MARINE TRAFFIC SIMULATOR AND ITS APPLICATION OF SAFETY ASSESSMENT IN HUANGPU RIVER OF SHANGHAI

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Abstract: As a main purpose of education and training for seafarers, ship handling simulators is widely introduced to maritime universities all over the world from 1980's. Later, it has been used for marine traffic safety assessment and accident case study by research institutes as well. However, be limited by its characteristics such as relatively small scale of simulation, conclusions of safety assessment by using ship handling simulator could not always be drawn properly. Under such circumstances, Marine Traffic Simulator was developed by several researchers. In previous researches it was successfully applied for marine traffic safety assessment in most congested waterways such as Osaka Bay, Tokyo Bay, Straits of Malacca / Singapore and Shanghai area. In this paper, Marine Traffic Simulator is applied in Huangpu River of Shanghai which is the future global shipping center with great growth in these years.

1. INTRODUCTION

In recent years, China has a double digits growth rate of GDP and on the other hand, Shanghai, leading role in Chinese economy, has surpassed Singapore became to be world busiest container port. Under current situation, Chinese government has set a magnificent port construction project by using the opportunity of 2010 Shanghai EXPO in order to make Shanghai the center of global shipping industry. Therefore, an increasing of traffic flow accompany with the development of Shanghai port is certainly predictable and safety assessment of waterway in Shanghai turned to be urgently required so as to ensure marine traffic in safe. Marine Traffic Simulator developed by Hasegawa Lab had successfully simulated the traffic flow in congested ports and waterways such as Osaka Bay, Tokyo Bay, Straits of Malacca and Singapore. In this paper, authors propose an application of Marine Traffic Simulation in Huangpu River of Shanghai which is an inland waterway and compose a very significant part of Shanghai Port. Safety assessment was completed under several cases considering different navigation conditions. The results were discussed by comparing numbers and places which near-miss and collision occurred.

2. MARINE TRAFFIC SIMULATOR

2.1. Structure of Marine Traffic Simulator

Briefly speaking, Marine Traffic Simulator developed by Hasegawa et al. is consists of a traffic flow generating system and an automatic navigating system. First of all, OD table is used for define the simulation area which 'OD' represents each ship's origin and destination. Between all those origins and destinations, ships are generated and eliminated just like departure and arrival. Of course, those points could be either berths or waypoints. Based on real marine traffic statistics or its arbitrary modification, ships are created and each ship is given a unique maneuverability depends on its type, length and loading condition etc. For example, well-known KT model is introduced to be one of the maneuverability parameters to decide basic ship's movement during the simulation.

On the other hand, automatic navigating system is the most extraordinary characteristic of Marine Traffic Simulator which distinguish from normal ship handling simulators. That system is a combination of fuzzy reasoning for collision risk recognition and expert system for conflict resolution for decision making. The system has been developed by Hasegawa and it was validated to work in model ship experiments as shown in Figs.1 and 2.

Fig.1 Model ship tested for collision avoidance experiment

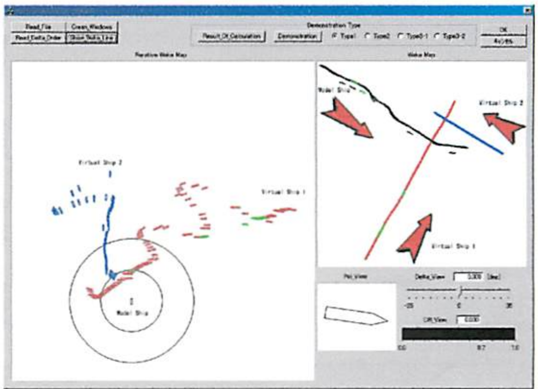
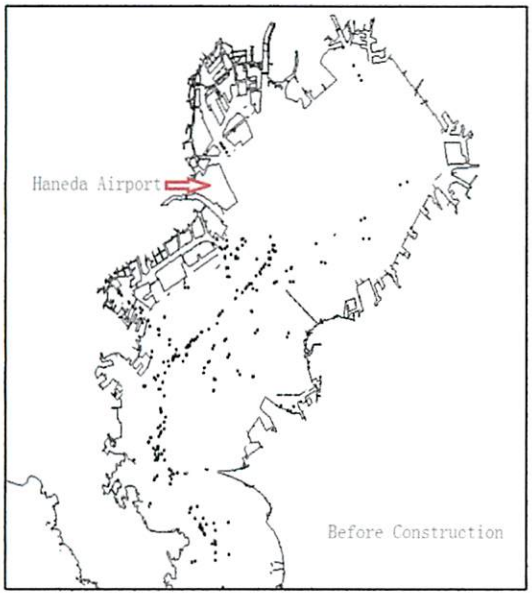


