Research Highlight 1: Game Analysis of Port Dangerous Goods Management Based on Creating Shared Value, by Visiting Scholar Associate Professor Han Zhen (Track Leader: Professor MENG Qiang)

Background

In recent years, the sudden and serious accidents about port dangerous goods occurred frequently in China, such as the massive explosion of oil storage tank at Dalian Port on July 16, 2010, the massive explosion of Sinopec oil storage and transportation pipeline at Qingdao Port on November 22, 2013, and the massive explosion of dangerous cargo at Tianjin Port on August 12, 2015. Generally speaking, we can see that, with the development of ports, the requirements of safety and environmental protection become more and more important in China. It becomes a hot topic in China on how to effectively manage dangerous goods and avoid events happening again.

Why did these safety incidents happen frequently in China? In this study, we found that most of these accidents are resulted from the problems in safety management. The reasons come from two aspects. Firstly, Government Regulators have some undefined and unclear responsibilities, which lead to many management issues occurring frequently in this condition such as Multi-Thread Management and Blind Spots Management. Secondly, some Port Corporations pay more attention to profit but ignore the public safety and Corporate Social Responsibility. In general, the primary function of the government is to pursue the maximization of social utility, while the ultimate goal of a corporation is to maximize the profit.

Hence, faced with the problems of Port dangerous goods management, there are three questions need to be further discussed. The first one is how to balance the relationship between the two different responsibility subjects. The second one is how to make the government supervising the public safety and protect the environment effectively. The third one is how to make the corporations fulfilling the Corporate Social Responsibility consciously.

So, three key objectives should be achieved in this paper. The first is making clear the responsibility relations between government regulators and port corporations. The Second is the evolution process of responsibility relations would be analyzed in the view of corporate social responsibility. The third is providing the evidence of decision-making for policy-makers.

Research Perspective

In this section, we consider the safety management from a new vision. In traditional perspective, safety management often is considered as a part of operation management. Because the business goal is to seek maximum profits, it often makes the corporation ignore its social responsibility that directly related to its business & product, and pays no attention to public welfare. However, the safety management of port dangerous goods often causes some social problems such as accidents of public safety, environmental pollution, etc. So it is essential to solving these issues in the framework of Corporate Social Responsibility (CSR).

In general, there are two ways to fulfill CSR. One way is to undertake CSR through own business or products. Corporations often make up for the losses of social value caused by environmental pollution or public safety issues, through their own profits directly. For example, setting and applying the Carbon tax of steel industries is a better way for behavior compensation. Another is to undertake CSR through participating in activities of charity and public welfare, which can make up for the losses of social value in an indirect way. However, in fact, most of the corporations are unwilling and passive in the course of undertaking CSR. This is a natural instinct for most of the corporations in the world. Even participating in public welfare activities, these corporations also have more or less commercial purposes.

Hence, it is necessary to find a way to make companies fulfill their CSR willingly and actively. Here we should introduce a vital concept of Creating Shared Value (CSV), which was put forward by Porter M. E, in 2011. The Shared

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value what he said is the corporate policies and practices that enhance the competitiveness of a company, while simultaneously advancing social and economic conditions in the communities in which it operates. It means that corporations should balance the relationship between profit and social values through own business or products. In a sense, that is economic value can be created by creating social value.

Based on the vision of CSV, safety management will realize four different safety levels: Qualification, Operation Safety, Public Safety, and Social Responsibility, as figure 1 shows. All of the safety levels constitute the main evaluation criteria of Safety Assessment System. Qualification and Operation Safety originate from the process of pursuing profit. Public Safety and Social Responsibility originate from the process of pursuing social value.

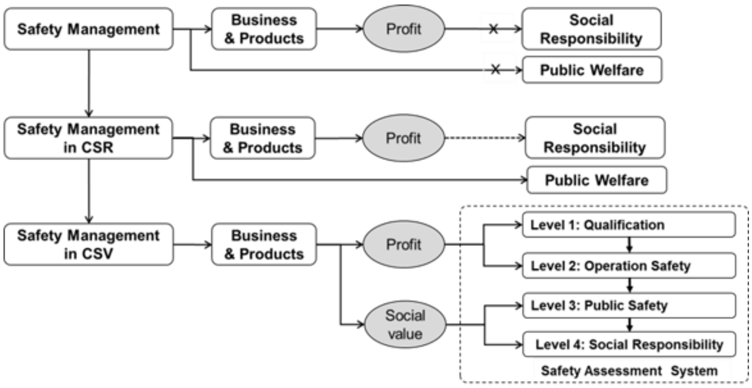

Figure 1. Research Perspective of Safety Management

Port Logistics System in General

In general, there are three subjects in a port logistics system, upstream corporations, downstream corporations, and government regulators (consisting of two departments: maritime bureau and port authority). The upstream corporations in port logistics system, including cargo owner and ship owner. Both of Cargo Owner and Ship Owner, are all creating the similar demand in the port logistics system, which can be called as port logistics demand. The demand includes two terms, logistics service demand, and port resource demand. Logistics service demand is a kind of demand for logistics activities. Port resource demand is a kind of demand for using the port facilities and hardware conditions. The downstream in port logistics system, it can be called port corporations, including two different types, port resources operators, and logistics service providers.

The demand and service process of port logistics system can be illustrated in figure 2.When the upstream order port logistics service through the agent, port resources operators will order logistics service from logistics service providers, and integrate port resources, logistics service to satisfy demand.

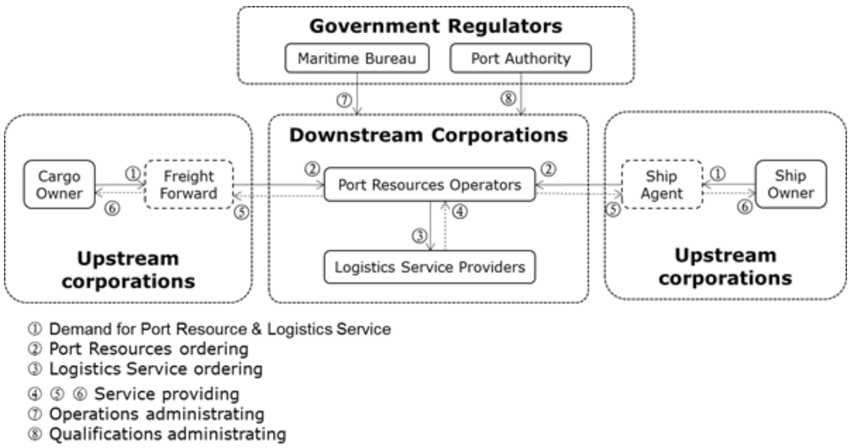

Figure 2. Analysis of Port Logistics System

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The Framework of Game Analysis

Based on the view of CSV, we can establish the framework of game analysis, which includes two games, as figure 3 shown. Firstly, game one is to make an evolutionary game analysis between Port Corporations and Government Regulators. Then, the related variables setting will be introduced to the Game two. Secondly, game two is to make two stages leader-follower game analysis. Stage one is a leader-follower game between port resources operators and logistics service providers, in which port resources operators are considered as the leader, logistics service providers are considered as the follower. Stage two is a leader-follower game between government regulators and port corporations, in which government regulators are considered as the leader, port corporations are considered as the follower.

