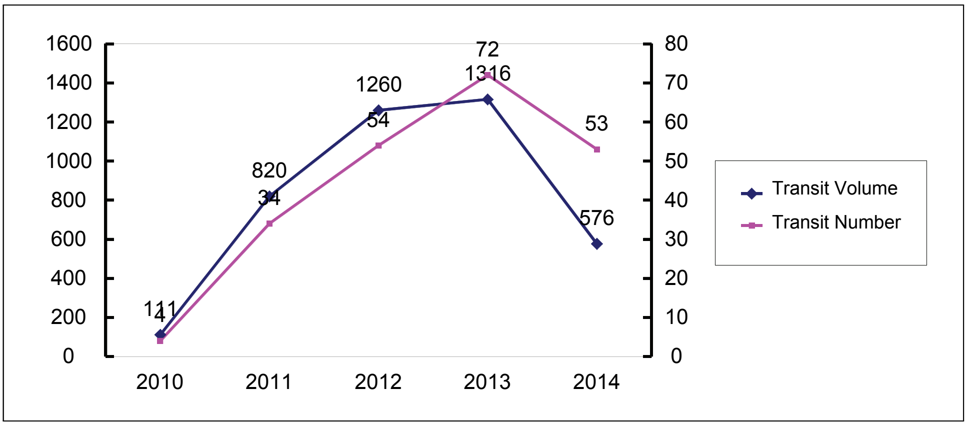
2. Possibility and Challenges of the NSR

The NSR has contributed in changing the map for international logistics of the 21st century and this particular issue is still rising. This is a revolutionary event in logistics since the NSR could reduce more than approximately 10 days or 7,000 km in distance compared to the previously existing route passing the Suez Canal when going to Europe from Asia. Although it varies from case to case, it is reported that approximately 25% of the ocean freight charge could be reduced in terms of expense.[4)]

However, many negative opinions exist in using this NSR yet. Concerns on harsh climate condition, unconfirmed maritime information, and poor condition of logistics infrastructure, and environmental destruction in Arctic region are some of the elements that are perceived as obstacles in utilizing the NSR. Despite these concerns, the use of NSR is already in progress as seen in the <Figure 1>. The number of vessel passing through the NSR is increasing rapidly, for example there were 34 transits in 2011, 46 transits in 2012, 72 transits in 2013 in the NSR.[5)] However, the fact that Russian government controls the examination of the management system of the NSR and that the country is currently undergoing political sanction due to the Ukraine crisis make it hard for the countries to pass through Russian part of the NSR. Therefore, the number of ships navigating in the NSR seems to reduce, yet, the use of NSR will consistently increase without doubt.

Figure 1. Increasing the number of shipping via the NSR

(Unit: USD thousand, ton)



Source: Arctic Logistics Information Office, "Northern Sea Route Information Office in Centre for High North Logistics", http://www.arctic-lio.com/NSR, each year (Access date: Nov. 10, 2015)

4) Lee, S.W. Song, J.M. & Oh, Y.S., "Shipping & Port Condition Changes and Throughput Prospects with Opening of the Northern Sea Route", KMI press: Seoul, 2011, p. 100.

5) Lee, S.W., "Essential Factors in Commercializing Arctic Shipping", presentation material, KMI press: Seoul, 2013, p. 3.

As shown in <Table 1>, the main objects of cargo using the NSR are mostly liquid cargo such as crude oil, refined oil, gas etc. Moreover, it contains 3 times more cargo from Europe to Asia than that from Asia to Europe. Most of the traffic is done within Russia. However, it is known that the frequency of utilization among East Asian countries figured out to be also very high, showing 9 times transits from both South Korea and China.[6)]

Table 1. Increasing the number of shipping via the NSR, 2012

Cargo Type	No. of Vessels	Cargo Volume(t)	Full displacement	Eastbound Cargo	Westbound Cargo
Liquid	26	894,079	-	661,326	232,753
Bulk	6	359,201	-	262,263	96,938
Frozen Fish	1	8,265	-	-	8,265
Ballast	6	-	472,075	-	-
Repositioning	7	-	78,351	-	-
Total	46	1,261,545	550,426	923,589	337,956

Source: Lee, S.W., “Shipping and Offshore Conference in Huston”, Presentation Material, KMI press: Seoul, 2013, p. 7.