Fig.2 An sample result of automatic collision avoidance of a model ship with two other virtual target ships

2.2. Applications

As an efficient tool for marine safety assessment, Marine Traffic Simulator had been widely utilized. One example is the study for runway expansion project of Haneda Airport in Tokyo Bay which is shown in Fig.3. Numbers and area of near-miss occurred in the simulation had been considered in order to observe how great the effect will be brought after expansion construction. Thus, marine safety issue had been evaluated and reasonableness of design plan could also been judged.



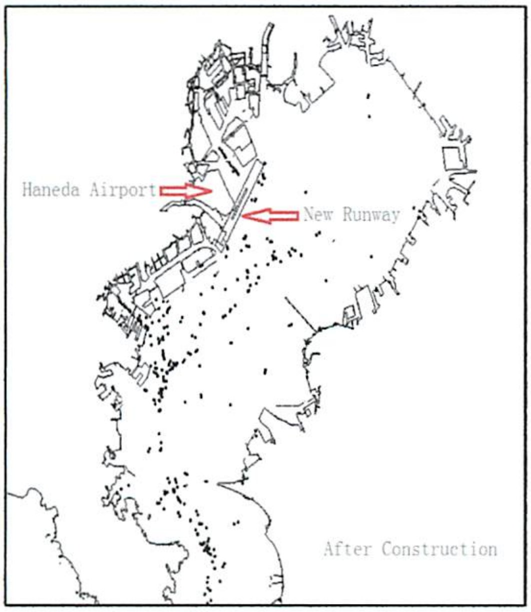


Fig.3 Near-miss points before (upper) and after (below) of runway expansion (Haneda Airport, Tokyo)

Moreover, since the simulator is modified to be easily applied for any given waterway area, such large scale simulation even in Straits of Malacca and Singapore has also been successfully conducted. Shown in Fig.4.

Fig.4 An example of marine traffic simulation in Singapore Straits

3. SIMULATION IN HUANGPU RIVER OF SHANGHAI

3.1. General Information of Huangpu River in Shanghai

Huangpu River in this paper indicates waterway of 36.3 nautical miles between Wu Song Kou (31°24'N, 121°32'E) and Min Hang Power Plant (30°59'N, 121°22'E) according to definition of Shanghai Port boundary. It is major part of Shanghai Port and has facilities for oil, bulk, chemicals, general cargo, passengers and containers.

Depths in Huangpu River are subject to continual change, but the river can be entered by any ship whose draft under 10 meters. River widths are from 280 to 530 meters and widths of navigable channel are decreased to range from 220 to 380 meters when ship within a draft of 5 meters.

A Traffic Separation Scheme is established in the approaches to Chang Jiang and Chang Jiang itself including Huangpu River which is a buoyed channel as well. Huangpu River is divided into 4 sailing lanes which from center line to west bank side are main inbound fairway for ships over 500GT or length above

50 meters and auxiliary inbound fairway for ships under 500GT or less than 50meters. While lanes close to east bank side are for outbound ships.
Following regulations apply in Huangpu River such as speed must be regulated to an upper limit of 8 knots. Furthermore, near river bends, overtaking is prohibited and meeting with other ships should be avoided.

3.2. Statistical Data of Traffic Flow

A 3-days 24-hours visual observation of traffic flow in Huangpu River had been carried on by Shanghai Maritime University in April 2009 near Wu Song Kou VTS Station shown in Fig.5. In this paper, authors refer those statistical data to set total number of transiting ships in the simulation.

