# FEASIBILITY STUDY ON INTELLIGENT MARINE TRAFFIC SYSTEM [1]

**Kazuhiko Hasegawa* Yasuhiro Shigemori** Yuichiro Ichiyama*****

** Dept. of Naval Architecture and Ocean Engineering,*
*Osaka University, 2-1 Suita, Osaka, 565-0871 Japan*
*email: hase@naoe.eng.osaka-u.ac.jp*
*** Sumitomo Electric Industries, Ltd.*
*at that time, Dept. of Naval Architecture and Ocean Engineering,*
*Graduate School, Osaka University*
**** Dept. of Naval Architecture and Ocean Engineering,*
*Graduate School, Osaka University*

Abstract: Four-year research of virtual VTS (Vessel Traffic Service) project will terminate in FY2000 and new five-year project of Marine ITS (Intelligent Transport Systems) is started by Ministry of Transport, Japan from FY2000. The project contains three objects. Automatic collision and grounding avoidance system, marine traffic control system in congested waterways and berthing/deberthing supporting system. In this paper, the project is briefly explained and some feasibility study of the second item is discussed based on the research done by authors. Some future direction of this area is suggested.

Keywords: Marine system, Ship control, Traffic control, intelligent control, Simulation

## 1. INTRODUCTION

ITS (Intelligent Transport Systems) is new age transportation system for land, air and marine transportation. However, at this moment, it is mainly aiming for land transportation. Ministry of Transport, Japan has initiated Marine ITS project from FY2000 for five years.

ERTICO (ERTICO, 1991-) defines ITS as follows. Intelligent Transport Systems, or "ITS", are the marriage of information and communication technologies with the vehicles and networks that move people and goods. "Intelligent", because they bring extra knowledge to travellers and operators. In cars, ITS systems help drivers navigate, avoid traffic holdups and avoid collisions. On trains and buses, they let managers optimise fleet operation and offer passengers automatic ticketing and real-time running information. On the road network, ITS systems co-ordinate traffic signals, detect and manage incidents and display information, guidance and instructions to drivers (ERTICO, 2000).

In case of marine ITS, the above definition is still applicable, but some extra consideration is needed. The authors are leading this area for long time. The four-year project of virtual VTS (Vessel Traffic Service) supported by Ministry of Education, Science, Sports and Culture, Japan is the final stage switching to Marine ITS. This paper is partially aiming for the summary of the project and the introduction of the new project supported by Ministry of Transport, Japan.

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For safety of navigation in congested waterways, radar plays an important role. ARPA (Automated Radar Plotting Aids) or ECDIS (Electric Chart Display and Information System) are recently added as additional operational aids. However, the number of ship casualties doesn't change drastically for these ten years, or number of big disasters such as oil spills rather increased.

On the other hand, rapid progress in Internet, GPS and satellite communication have brought us various changes in technology. Combining these technologies, the authors came up to an idea (Hasegawa, 1997). The idea was discussed several times at various symposia/conferences or on a journal (Hasegawa and Taniguchi, 1998), (Hasegawa, 1999). In this paper AIS (Universal Ship-borne Automatic Identification System), one of communication protocols is intended to be used for this system. To verify the system, simulation is conducted by using SAFES (Hasegawa, 1993) and SMARTS (Hasegawa, 1990). The results of the simulation show applicability of AIS and usefulness of SAFES and SMARTS for the feasibility study of V-VTS or future Marine ITS.

## 2. MARINE ITS (INTELLIGENT TRANSPORT SYSTEMS)

Marine ITS is one of the newest project promoted by Ministry of Transport, Japan. It starts in FY2000 for five years. The project has three main topics.

- Collision and grounding avoidance system
- Traffic control system in congested waterways
- Berthing/deberthing supporting system

### 2.1 *Collision and Grounding Avoidance System*

This topics is already studied in so-called "Ultra-Automatic Ship Project" of Japan in 1983–1988(Ohshima and *et al.*, 1989,1990). It follows this project for automatic collision avoidance algorithm, but includes new technologies such as AIS and ECDIS. AIS detects target ships automatically and predicts their future position. Remote sensing technology will be applied for detecting target ships, too.

- Detection and trace of target ships
  - · Surveillance system using AIS
  - · Collection of target ship information by remote sensing
  - · Integration
- Collision/grounding avoidance system
  - · ECDIS and own ship data
  - · Target ship data
  - · Integration
- Full-scale expriment

### 2.2 *Traffic Control System in Congested Waterways*

This topic includes the following research items.