Thirdly, we will introduce safety assessment system based on the two games. The reasons are as follows: safety assessment is the basis and standard for government supervision of port dangerous goods. It is also the guideline and reference for corporations in port dangerous goods management. Meanwhile, the safety assessment is an important variable to achieve system goals. On the one hand, it can determine the penalty and reward criteria from the government. On the other hand, it also can determine the cost and yield of the corporation. Finally, one thing needs to be clear: safety assessment should be completed by the third-party qualified organization.

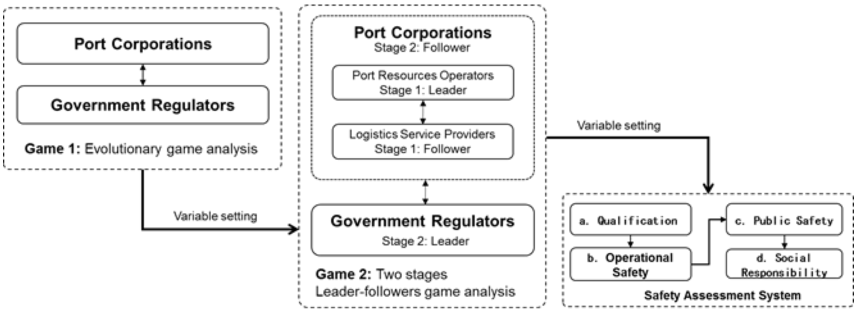

Figure 3. The Framework of Game Analysis

Evolutionary Game Analysis

In light of the above, we first construct a stylized evolutionary game model between government regulators and port corporations. Government regulators have two strategies. If the strategy of government regulators is supervising the safety management of port corporations, we describe this state as "Administrating", otherwise describe it as "NOT administrating". Port corporations have two strategies. If the strategy of port corporations is obeying the regulation of port dangerous goods management, and creating social value through its business and products, we describe this state as "Undertaking", otherwise describe it as "NOT Undertaking". We assume that the probability of government regulators taking "Administrating" is x(0≤x≤0), taking "NOT administrating" is 1-x. The probability of port corporations taking "Undertaking" is y(0≤x≤0),taking "NOT administrating" is 1-x. To facilitate our description, the

Table 4.1 Game Parameters and Decision Variables

Game Players	Strategies	Parameters/variables
Port Corporations (Corp.)	Corp.="Undertaking"	C_1: Extra costs of Corp.
		x: Positive weight of Undertake
	Corp.="NOT Undertaking"	B: Extra Benefit of Corp.
Government Regulators (Gov.)	Gov.="Administrating"	C_2: Extra costs of Gov.
		y: Positive weight of Administrate
	Corp.="Undertaking" Gov.="Administrating"	R: Reward from Gov.(Subsidy)
	Corp.="NOT Undertaking" Gov.="Administrating"	F: Fine on Corp.
	Corp.="NOT Undertaking"	M: Cost of Environmental governance

Table 4.2 Pay Off Matrix for Corporation-Government

		Corp. "Undertaking"(y)	Corp. "NOT Undertaking"(1-y)
Gov.	"Administrating"(x)	$-C_2$, $-C_1$	F-C_2-M, B-F
	"NOT Administrating"(1-x)	0, $-C_1$	$-M$, B

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Evolutionary Game Analysis

notations and decision variables used in this game are summarized in Table 1. Then the payoff matrix can be established for regulators and port corporations as Table 2 shows.

According to the payoff matrix, we can obtain the expected benefits of government "Administrating" strategy $U_{gov.\_Y} = -xC_2 + (1-x)(F - C_2 - M)$, the expected benefits of "NOT administrating" $U_{gov.\_N} = x \cdot 0 + (1-x)(-M)$, and the average expected benefits of government mixed strategy $\overline{U}_{gov.} = yU_{gov.\_Y} + (1-y)U_{gov.\_N}$. In the same way, the expected benefits of corporation "Undertaking" strategy can be obtained $U_{corp.\_Y} = y(-C_1) + (1-y)(-C_1)$, the expected benefits of "NOT Undertaking" $U_{corp.\_N} = y(B - F) + (1-y)B$, and the average expected benefits of the corporate mixed strategy $\overline{U}_{corp.} = xU_{corp.\_Y} + (1-x)U_{corp.\_N}$.

The basic idea of the dynamic game theory is to look for equilibrium states and examine their stability by establishing replicator dynamic function. The replicator dynamic function of government can be obtained as shown in Equation 1:

$$\begin{cases} F(x) = \frac{dx}{dt} = x\left(U_{corp.\_Y} - \overline{U}_{corp.}\right) = x(1-x)[yF - (B + C_1)] \\ F(y) = \frac{dy}{dt} = y\left(U_{gov.\_Y} - \overline{U}_{gov.}\right) = y(1-y)[F - C_2 - xF] \end{cases} \quad 1$$

According to Stability Principle of Differential Equations and characteristics of Evolutionary Stable Strategy (ESS), we can take the derivative of replicator dynamic function to get possible ESS points, $\frac{dF(x)}{dx} = (1-2x)[yF - (B + C1)]$ and $\frac{dF(y)}{dy} = (1-2y)(F - C2 - xF)$. As the condition of $\frac{dF(x)}{dx}|_{x=x^*} < 0$ and $\frac{dF(y)}{dy}|_{y=y^*} < 0$ is satisfied, x^* and y^* should become an ESS Points. Finally, 5 possible ESS points $E_1(0,0), E_2(0,1), E_3(1,0), E_4(1,1), E_5(\frac{F-C_2}{F}, \frac{B+C1}{R+F})$, can be found under the condition $0 \le \frac{F-C2}{F} \le 1, 0 \le \frac{B+C1}{R+F} \le 1$.

In order to judge the 5 points' state, we use the Jacoby matrix to analyze the state of each point. If the point's $\det(J) > 0$ and $tr(J) < 0$, the point can be considered as stable ESS during the process of dynamic evolution. From the table, we can see that all of the five points, from E_1 to E_5, can not meet the conditions, and are not ESS.

Table 3. System Stability Analysis

ESS	$\det(J)(>0)$		$tr(J)(<0)$		*Results*
$E_1(0,0)$	$(C_2 - F)(B + C_1)$	+ -	$C_2 + B + C_1 - F$	+ -	No ESS
$E_2(0,1)$	$(C_2 - F)(R + F - B - C_1)$	>0	$R + C_2 - B - C_1$	>0	No ESS
$E_3(1,0)$	$-C_2(B + C_1)$	0<	$B + C_1 - C_2$	+ -	No ESS
$E_4(1,1)$	$-C_2(R + F - B - C_1)$	0<	$C_2 + B + C_1 - R - F$	+ -	No ESS
E_5	$\frac{C_2(F - C_2)(B + C_1)(R + F - B - C_1)}{F(R + F)}$	>0	0	=0	No ESS

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Evolutionary Game Analysis

If we only consider the safety management of port dangerous goods as a mandate action, the safety management system will not be able to achieve a stable state. And if we consider it as a part of the corporate social responsibility, some dynamic governance strategies can be introduced to this system by the government, in which condition all of the players in the game will shoulder their own responsibilities willingly. Hence, it is necessary to introduce dynamic penalty and reward mechanism. Let Penalty variable F=f(x)=f(1-x), and reward variable R=r(x)=r(1-x), then we can get the Equation 2.

$$\begin{cases} \mathrm{F}(x) = \frac{dx}{dt} = x(1-x)[y(\mathrm{f}(x)+\mathrm{r}(x)) - (B+C_1)] \\ \mathrm{F}(y) = \frac{dy}{dt} = y(1-y)[\mathrm{f}(x) - C_2 - xf(x)] \end{cases} \qquad 2$$

Based on the above discussion, we can obtain $x* = 1 - \sqrt{\frac{C_2}{f}}$ and = $y* = \frac{B+C1}{r+f} \cdot \sqrt{\frac{f}{C_2}}$, under the condition of $0 < \frac{B+C1}{r+f} < \sqrt{\frac{C_2}{f}} < 1$. Though the Jacoby matrix, it is clearly that the point (x*, y*) meet the conditions of $\det(J)\,|_{x=x*,y=y*} = 2fx^*(1-y^*)\frac{B+C_1}{f+r}$ >0, $tr(J)\,|_{x=x*,y=y*} = -x^*$ <0. It denotes that with introducing the dynamic parameters of F and R, there will be a feasible ESS, which can make the safety management system of port dangerous goods evolve into a stable equilibrium state.