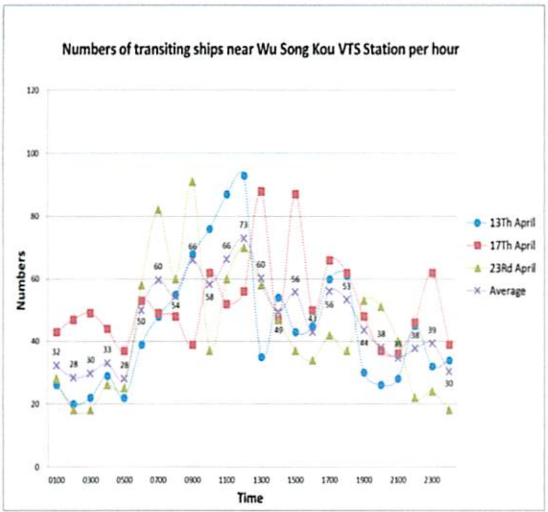


Fig.5 Numbers of transiting ships near Wu Song Kou VTS Station per hour

3.3. Setting of Input Data

3.3.1. Range of the Simulation and Navigation Route

In order to ensure the simulation is comprehensive and close to real traffic situation, this simulation's range is waterway from Wu Song Kou to Min Hang Power Plant which is the official harbor boundary. Furthermore, adjacent waterway in Chang Jiang from Liu He Kou to Wu Hao Gou is also considered so that every ship will enter into Wu Song Kou within normal speed. Besides, 85 waypoints are set in accordance with the changing of river's curvature among 36.3 nautical miles simulation area in the river that can ensure smooth navigation when ships are sailing around bending channels.

3.3.2. Ship's Type and Maneuverability Parameter

According to the AIS information provided by "Vesseltracker.com" and statistical data provided by Shanghai Maritime Safety Administration, main ships' types existing in this simulation are including general cargo ship, oil tanker, container ship, bulk carrier, passenger ship, ferry and operation ship. Thus, there are 19 types in total (shown in Table.1) after considering their loading condition. All of them have been assigned maneuverability values such as K' and T' which are based on results of past model ship experiment by Osaka University.

Ship's Type	Length	Cb	K'	T'	Time Constant of Velocity	Time Constant of Rudder	PD Controller of K	PD Controller of T
General Cargo Ship 1 Ballast	44	0.69	1.90	0.98	35	2	1.2	1.2
General Cargo Ship 1 Full	44	0.69	2.11	1.11	35	2	1.5	0.9
General Cargo Ship 2 Ballast	70	0.71	1.20	1.10	50	2	1.2	1.2
General Cargo Ship 2 Full	70	0.71	1.70	1.90	50	2	1.5	0.9
General Cargo Ship 3 Ballast	144	0.73	0.92	0.72	100	2	1.0	1.5
General Cargo Ship 3 Full	144	0.73	1.25	1.55	100	2	1.2	0.9
Oil Tanker 1 Ballast	42	0.75	0.60	0.30	35	2	1.0	1.8
Oil Tanker 1 Full	42	0.75	1.10	2.50	35	2	1.5	0.9
Oil Tanker 2 Ballast	62	0.75	0.70	0.40	50	2	1.0	1.8
Oil Tanker 2 Full	62	0.75	1.30	2.70	50	2	1.5	0.9
Oil Tanker 3 Ballast	185	0.80	0.87	0.42	170	2	1.0	1.8
Container Ship	158	0.60	1.66	2.73	150	2	1.5	0.9
Bulk Carrier 1 Ballast	145	0.78	0.88	0.98	135	2	1.2	1.2
Bulk Carrier 2 Ballast	190	0.78	0.81	1.11	180	2	1.5	1.2
Passenger Ship 1	80	0.56	0.95	1.96	70	2	1.0	0.9
Passenger Ship 2	150	0.56	1.10	1.10	140	2	1.0	1.2
Cruise	264	0.54	1.50	1.00	240	2	1.0	1.2
Ferry Boat	27	0.54	1.47	2.16	30	2	1.5	0.9
Operation Ship	80	0.60	2.07	2.06	50	2	1.5	0.9

Table.1 Ship's type and maneuverability particular

3.3.3. Reckoning of Distribution Rate

Based on statistical data of traffic flow in Fig. 6, distribution rate of ship's generation time has been decided. In addition, ferry's departure time and frequency are also been fixed by checking time schedule on homepage of ferry's company. On the other hand, ship's type and each berth's departure amount are also reckoned by comparing with real observation and information from internet.