In this context, the Russian Government and a South Korean research institute have presented the estimation of the amount of cargo passing through the NSR located in Russia. The Russian Government estimated all the cargoes passing through the NSR until 2030 and forecasted the approximate volume of cargo transported to be 1.2 billion tons. The Korea Maritime Institute analyzed the expense condition of cargo limited to containers by comparing with that of Suez Canal route and predicted the approximate volume of cargo transported to be 12 million TEU by 2030 on the assumption that expense for using the NSR is same as previously existing route.

3. Commercializing Ways through the NSR

3.1 Efforts of the Republic of Korea

Despite these difficulties, three Northeast Asian countries including China, South Korea and Japan take continually considerable efforts to explore the NSR. In particular, South Korea makes a lot of effort regarding the NSR. Dasan Scientific Research station was established in the Arctic region in 2012 and the first icebreaker named “Araon” was built in 2009 directed by South Korea. Also, active participation of South Korea in the Arctic Council has led the status of South Korea as the permanent observer. Moreover, South Korea has concluded MOU for port development in Asia with Russia and MOU for Shipping and Arctic utilization with Norway. Already, it carried out pilot shipping[7)] of NSR twice by South Korean logistics companies.

6) Rosatomflot, http://www.rosatomflot.ru/index.php?menuid=16, 2014, (Date: 2015.11.11)

7) In October, 2013, a South Korean liner shipping company (H company) successfully operated a pilot service

Since then, various efforts have been made to accelerate the international cooperation for tackling the tasks and issues raised by the commercialization of the NSR. Such efforts have begun at bilateral and multilateral level in the Arctic region including East Eurasia. According to the figure 1 below, both sea and land routes will provide the countries inter-connected transportation. Therefore, development of ports in the Russian Far East and North Korea and the railway project between North and South Korea will be essential and should be preceded beforehand so as to achieve commercializing NSR successfully.

Figure 2. The East Eurasia logistics networks connecting the NSR

Source: Reorganized by KMI based on the Google Map data (Access date: Nov. 12, 2015)

3.2 Two possible business models through the NSR

For achieving the Eurasia logistics networks connecting to NSR as shown in Figure 1, have to develop utilizing business models between the regions and South Korea in terms of cargoes and passengers. In this context, this study proposes some business models based on trade between South Korea and Russia, and the economic potential of East Asia.

through the route for the first time. They transported approximately 40,000 tons of naphtha from Ust-Luga port located in Northern Russia to Gwangyang in South Korea. The shipping total distance transported was 15,970km which include 4,254km of the NSR, taken 35 days. Further, in July 2015, another domestic shipping company (D company) sailed the second trip through the NSR, featuring the first commercial service by way of the NSR. They transported loading/unloading equipment for maritime oil and gas specialized for the polar region from Mussafah in UAE to the coast of Noviy port in the Yamal Peninsula of Russia. Total shipping distance was around 16,700km including about 500km of the NSR.

3.2.1 Wood pellets

Firstly, wood pellets are one of the largest internationally traded solid energy commodities used specifically for energy purposes. The trading volume reaches about 4 million tons – they can be compared to bio-diesel or bio-ethanol. While the handling of wood pellets requires care, advantages over other types of solid biomass such as wood chips or agricultural residues are their storability and relatively easy handling. Wood pellets also have low moisture content and relatively high energy density. And it is economically more feasible to transport wood pellets instead of wood chips above 5,000 nautical miles (9,300 km).[8] It means that wood pellets are economical for long-distance transport. On the other hand, South Korea's imported wood pellets have been increased from 122,447 tons in 2012 to 1,849,641 tons in 2014.[9] Also the demand of wood pellets was expanding because of the execution of RPS system.[10] Finally, those kinds of compressed wood pellets can be used as a new renewable energy. In particular, according to <Table 2>, Russia's exports increased 12 times from 2011 to 2012. The volume of wood pellets, which are exported from Russia, is increasing every year.

Table 2. Import volume of wood pellets in South Korea

(Unit: ton)

Country	2009	2010	2011	2012	2013	2014	2015 (Until Sep.)
Vietnam	638	4,399	7,237	30,296	157,226	742,794	669,993
Canada	1,118	1,440	2,022	2,646	79,795	344,261	77,113
China	8,774	8,084	5,582	3,648	10,220	287,063	3,010
Malaysia	49	3,264	7,626	30,698	78,420	168,336	99,538
Thailand	-	-	23	314	9,315	100,752	21,159
USA	43	327	105	184	32,018	61,944	18,641
Indonesia	723	797	225	8,933	33,534	62,729	34,487
Russia	-	-	3,301	41,731	76,941	34,756	59,222
Australia	-	-	-	-	-	26,751	-
Japan	4	285	2,186	3,546	4,629	4,290	435
all	12,042	20,893	29,678	122,447	484,668	1,849,641	987,993