Two stages Leader-Follower Game Analysis

The results of game one indicate that if considering the safety management as a part of CSR, the safety management system will get to stable state. In the section, on the basis of the results, we consider a two-stages Leader-Follower game. Let S represent the safety level of port dangerous goods, Se is expected safety level of government. When S<Se, k_i (i=1,2) denotes the basic fine of government(k_1 :fine on the Logistics Service Providers, k_2 : fine on the Port Resources Operators). When S>Se, k_i denotes the basic reward of government (k_1 : reward for the Logistics Service Providers, k_2 : reward for the Port Resources Operators). Then we assume the function $K_i\ (s_i) = k_i \cdot (S_i - S_e)$, which K_i is closely related to $S_i - S_e$.

With introducing the three variables of S, Se, Ki, build a game analysis framework of CSV, which means Se representing the common social value can measure the degree of CSR performance through safety assessment work, and Ki as an adjustable parameter of penalty and reward, can help the system to find the ESS, make corporations and government creating the common social value together. This listing of the other variables in this game can be compared directly to Table 4.

Table 4. Decision variables of the game

Variable	Unit	
U	/	Social Utility
Q_i	TEU	Port service capability *i=1, capability of port resources* *i=2, capability of logistics service*
P	Yuan/TEU	Unit Price of dangerous goods port service
P_i	Yuan/TEU	Unit Price *i=1, Unit Price of logistics service ordering* *i=2, Unit Price of port resources ordering*
P_0	-	Price of basic fee
G	-	Class coefficient of dangerous goods
O	-	Operating coefficient
I	Yuan	Investment of port infrastructure
λ	-	Investment elasticity coefficient
A_0	TEU	Maximum of port handling capacity
A	TEU	Positive constant coefficient
M	Yuan	Marginal Cost of Environmental governance
C_i	Yuan	Unit Cost *i=1, Unit Cost of port resources* *i=2, Unit Cost of service ordering*
MC	Yuan/TEU	Marginal Cost of improving the safety levels
a_2	-	First-order coefficient
b_2	-	Second-order coefficient
S		Safety level
S_e		Expected value of safety level
k_i	Yuan	Basic administration cost $s < s_e$, Basic Fine, $i = 1,2$ *i=1, fine on the Logistics Service Providers* *i=2, fine on the Port Resources Operators* $s > s_e$,Basic Reward, $i = 1,2$ *i=1, reward for the Logistics Service Providers* *i=2, reward for the Port Resources Operators*

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Two stages Leader-Follower Game Analysis

In game theory terms, the Stackelberg leadership model is a classic strategic game for solving optimization problems in economics, in which the leader moves first and then the follower move sequentially. According to the Stackelberg games, we try to model three player's behavior. In the first stage, we firstly model the behavior of logistics service providers and get the expression of π_2, as shown in the Equation3.

$$\pi_2 = (P_2 - C_2) \cdot Q_2 - Q_2 \cdot \int_0^s MC_2(s)ds + Q_2 \cdot K_2(s) \quad 3$$

In general, the actual charges of port consist of three parts, the price of basic fee P_0, the class coefficient of dangerous goods G, and operating coefficient O. So the price function $p(Q)$ can be expressed as $P_i(Q) = Q \cdot P_0 \cdot G \cdot O \; (i = 1,2)$. Where P_1 denotes the unit price of logistics service order, which can be described as *labor costs in logistics services*, P_2 denotes the unit price of port resources ordering, which can be described as the payback of port investment. Accordingly, the price function $p(Q)$ also can be expressed by $p(Q) = \sum_{i=1}^{2} P_i(Q)$. MC_2 denotes marginal cost of improving the safety levels, which is a quadratic function of S. Let $\frac{\partial \pi_2}{\partial S} = 0$, then the follower's optimal safety level can be obtained as $s^* = \frac{\sqrt{4k_2 b_2 + a_2^2} - a_2}{2b_2}$.

Secondly, as stage one's leader, the behavior of port resources operators can be modeled in the Equation4.

$$\pi_1 = P_1 \cdot Q_1 - I - Q_1 \cdot C_1 + Q_1 \cdot K_1(s) \quad 4$$

Now we introduce the Cobb–Douglas production function, which is a particular function in economics, to describe the nonlinear increasing relation between investment of port infrastructure (Facilities and resources) and port service capability. Let $I = \left(\frac{A_0 - Q_1}{A}\right)^{-\frac{1}{\lambda}}$, A_0 is maximum of port handling capacity, which satisfy with $Q_1 < A_0$, and λ is the elasticity coefficient of investment, the larger λ is, the larger influence. Let $\left.\frac{\partial \pi_1}{\partial Q_1}\right|_{s=s^*} = 0$, then the leader's optimal service capability is $Q_1^* = A_0 - \frac{1}{\lambda} \cdot (A\lambda)^{\frac{1}{1+\lambda}} \cdot \left[P_1 - C_1 + k_1\left(s^* - s_e\right)\right]^{\frac{-\lambda}{1+\lambda}}$.

Finally, as stage two's leader, the behavior of Government can be described as the social utility modeled in the Equation 5.

$$U = \sum_{i=1}^{2} \pi_i + \int_0^Q P(Q)dQ - P(Q) \cdot Q - \sum_{i=1}^{2} Q_i K_i - QM(S) \quad 5$$

We assume the social utility including four parts, benefit from corporations, consumer surplus, cost of administration,

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Two stages Leader-Follower Game Analysis

and cost of environmental governance. Consumer surplus is expressed as $\int_0^Q P(Q)dQ - P(Q)\cdot Q$ .And M was defined as the marginal cost of environmental governance for dangerous goods. Our ultimate goal of optimization is to maximize the social utility, as Equation 6 shown.

$$\underset{S^*,Q^*}{MaxU} \quad s.t. \begin{cases} MaxU = \sum_{i=1}^{2} \pi_i + \int_0^{Q^*} P(Q)dQ - P(Q^*)\cdot Q^* + Q^* \sum_{i=1}^{2} K_i(S^*) \text{-} Q^* M(S^*) \\ Q^* = Q_1^* \\ 0 \le S_e \le S^* \le 1 \end{cases} \quad 6$$

According to the charge standard of container dangerous goods of Dalian Port, China, we set P1 and P2.With 25% Profit Margin (It is to be clear that 25% is the average profit margin in the service industry), C1 and C2 also can be estimated. Other parameters are based on the size of the total.