3.3.4. Designating Condition of Several Cases

Traffic Separation Scheme has been introduced to Huangpu River and it comprises one 4 way channel throughout whole river. (See 3.1) As width of each sailing lane is always taken into account to design waterway, therefore, it is also necessary to consider it in assessing marine traffic safety by simulation. In this paper, authors suggest two possible cases which Case.1 is the real plan being applied in effect. Shown in Fig. 6

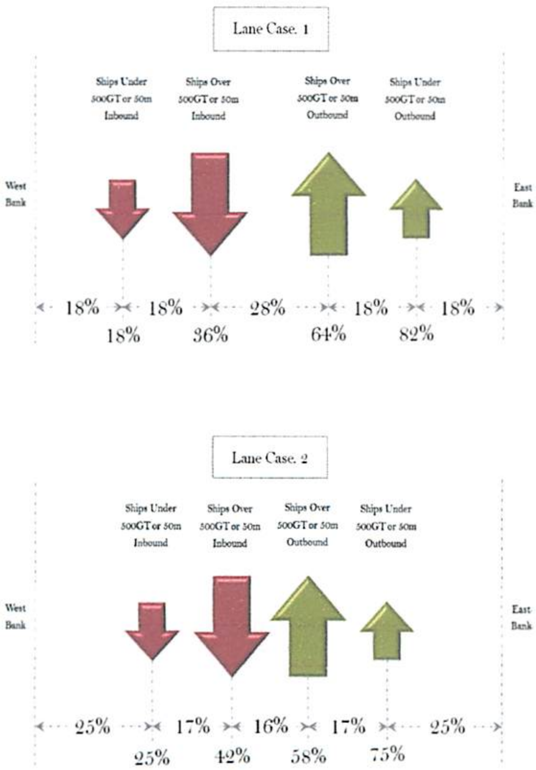


Fig.6 Width of 4 way channel in Lane Case.1 and Lane Case.2

Another designating condition is about cross-river ferry boats. As we all know, several new ferry lines are in operation during EXPO 2010. To considering amount of navigating ferries so that influence to river traffic safety will be checked in the simulation.

4. RESULTS OF SIMULATION

By using of input data above mentioned, several cases of 24 hours simulations have been done. As a result, marine safety in Huangpu River of Shanghai also has been evaluated.

4.1. Collision Accident

Fig.7 shows the ratio of ship's type that collision accident occurred. Fig.7 demonstrates that tankers have highest ratio of collision while their number of ships are not the most in the simulation.

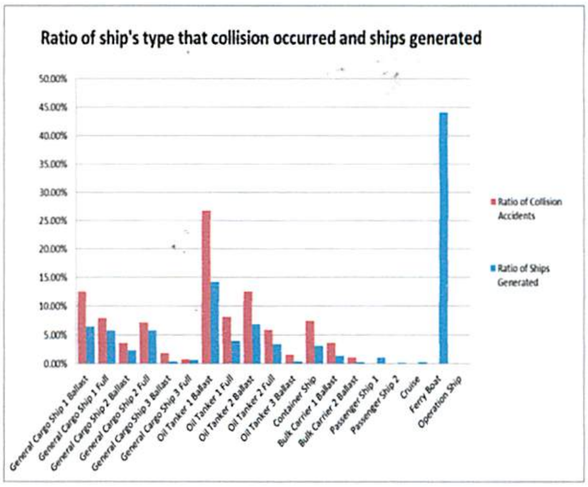


Fig.7 Ratio of ship's type that collision accident occurred and total number of ships in the simulation