Source: Korea International Trade Association, http://stat.kita.net/stat/cstat/peri/item/ItemList.screen, 2015 (Access date: Nov. 12, 2015)

There are two business models. One of them is "To-Be Biz model" which is imported by South Korea after wood pellets made in Russia or made in South Korea after materials had imported from Russia. Like this, the domestic demand for wood pellets is growing exponentially and it is possible to import materials from Russia

8) Steiner M., Junginger M., Hiegl W., Sikkema R., Faaij A., Hansen M. T., The European wood pellets markets: current status and prospects for 2020, Society of Chemical Industry and John Wiley & Sons, 2011, p. 251.

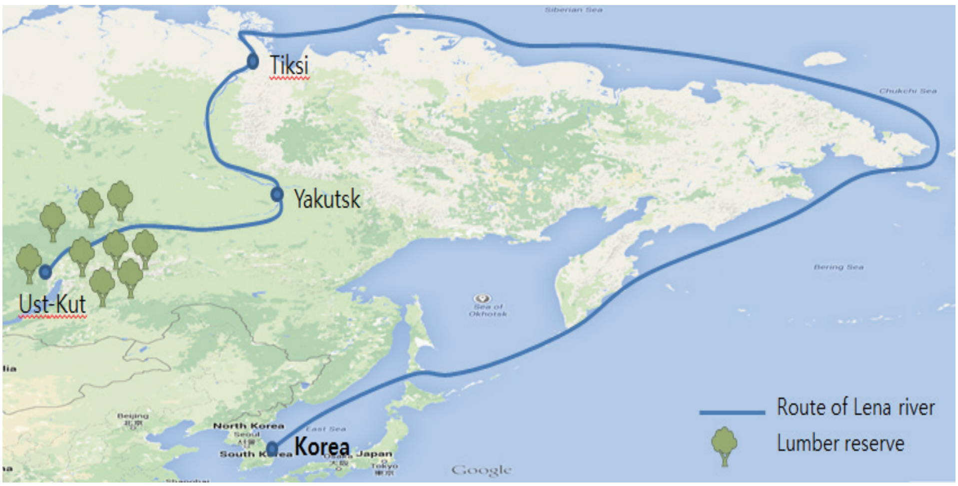
9) Korea International Trade Association, http://stat.kita.net/stat/cstat/peri/item/ItemList.screen, 2015, (Date: 2015.11.12)

10) National Renewable Energy Laboratory, "Renewal Portfolio Standard", http://www.nrel.gov/tech_deployment/state_local_governments/basics_portfolio_standards.html, (Date: 2015.11.10)

along with import from Southeast Asia and North America. As a result, domestically manufactured models can be considered not only complete products made by wood pellets but original materials.

Depicted in <Figure 3>, the wood pellets are passed through Ust-Kut, Yakutsk, Lena River, Bering Sea, Northeast Asia (South Korea, China, Japan), subsequently to the provinces of South Korea. Furthermore, following the improved economic conditions in Northeast Asia, demands to Russia's wood pellets that feature high quality and abundant natural resource are expected to increase gradually.

Figure 3. The transport route for Russia's wood pellets



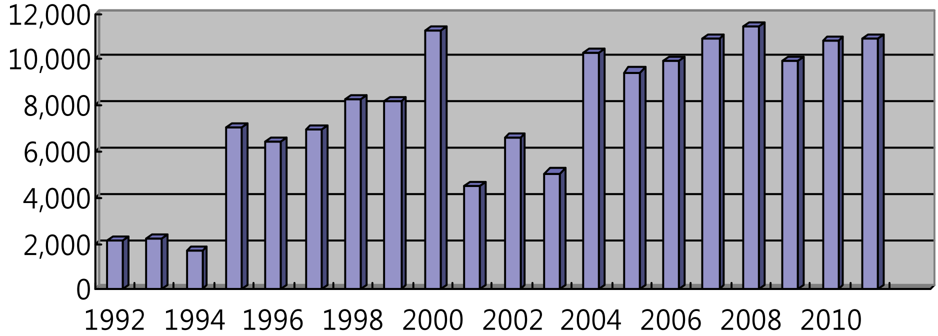
Source: Reorganized by KMI based on the Google Map data (Access date: Nov. 11, 2015)