Table5. Variables of the Illustrative Examples

Parameter/ Variable	Unit	Value	Parameter/ Variable	Unit	Value
S_e		[0,1]	A	-	10^8
k_2	Yuan	*240*	λ	-	0.5
k_1	Yuan	*1000*	C_1	Yuan	*150*
a_2	-	20	P_2	-	2700
b_2	-	300	C_2	Yuan	*2000*
A_0	TEU	5*10^5	P_1		200

In fact, Se represents the standard of shared social value, which government expects corporations to realize. So we need to discuss corporations behavior through analyzing Se.

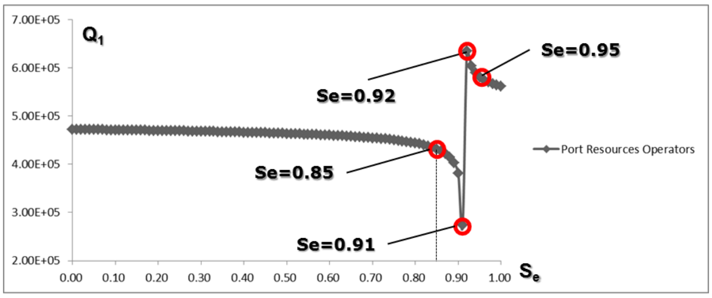

Figure 4. Trend Chart of Q1 with Different Se

As the Figure 4 shows, Q1 curve exists a turning point when Se=0.91. When Se>=0.91, the safety management system (with Q1 port service capability) is in safety level 3 and level 4,which means that the corporations begin to fulfill CSR with its own business. If Se <0.85,thesystem is in the safety level 1. If 0.85 < Se < 0.91, the system is in the safety level 2.If 0.92 <Se < 0.95, the system is in the safety level 3.If Se >0.95, the system is in the safety level 4.

In order to further analyze the influence factor of S, we compare trends in k2, a2,b2, and S as Figure 5 shown.

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Two stages Leader-Follower Game Analysis

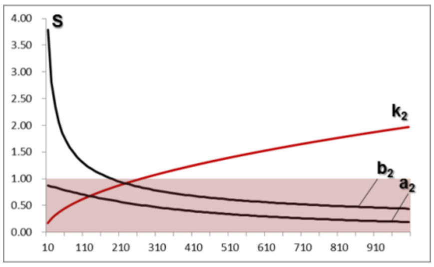

Figure 5. Comparing trends in k2, a2,b2, and S

In fact, a2 and b2 are determined by the internal behavior of corporations, and k2 is determined by government regulators, which can be adjusted and changed flexibly through decision making. So we choose K2 to observe the regulation effect of variables, set K2’s adjustment interval in [200,320] with the condition of Se=0.93.

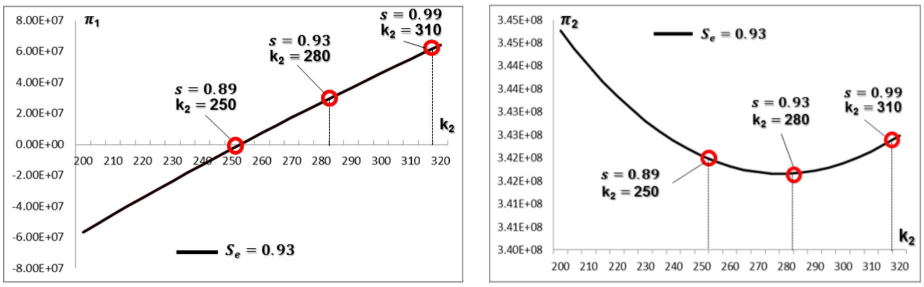

Figure 6. Returns and Profits with Different k2 Values

As Figure 6 shown, when k2 change in the interval of [250,310], the Port Resources Operators can get positive returns and profits. When k2 >280, meanwhile s>0.93, $\pi 1$ and $\pi 2$ will form growth trend together.

Conclusion

In summary, the research results show that the vision of CSV is suited for management of Port Dangerous Goods. When the issue of safety management is regarded as a kind of Corporate Social Responsibility and Shared Value, the game between Port Corporation and Government can evolve into a stable state. Meanwhile, with introducing Dynamic Penalty and Reward variables, the ESS can be found, which will be in a win-win situation for both sides.

Finally, we can consider S* as the main result of safety assessment work, It is determined by the decision of the logistics provider. The demand for Q1* is determined by the decision of port resource provider. Se and K2 are the main tools and means in safety governance, which reflected in the government’s expectations of Social Responsibility for Corporate.

Research Highlight 2: Big Data Analysis to Marine Traffic through the Boundary of the Singapore Strait, by Dr. Yang Jiasheng (Track Leader: Professor MENG Qiang)

Problem Statement

The Singapore Strait is one of the most important waterways in the world as it forms the main shipping route between the Indian Ocean and the Pacific Ocean. With the continuous growth in world trade, marine traffic flow has tremendously increased in Singapore Strait in the past decades. In addition, ship sizes have also steadily enlarged as the economies of scale achieved through the deployment of larger ships help to reduce operating costs. Ship's manoeuvrability and controllability behaviour is significantly affected by its size. It is believed that the traffic characteristics in Singapore Strait will be potentially varied with size and density distribution of ships arriving at the Strait, which maritime authorities will be very interested in for marine traffic management.

Objectives

In this study, our objective is to investigate ship traffic characteristics with the consideration of ship size. We classify all ships into two types based on ship length: small ship and large ship. Thus, ship headway can be divided into four types based on the follower-leader pattern: small ship-small ship (S-S), small ship-large ship (S-L), large ship-small ship (L-S), large ship-large ship (L-L). Then the spatial-temporal analysis of traffic flow arriving at Singapore Strait is statistically carried out by studying arrival time, lateral distribution and time headway of ship traffic flow. The analysed results demonstrate its potential application in strait capacity estimation and maritime simulation studies.

Data Collection

Since 31 December 2004 all ships over 300 GT in international voyages, all cargo ships over 500 GT and all passenger ships are required to equip AIS. Through VHF radio, AIS information can be exchanged between stations (ship and coastal). It includes static information and dynamic information. 19 days AIS data (from 1th Oct. 2013 to 19th Oct. 2013) collected from official AIS database are used in this study, which cover the main waterways of Singapore Straits with Longitude from 103.6 to 104.3, as shown in Figure 1. Since AIS data does not contain the ship characteristics like ship dimensions, these ship characteristics could be further searched from online ship database based on ship MMSI number, which is a unique registration number of each ship.