4.2. Near-miss

In this paper, near-miss is defined as "Keep target ship clear in the limit range and collision risk is over 0.7". That limit range is calculated by utilizing Inoue's equation (Kobe

University) following showed

$$FA = (0.0015 \times Lt + 2.076)Lo$$
$$SP = (0.008 \times Lt + 0.667)Lo$$

Here, FA represents for the limit range fore and aft, meanwhile, SP represents for the limit range starboard side and port side. Besides, Lo and Lt are for length of own ship and target ship. Collision Risk (CR) is the parameter for avoiding and it is determined by using fuzzy-set theory. Fig. 8 is the distribution map of near-miss count. The distribution map shows that most near-misses are occurred in the waterway near Zhang Hua Bang Wharf. It shares almost half of all near-miss which is very close to real traffic situation in Huangpu River.

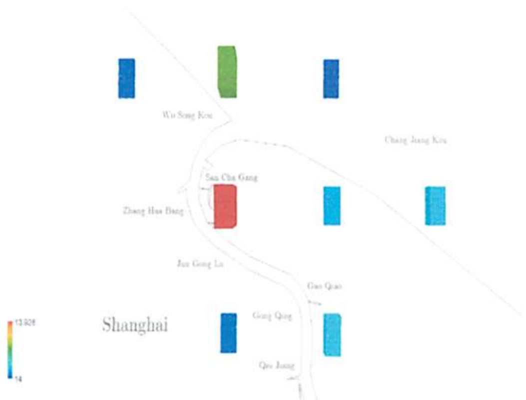


Fig.8 Distribution map of near-miss count

Moreover, difference can be found in comparing with numbers of near-miss occurred under different cases of 4 way channel's width. Case.1 which is the real plan used now shows less numbers of near-miss than Case.2. That suggests the simulation is close to the truth. However, the results whatever with or without ferry boats in the simulation are not as expected. In case of simulation with ferry boats, number of near-miss should be much more because of almost doubled number of ships. That shows small boats with good maneuverability such as ferry boats won't make great effect on traffic safety. Shown in Fig. 9

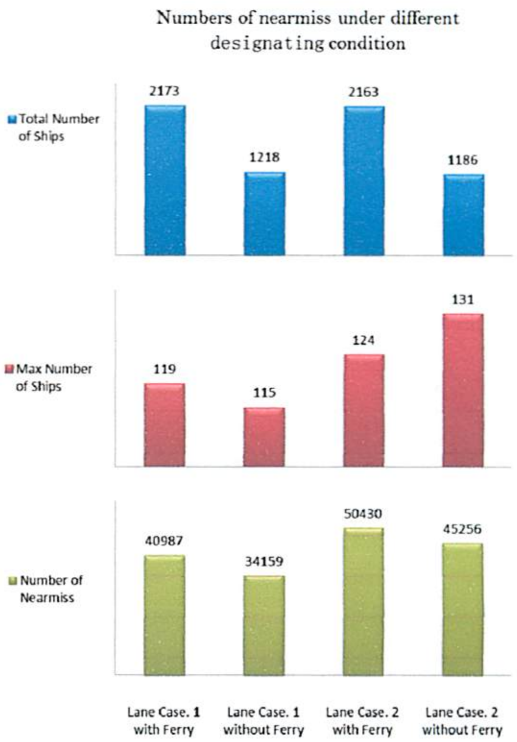


Fig.9 Numbers of near-miss under different designating condition

5. CONCLUSIONS

In this paper, authors introduced Marine Traffic Simulator and demonstrated for safety assessment in Huangpu River of Shanghai. As the detail analysis is still going on, the quantitative conclusions cannot be drawn yet. However, the applicability of Marine Traffic Simulator to very congested narrow and bend waterways such as Huangpu River was proved.

The main conclusions can be drawn as follows.

(1) Marine Traffic Simulator is briefly introduced.

(2) For safety assessment of congested waterways, Marine Simulator is much appropriate than ship handling simulator.
(3) As an index to assess the safety, the number and the distribution of near-miss are much appropriated than those of collisions, because near-miss is mainly depends on conditions such as traffic density and geographical situation, while collision is much subjective and depending on operator's skill or seamanship.

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