3.2.2 Cruise

The second one is the business model of cruise route development. From <Figure 4> as below, tourist industry regarding the North Pole and the Arctic Oceans has been increasing constantly since 2000s because of the growth of income and environment-friendly experience tour. In the past 15 years, Arctic marine tourism has been increased approximately 8 times in the North European countries, Canada, and Alaska. The North Pole tourism consists of Alaska Glacier Bay national park, Nunavut territory of Canada, Greenland/Iceland cruise tour and Sweden/Norway/North area of Finlan d.[11]

11) Arctic Portal, "Sustainable Arctic Tourism", http://portlets.arcticportal.org/tourisminthearctic, 2012, (Date: 2015.11.11)

Figure 4. Arctic visitation, 1992-2010



Source: National Park Service, http://www.nps.gov/ (Access date: Nov. 11, 2015)

In this context, in the provinces which are located in the East Sea, cruise route development plan is pushing forward a business. Geographically, the ports of these provinces are located between northeastern cruise route and the arctic route. If the provinces take advantage of this geographical benefits and the growing arctic market which is developing 16% each year, there are high development possibilities of cruise industry. Therefore, it is necessary to carry forward to making tour programs connecting the arctic route, ports of the provinces, Japan and China and Southeast Asia cruise like a belt by using cruise, aircraft and railroad.

Figure 5. New-cruise route linked with South Korea

Source: Reorganized by KMI based on the Google Map data (Access date: Nov. 11, 2015)

4. Conclusion

In this aspect, a staged approach is urgently needed in order for the East Asian countries and the Arctic States to make the right use of NSR. This study highlights a few of the expected business models which is able to attract cargoes from the commercialization of NSR in terms of South Korea. Overcoming the above-mentioned obstacles has to be preceded before the commercialization of the NSR. Therefore, following measures are to be taken in order to reduce the obstacles.

First, a closer examination of ports and their infrastructure around the Arctic Ocean is required for the commercialization of the NSR. The support of various services and the secured passing of cargoes through the ports are required for the operation of the NSR regardless of liner or steamer. In this regard, the analysis should be made on various information regarding ports surrounding the NSR, and it is necessary to jointly develop main ports and select hub ports by cooperating with neighboring countries.

Second, target and demand for the infrastructure required for NSR should be identified. The ports surrounding NSR are functionally different from general ports. Many special facilities must be equipped in order for the ports to operate in extreme situation.[12)]

Third, a large amount of money will cost in constructing port and logistics infrastructure in the regions affected and seeking for the procurement of the financial aid is required. In order to smoothly promote the relevant businesses and to encourage active participation of the companies from coastal countries and user countries, the governments and the public institutions of the affected countries shall participate in the procurement of the relevant funds. The government-run bank of South Korea, China and Japan and the participation of recently mentioned AIIB[13)] or a new multilateral cooperative bank like, so called, Arctic Investment Bank, might be good alternatives.

Fourth, although there is an urgent requirement for securing the ports and logistics infrastructure in order to commercialize the NSR, logistics can be competitive only when it is connected as a whole. Therefore, only under the connection of ports around the Arctic Ocean and the logistics network coming from the Fast East Russia, Northern Mongolia, and Northern China make logistical functions possible to perform.

Last, considering the problems on the international governance amongst respective governments as discussed above, South Korea requires taking considerable pains to develop business models linked with NSR that can maximize benefits and profits of its economy. Particularly, as mentioned above, a business model to import Russia's wood pallets from East-Siberia regions via Far-East Russia, and a business model linking with the polar area-cruise will suggest useful insights for activating

12) Ibid. pp. 137-138.

13) The Asian Infrastructure Investment Bank (AIIB) is an international financial institution proposed by the government of China. The purpose of the multilateral development bank is to provide finance to infrastructure projects in the Asia region; http://en.wikipedia.org/wiki/Asian_Infrastructure_Investment_Bank (Date: 2015.04.24)

ports in South Korea's eastern provinces, in that the models provide the way to attract both cargoes and passengers. Taking these opportunities into account, each province in South Korea needs to take their own efforts to secure a regional logistics hub and invite the relevant industries to port back-up areas and/or free trade zones.

The Korean Peninsula is located at both the starting and the ending point of the Eurasian logistics network connecting NSR, accordingly taking an important role and the possible method at present will be an integration of logistics network in the area. In doing so, both maritime and land logistics networks should be established connecting each other and various enterprises need to extend their businesses in Eurasia and NSR where required.

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