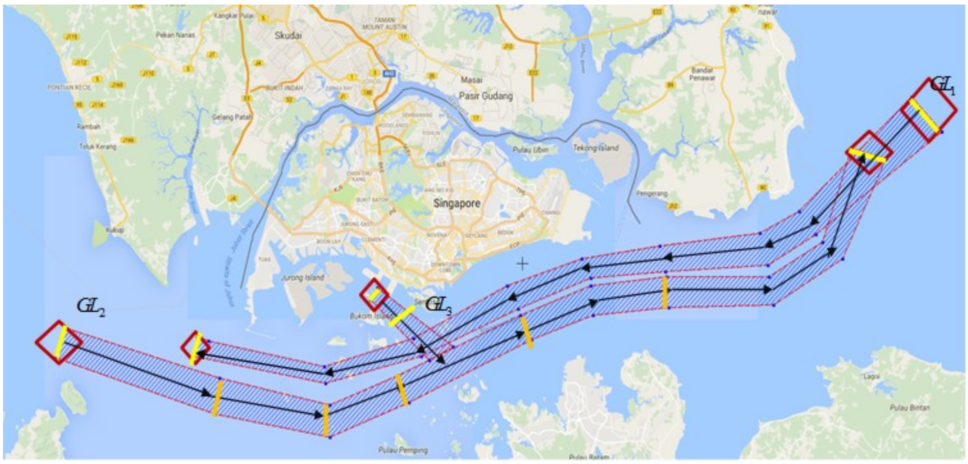

Figure 1. The Singapore Strait

Methodology

In order to consider ship dimension effect in the study, we classify all ships into two types based on their length: Small ship (S) and Large ships (L). Figure 2 illustrates the ship length distribution in Straits (based on 2013 October AIS data). After the statistical analysis, we divide the ship scale into two equal segments based on their length: small ship represents all ships with the length between 21 m to 192 m; large ship represents all ships with the length between 192m

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Methodology

and 367 m. Thus, according the follower-leader pattern, ship headway could further be classified into four types as: small ship-small ship (S-S), Small ship-Large ship (S-L), Large ship-Small ship (L-S), Large ship-Large ship (L-L).

In the headway distribution analysis, the median values of the ship headways are first calculated for each type of headway. Mann-Whitney nonparametric tests are then carried out to validate whether the median headway for each type differs statistically with ship dimension. Furthermore, four commonly used probability models, namely lognorm, norm, weibull and inverse gauss, for each headway types is fitted to the observed vessel headways along each gate line. The maximum likelihood estimation (MLE) technique is applied to predict optimal distribution parameters for each type of headway. After that, a goodness-of-fit K-S test is carried out for the selection of the best-fitted model, which has a lowest K-S test statistics. In this study, we choose the significant level $\alpha = 0.05$ as the critical value. The similar statistic procedures are further used in the analysis of arrival and lateral distribution on the gate lines.

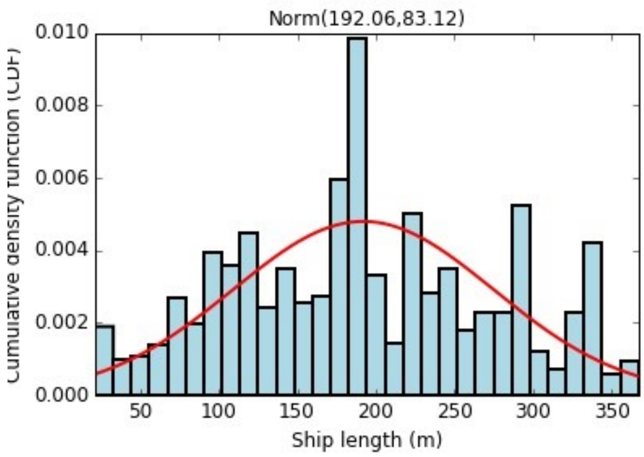

Figure 2. Ship Dimension Distribution in the Singapore Strait

Results

1. In the Table 2, one can see that lateral distributions of small ship and large ship flows on gate line 1 have the close mean values, but small ship flow has the larger standard deviation than large ship flow. It means that small ships travel in the wider waterway than large ships in the Singapore Strait. The reason behind this phenomenon could be that small ships have small draught, better manoeuvrability and controllability in the shallow waterway like Singapore Strait.

2. Table 3 gives the non-parametric test results for each of the four headway types. As show in Table 3, the S-S, S-L, L-S, L-L median headways are generally different with each other. It could be observed that L-L headway is normally larger than S-S headway, and L-N headway are normally larger than N-S headway. It is probably because the captains on large ships take a more conservative attitude to manoeuver ships when traveling in the Singapore Strait due to the relatively poor maneuverability of large ships in the shallow waterway.

3. The goodness-of-fit test for each distribution is conducted by K-S testing technique with 5 percent significant level. In the test, we choose the distribution model to make the lowest K-S statistic value as the best fit model. Table 4 illustrates the best fitted headway distributions with the estimated parameters, the K-S test statistic values and p-values. It is observed that inverse gauss and lognorm are those two distributions better to fit ship headway data.

Research Highlight 2: Big Data Analysis to Marine Traffic through the Boundary of the Singapore Strait, by Dr. Yang Jiasheng (Track Leader: Professor MENG Qiang)

Results

Table 2. Sample Size and Statistical Parameters of Lateral Distribution on the Gate Lines

Gate line	Ship type	Sample size	Mean (km)	Median (km)	SD (km)	Mode (km)	Skew (km)	Kurtosis (km)
1	S	1305	2.88	2.62	1.37	2.62	0.19	9.30
1	L	816	2.78	2.70	0.74	2.69	0.13	26.98
2	S	877	3.28	3.18	0.55	3.11	0.30	10.48
2	L	652	3.42	3.31	0.44	3.27	-	-
3	S	1344	0.87	0.91	0.31	1.05	-0.57	1.36
3	L	225	0.76	0.72	0.24	0.64	0.49	7.51

Table 3. Non-parametric Statistical Analysis for Different Headway Types

Gate line	Headway type	Sample size	Median (minutes)	Mann-Whitney test (p-value)		
				S-L	L-S	L-L
1	S-S	398	16	0.33	0.07	0.00
s1	S-L	269	16		0.17	0.01
1	L-S	272	18			0.07
1	L-L	217	19			
2	S-S	302	15	0.18	0.26	0.20
2	S-L	205	14		0.41	0.05
2	L-S	210	14			0.07
2	L-L	159	16			
3	S-S	525	14	0.22	0.01	0.05
3	N-L	104	14		0.14	0.13
3	L-S	119	16			0.36
3	L-L	29	18			

Table 4. Estimated Parameters of the Fitted Distribution for Ship Headway on the Gate Lines

Headway type	Distribution type	Parameters				k-s value	p-value	Best fit
S-S	lognorm	0.3	-16.4	32.3		0.062	0.09	invgauss
	norm	17.4	10.1			0.082	0.01	
	Weibull	93.2	1.5	-46.2	21.5	0.062	0.09	
	invgauss	0.2	-10.6	185.9		0.059	0.12	
S-L	lognorm	0.3	-10.7	26.7		0.063	0.23	invgauss
	norm	17.6	9.6			0.099	0.01	
	Weibull	0.5	2.9	0.9	25.4	0.065	0.19	
	invgauss	0.1	-10.2	216.0		0.062	0.24	
L-S	lognorm	2.6	0.0	1.6		0.608	0.00	invgauss
	norm	18.6	10.2			0.098	0.01	
	Weibull	1.9	0.3	0.0	1.8	0.532	0.00	
	invgauss	0.1	-14.7	322.2		0.076	0.08	
L-L	lognorm	0.2	-40.2	59.2		0.077	0.14	lognorm
	norm	19.9	9.8			0.100	0.02	
	Weibull	0.0	23.1	2.0	35.5	0.078	0.13	
	invgauss	0.0	-27.9	1075.4		0.080	0.12	

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Conclusion

This study carries out an analysis of temporal-spatial distribution of ship traffic flow on the boundary of Singapore Strait with the use of big AIS data. In order to consider the effect of ship size, all the ships in the Singapore Strait are classified into two types based on their ship length. It is found that small ships come to Singapore Strait uniformly, but large ships arrive at Singapore Strait basically with the normal distribution, and their peak hour is generally day time. In addition, it is also noted that lateral distributions of ship traffic flow are different on the different gate lines. The main route used by ship traffic flow may not be the deepest water route.

Furthermore, time headway is analyzed based on the follower and leader ship types. The non-parametric Mann-Whitney test demonstrates the median difference of time headway with ship dimension. Then a useful methodology is applied to determine the best-fit distribution for each headway type in the different gate lines. It is found that inverse gauss distribution is the most appropriate statistic distribution for all of the headway types of marine traffic flows.

Published Technical Papers (with Abstracts)

1. **Haobin Li, Giulia Pedrielli, Loo Hay Lee, Ek Peng Chew (2017), Enhancement of supply chain resilience through inter-echelon information sharing. *Flexible Services and Manufacturing Journal, Volume 29, Issue 2, Pages 260-285.***

Abstract:

Supply chains in the globally interconnected society have complex structures and thus are susceptible to disruptions such as natural disasters and diseases. The impact of the risks and disruptions that occur to one business entity can propagate to the entire supply chain. However, it has been proposed that cooperation amongst business entities can mitigate the impact of the risks. This paper aims to investigate the value of information sharing in a generalized three-echelon supply chain. The supply chain model is built in a system dynamics software, and three decision-making rules based on different levels of information sharing are developed. Performances of the three ordering policies with shock applied are compared. The results of the experiments prove the value of information sharing in the supply chain when shock exists.

2. **Yuan Wang, Xinjia Jiang, Loo Hay Lee, Ek Peng Chew, Kok Choon Tan (2017), Tree based searching approaches for integrated vehicle dispatching and container allocation in a transshipment hub. *Expert Systems with Applications, Volume 74, Pages 139-150.***

Abstract:

This study addresses the integration of Vehicle dispatching and container storage location problem with consideration of loading and unloading activities simultaneously. A MIP model is formulated to describe the interrelation between vehicle scheduling, yard crane scheduling and container storage location. A tree structure is used to represent the whole solution space. This representation has a good property as it captures the neighborhood structure and enhances the performance of local search and adaptive searching algorithms. Three variants of tree based searching approaches are developed, namely, the Nested Partitions method (NP), the Beam Search method (BS), and Stochastic Beam Search method (SBS). Extensive experiments show that these proposed methods can find a promising solution in matter of seconds for a practical problem and the Stochastic Beam Search method (SBS) method performs nearly as well as Nested Partitions method (NP) while gaining great computational efficiency. Due to this merit, SBS method is suggested to solve real time integrated vehicle dispatching problem in a relative large scale and may applied in other real time complex system scheduling.

3. **Hui Xiao, Siyang Gao, Loo Hay Lee (2017), Simulation budget allocation for simultaneously selecting the best and worst subsets. *Automatica, Volume 84, Pages 117-127.***

Abstract:

Motivated by the practical needs in simulation optimization, this paper considers the problem of selecting the best m and worst n designs from a total of k alternatives based on their mean performance values, which are unknown and can only be estimated via simulation. In order to improve the efficiency of simulation, this research characterizes an asymptotically optimal allocation of simulation replications among the k designs such that the probability of correctly selecting the best m and worst n designs can be maximized, and develops a corresponding selection procedure for implementation purpose. The efficiency of the proposed procedure is demonstrated via numerical experiments.

Published Technical Papers (with Abstracts)

4. **Siyang Gao, Loo Hay Lee, Chun-Hung Chen, Leyuan Shi (2017), A sequential budget allocation framework for simulation optimization.** ***IEEE Transactions on Automation Science and Engineering, Volume 14, Issue 2, Pages 1185-1194.***

Abstract:

Singapore Many problems in automation and manufacturing are most suitable to be modeled as simulation optimization problems. Solving these problems typically involves two efforts: one is to explore the solution space, and the other is to exploit the performance values of the sampled solutions. When the amount of computing budget is limited, we need to know how to balance these two efforts in order to obtain the best result. In this study, we derive two measures to quantify the marginal contribution of exploring the search space and exploiting the performance values. A sequential budget allocation framework is designed by keeping the two measures approximately the same at each iteration. Numerical experiments on both continuous and discrete simulation optimization problems demonstrate that our new approach can significantly enhance the computing efficiency.

5. **Liye Zhang, Qiang Meng, Tien Fang Fwa (In Press), Big AIS data based spatial-temporal analyses of ship traffic in Singapore port waters.** ***Transportation Research Part E: Logistics and Transportation Review.***

Abstract:

This study develops a tangible analytical approach to analyze ship traffic demand and the spatial–temporal dynamics of ship traffic in port waters using big AIS data. By applying the developed approach to the Singapore port waters, we find that the origin-to-destination pairs and navigation routes in the Singapore port waters keep stable over time. Furthermore, there are several hotspot areas in the Singapore Strait where ship sailing speeds are relatively high and ship sailing speeds in a few water areas vary greatly. More interestingly, we find that these hotspot areas well coincide with the spatial distribution of ship accidents.

6. **Bojian Zhou, Min Xu, Qiang Meng, Zhongxiang Huang (2017), A day-to-day route flow evolution process towards the mixed equilibria.** ***Transportation Research Part C: Emerging Technologies, Volume 82, Pages 210-228.***

Abstract:

This study investigates a travelers' day-to-day route flow evolution process under a predefined market penetration of advanced traveler information system (ATIS). It is assumed that some travelers equipped with ATIS will follow the deterministic user equilibrium route choice behavior due to the complete traffic information provided by ATIS, while the other travelers unequipped with ATIS will follow the stochastic user equilibrium route choice behavior. The interaction between these two groups of travelers will result in a mixed equilibrium state. We first propose a discrete day-to-day route flow adjustment process for this mixed equilibrium behavior by specifying the travelers' route adjustment principle and adjustment ratio. The convergence of the proposed day-to-day flow dynamic model to the mixed equilibrium state is then rigorously demonstrated under certain assumptions upon route adjustment principle and adjustment ratio. In addition, without affecting the convergence of the proposed day-to-day flow dynamic model, the assumption concerning the adjustment ratio is further relaxed, thus making the proposed model more appealing in practice. Finally, numerical experiments are conducted to illustrate and evaluate the performance of the proposed day-to-day flow dynamic model.

Published Technical Papers (with Abstracts)

7. **Yadong Wang, Qiang Meng, Zhijia Tan (2017), Short-term liner shipping bunker procurement with swap contracts.** ***Maritime Policy & Management, Pages 1-28.***

Abstract:

The bunker price fluctuations in recent years have severely threatened the stability of liner shipping companies' operations. As an efficient countermeasure, the swap contract is widely adopted throughout the liner shipping industry to hedge the procurement risk resulting from the bunker price fluctuation. This paper looks at the short-term liner shipping bunker procurement problem with swap contracts (BPPSC), aiming to optimally plan the amount of bunker purchased from the spot market and the amount hedged by the swap contract for several months ahead. This BPPSC is first formulated as a bunker procurement cost mean-variance minimization (MVM) model, and is subsequently solved using a tangible two-step approach developed in this study. In the first step, the movements of the swap contract price and the spot market price of the bunker are described using a calibrated multivariate generalized autoregressive conditional heteroskedasticity (mGARCH) time series model. In the second step, the MVM model is approximated and solved by a price scenario tree constructed from the mGARCH time series model. A numerical example shows that the risk hedging strategy obtained can simultaneously control the bunker procurement cost as well as the procurement risk from price fluctuations.

8. **Ruiming Tang, Antoine Amarilli, Pierre Senellart, Stéphane Bressan (2017), Get a sample for a discount: sampling-based XML data pricing.** ***Retrieved from osf.io/5y84h***

Abstract:

While price and data quality should define the major trade- off for consumers in data markets, prices are usually prescribed by vendors and data quality is not negotiable. In this paper we study a model where data quality can be traded for a discount. We focus on the case of XML documents and consider completeness as the quality dimension. In our setting, the data provider offers an XML document, and sets both the price of the document and a weight to each node of the document, depending on its potential worth. The data consumer proposes a price. If the proposed price is lower than that of the entire document, then the data consumer receives a sample, i.e., a random rooted subtree of the document whose selection depends on the discounted price and the weight of nodes. By requesting several samples, the data consumer can iteratively explore the data in the document. We show that the uniform random sampling of a rooted subtree with prescribed weight is unfortunately intractable. However, we are able to identify several practical cases that are tractable. The first case is uniform random sampling of a rooted subtree with prescribed size; the second case restricts to binary weights. For both these practical cases we present polynomial-time algorithms and explain how they can be integrated into an iterative exploratory sampling approach.

9. **Qiang Meng, Xinchang Wang (2017). Intermodal network design for cargo transportation under intermodal operators' route choice behavior.** ***Transportation Research Part B: Methodological, Volume 95, Pages 76-104.***

Abstract:

We consider a discrete intermodal network design problem for freight transportation, in which the network planner needs to determine whether or not to build up or expand a link to minimize the total operating cost of carriers and hub operators under a general route choice model of intermodal operators. We formulate the problem as a mixed-integer nonlinear and non-convex program that involves congestion effects, piecewise linear cost functions, and a fixed-point constraint. We develop a series of relaxed and equivalent models to reduce the hardness of the problem and provide theoretical results to show the equivalences. We present two solution methods to solve the problem with one returning heuristic solutions and the other generating a globally optimal solution. We offer two numerical experiments to test the two solution algorithms and also shed light on their performance comparisons.

Conference Papers (with Abstracts)

1. **Ashish Dandekar, Remmy AM Zen, Stéphane Bressan (2017), Generating fake but realistic headlines using deep neural networks.** ***In proceedings of International Conference on Database and Expert Systems Applications. 28-31 August, 2017, Lyon, France.***

Abstract:

Social media platforms such as Twitter and Facebook implement filters to detect fake news as they foresee their transition from social media platform to primary sources of news. The robustness of such filters lies in the variety and the quality of the data used to train them. There is, therefore, a need for a tool that automatically generates fake but realistic news.

In this paper, we propose a deep learning model that automatically generates news headlines. The model is trained with a corpus of existing headlines from different topics. Once trained, the model generates a fake but realistic headline given a seed and a topic. For example, given the seed "Kim Jong Un" and the topic "Business", the model generates the headline "kim jong un says climate change is already making money".

In order to better capture and leverage the syntactic structure of the headlines for the task of synthetic headline generation, we extend the architecture - Contextual Long Short Term Memory, proposed by Ghosh et al. - to also learn a part-of-speech model. We empirically and comparatively evaluate the performance of the proposed model on a real corpora of headlines. We compare our proposed approach and its variants using Long Short Term Memory and Gated Recurrent Units as the building blocks. We evaluate and compare the topical coherence of the generated headlines using a state-of-the-art classifier. We, also, evaluate the quality of the generated headline using a machine translation quality metric and its novelty using a metric we propose for this purpose. We show that the proposed model is practical and competitively efficient and effective.

2. **Qing Liu, Debabrota Basu, Shruti Goel, Talel Abdessalem, Stéphane Bressan (2017), How to Find the Best Rated Items on a Likert Scale and How Many Ratings Are Enough.** ***In proceedings of International Conference on Database and Expert Systems Applications. 28-31 August, 2017, Lyon, France.***

Abstract:

The collection and exploitation of ratings from users are modern pillars of collaborative filtering. Likert scale is a psychometric quantifier of ratings popular among the electronic commerce sites. In this paper, we consider the tasks of collecting Likert scale ratings of items and of finding the n-k best-rated items, i.e., the n items that are most likely to be the top-k in a ranking constructed from these ratings. We devise an algorithm, Pundit, that computes the n-k best-rated items. Pundit uses the probability-generating function constructed from the Likert scale responses to avoid the combinatorial exploration of the possible outcomes and to compute the result efficiently. Selection of the best-rated items meets, in practice, the major obstacle of the scarcity of ratings. We propose an approach that learns from the available data how many ratings are enough to meet a prescribed error. We empirically validate with real datasets the effectiveness of our method to recommend the collection of additional ratings.

3. **Chun Ming Tommy Yip, Woei Wan Tan, Maowen Nie (2017), Effect of different FOU shapes on the performance in interval type-2 fuzzy PI control systems.** ***In proceedings of Fuzzy Systems (FUZZ-IEEE), 2017 IEEE International Conference on Fuzzy Systems. 9-12 July, 2017, Naples, Italy.***

Abstract:

The control performance of type-2 fuzzy logic controller (IT2-FLCs) is heavily dependent on the choice of antecedent and consequent sets. However, there are no clear guidelines on how to choose suitable FOU shape to achieve the desired control requirements. This paper aims to explore how differences in FOU shapes affect the control performance by analysing three different types of antecedent fuzzy sets. They are the triangular top wide, triangular bottom wide and the trapezoidal fuzzy sets. Analytical structures of these controllers are derived. The analytical structures of the triangular bottom wide and trapezoidal controllers show more common features than triangular top wide controller. Based on the characteristics of the analytical structure, it may be hypothesised that the control performances of IT2-FLCs that use triangular bottom wide and trapezoidal antecedent IT2 fuzzy sets would be more similar than an IT2-FLC constructed by triangular top wide antecedent IT2 fuzzy sets. The hypothesis is then verified by simulation results.

4. **Zhou Chenhao, Stephen Aloisius, Li Haobin, Lee Loo Hay, Chew Ek Peng (2017), Information Based Approach for Sort Operation in Logistic Industry (I).** ***In proceedings of 13th Conference on Automation Science and Engineering, 20-23 August, 2017, Xi'an China.***

Abstract:

With the explosive increase of e-commerce in Singapore, a world-leading logistic company has to sort thousands of packages to specific vehicles before dawn and then deliver to customers by noon every day, and thus, the operation efficiency becomes the key competitive indicator. As in the era of Industry 4.0, we aim to explore and utilize the data passing through the operations to improve the package sorting operation, which currently is purely based on First-Come-First-Serve strategy. Upon observation of the current operation, there are two major challenges, which are to: (1) reduce the sort operation duration, effectively reducing under-utilization of workstations and personnel, and to (2) minimize the waiting time for route fulfilment in order to reduce congestion at the loading bay. To tackle the problem, this study proposes an information based approach to determine the handle sequence of ULDs based on three metrics: the ULD ready time, the ULD processing time, and the ratio of the packages to routes on standby. The numerical experiment has shown that the proposed approach shaves off 10% of the sort operation duration, which equates to an annual reduction of about 2500 man-hours.

5. **Wang Yuan Jessica, Lee Loo Hay, Chew Ek Peng, Capacitated Competitive Facility Location Problem of Self-Collection Lockers by Using Public Big Data (I).** ***In proceedings of 13th Conference on Automation Science and Engineering, 20-23 August, 2017, Xi'an China.***

Abstract:

The growth of E-commerce has been an unstoppable force that has created increasing complexity in many supply chains. Other than the volume of demand, the expectations of customers are maturing, forcing many Third-Party Logistics (3PLs) to improve their delivery capabilities to stay relevant in the market.

Self-collection lockers as a deliver option has been a trend that is increasing popular in many countries. Many literature have studied and analysed its benefits as compared to traditional home deliveries. However, there is a gap in the literature regarding the analysis of such facility's locations. Currently no literature on facility problems covers the area of self-collection lockers by using public data. Using Singapore as an example, this paper will aim to construct a mathematical model to determine the optimal allocation of lockers based on urban big data.

The problem will be constructed as a Capacitated p-Maximal Coverage Location Problem (p-MCLP) in a competitive environment. There are few literatures that employ a mathematical model to solve a Capacitated p-MCLP with competition. Most mathematical models address the issue of capacity and competition separately and heuristics is employed to address both conditions. In this paper,3 models (un-capacitated, capacitated, capacitated with competition) are proposed and results from them are further analysed. In addition, various sensitivity analysis are

conducted to explore the effect of different parameters in the model. While this study is specific to the application of self-collection locker network, the model can be applied to other applications that have similar characteristics. The current use of this model could help 3PLs decide the locations to place their facilities when entering the market.

CMS Research Seminars

1. The Research of Car-Hailing APP's Business Models Based on Organizational Legitimacy, by Visiting Scholar Associate Professor Han Zhen (Track leader: Professor Meng Qiang)

Seminar Abstract:

Since 2014, E-Hailing car Platform (EHP) has always been a hot topic in society.

EHP's innovative activities rely on how to Motivate, Get, Integrate, and Use the Social Resources. It easily leads to more uncertainty for social public in the fields of Value, Regulation, and Cognition. These uncertainties will cause series of issues, which we can call "Issues of Organizational Legitimacy". Therefore, it is necessary to analyze the existing EHP's business models from the perspective of organizational legitimacy.

From three aspects, Pragmatic Legitimacy, Moral Legitimacy and Cognitive Legitimacy, we can rank the existing EHP's business models to Analyze business trends. The results indicate that Private EHP's OL is lowest in three models which need to be improved through increasing ML and PL. Taxi EHP, despite improving efficiency through EHP in short term, should be disappear in long term. And Self-made will be sustainable model in long-term. Finally, some strategies would be given to help EHP making scientific decisions.

2. Benchmarking of Maritime Research, Technology, and Innovation, by Researcher Mr. Jens Paul Landkammer (Track leader: Associate Professor Chai Kah Hin)

Seminar Abstract:

The cause of this research is the demand for an approach to measure innovation, technology, and research performance in maritime capitals. Common measurement methodologies do not specify the maritime sector or maritime hubs; hence this research aims to develop a new and different approach for a benchmark. A literature review is conducted to receive information about cluster systems, gain knowledge about clusters in general. Followed by reviewing specific maritime clusters and their key aspects. The concept about benchmarking and the use of key performance indicators is reviewed. This benchmark is focusing on Singapore, China, South Korea, Japan, USA, UK, Norway, Finland, Denmark, The Netherlands, France, Germany, Italy, and Russia. Key deliverable of the research is to compare Singapore's performance in the maritime sector compared to the other leading countries based on the developed performance measurement framework with the use of patent analysis, scientific literature analysis, and expert's knowledge.

3. Fuzzy reasoned waypoint controller for the autonomous vessel in simulation system, by Researcher Mr. Gaosong (Track leader: Professor Meng Qiang)

Seminar Abstract:

In order to simulate the vessel traffic flow in the Singapore Strait, a framework of vessel traffic flow simulation based on multi-agent is established. Correctly reflecting the behaviour of the vessel in the Singapore Strait is the key part of the simulation system. The vessel collision risk assessment system based on the fuzzy inference system is established on the basis of the preliminary expert investigation. By calculated the DCPA, TCPA, bearing and VCD among all vessels in simulation system to calculate and display the degree of collision risk among all vessels, and using fuzzy controller decides the desired heading of each vessel. After getting the desired heading, as a course keeping controller, PD is used to correct the instantaneous heading. The proposed controller simplifies the total control design process and increases calculates efficient. Simulations with different sets of waypoints are carried out to justify the effectiveness of the proposed controller.

CMS Research Seminars

4. **Spatial-temporal distribution of the vessel arrivals at the boundary of the Singapore Strait, by Researcher Dr. Yang Jiasheng (Track Leader: Professor Meng Qiang)**

Seminar Abstract:

In this presentation, we investigate the spatial-temporal distribution of ship arrivals at the boundary of the Singapore Strait, where vessel headway is divided into four types: small ship-small ship, small ship-large ship, large ship-small ship, and large ship-large ship. It is confirmed that ship headway is significantly different with different ship sizes. We further statistically study the effect of different factors to ships' spatial-temporal distribution. The analysed results demonstrate its potential application in strait capacity estimation and maritime simulation studies.

5. **A Modelling Study of Global Maritime Freight Demand Forecasting, by Researcher Dr. Sou Weng Sut (Track Leader: Associate Professor Chai Kah Hin)**

Seminar Abstract:

There is a huge increase in maritime trade volume in recent decades, and in particular, most of these traded commodities are transported by seaborne containers. Forecasting of maritime container demand in the context of international trade has always been of importance to government and policy makers so that countries and regions can plan ahead (in terms of infrastructure development or policies) to remain competitive. Numerous efforts have been made in the literature to forecast container demand but most of these studies have either adopted an economic approach or the transportation perspective. Few have actually considered the forecasting of maritime container demand from an integrative economic trade-transportation modelling perspective.

This seminar therefore presents the development of a quantitative demand forecasting approach that is capable of predicting future seaborne container demand in the global context. The integrated forecasting framework follows the conventional four step approach (i.e. generation, distribution, modal split and assignment) with combining efforts from economic approach and transportation perspective.

6. **Train Station-skipping Problem and Strategies, by Researcher Dr. Kang Liujiang (Track Leader: Professor Meng Qiang)**

Seminar Abstract:

The last trains running on different lines of an urban railway network can skip some stations to improve connections and reduce operational time or costs, which is referred to as the last train station-skipping problem. This study addresses the last-train station-skipping and energy-efficient scheduling problem in the subway system by means of optimizing the subway timetable and the last train station-skipping scheme. First, an integrated last train operational model is proposed to achieve energy savings and better performances of transfer waiting and in-train travel times. Second, an LP-relaxation method, a heuristic evaluation method and a heuristic evaluation method based on a genetic algorithm are designed to solve a real-life case study of Beijing Subway to demonstrate the effectiveness of our methods. Two operational strategies (station-skipping and deadheading) for the last trains are compared. The results indicate that the station-skipping plan shows an advantage in minimizing the in-train travel time and energy consumption.