- Advanced management of marine traffic flow
  - · New VTS system using AIS: Unification of Radar, AIS, ECDIS and Ship database
  - · Information provider by land AIS station
  - · Improving surveillance system
  - · Prediction and control of marine traffic flow
- Reliability of AIS
- Full-scale experiment

### 2.3 *Berthing/Deberthing Supporting System*

This topics was also included in "Ultra-Automatic Ship Project" of Japan in 1983–1988(Ohshima and *et al.*, 1989,1990). In the project, it was aiming for automatic berthing/deberthing system. However, it is rather difficult to establish it even now. In the new project, the system is considered as a supporting system, which includes the following items.

- Detection of own ship position using AIS
- Supporting system for tug boats' operation

## 3. AIS (UNIVERSAL SHIP-BORNE AUTOMATIC IDENTIFICATION SYSTEM)

AIS is a tools to exchange information in both ship-to-ship and ship-to-shore in congested waterways. It will improve and support safety of navigation.

### 3.1 *Standard information*

IMO requires the following information to be included in AIS message.

- Static information: IMO number, call sign, height and width, ship type, position of antenna.
- Dynamic information: ship's position, standard time, heading angle, course on ground, speed, rate of turn, etc.
- Navigation information: draft, type of cargo, departure and destination, waypoints etc.
- Safety message

All ships should report above information through AIS at regular interval. The reporting time depends on the situations of navigation. The details of information to be reported and interval are as follows.

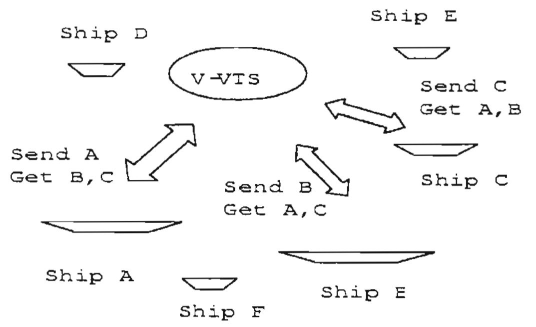


Fig. 1. Concept of V-VTS

- Static information: every 6 minutes or when requested
- Dynamic information: it depends on ship's speed and status
    - · berthing - 3 mins
    - · below 14 kts - 12secs
    - · from 14 to 23 kts - 6 secs
    - · above 23 kts - 3secs
    - · below 14 kts (when altering course) - 4 secs
    - · from 14 to 23 kts (when altering course) - 2 secs
    - · 23 kts (when altering course) - 2 secs
- Navigation information: every 6 minutes or when requested
- Safety message: when requested

These standardized data make it possible to get other ships' information for any ship or shore side.

### 3.2 *AIS and V-VTS*

The V-VTS is regarded as a database accessible from the network. Figure 1 shows the concept of V-VTS. Each ship will access to the V-VTS through a web browser such as Netscape or Internet Explorer. It will send own ship's information to the V-VTS and get those information of other ships. On the display it is just like radar, so it may be called as Internet radar. The own ship is displayed in the center and other ships are shown with their plan paths and present velocity vector. If the ship master click any ship on the display, the detail information of the ship will be displayed. The system uses Internet for its communication tool, so satellite communication is necessary. However, it is still expensive.

The idea is almost same with that of AIS. Each ship with AIS will report their information via VHF. AIS can be installed as the communication protocol in V-VTS, if the communication capacity is enough. Thus, it is considered that AIS is useful tool to build up V-VTS. In this paper simulation is conducted to investigate the feasibility of Intelligent Marine Traffic System using AIS.

## 4. INTELLIGENT MARINE TRAFFIC SIMULATION

### 4.1 *Ship Auto-navigation Fuzzy Expert System (SAFES)*

As a tool of marine traffic simulation system, ship automatic navigation system is required. SAFES (Hasegawa, 1993) is such a tool. It can be applied for any configuration of waterways and any numbers of ships. System will instruct each ship to follow her mission including collision/grounding avoidance manoeuvres.

### 4.2 *Marine Traffic Simulation System (SMARTS)*

The Marine Traffic Simulation System (SMARTS) (Hasegawa, 1990) was developed using SAFES. It can automatically create marine traffic according to the statistical data etc. To realize traffic simulation, the following procedure is used.

(1) Set destination and departure gates/ports of each ship according to the statistics
(2) Determine the creation or deletion of each ship according to the arrival time or finish of the task
(3) Set route including waypoints for each ship
(4) Set parameters of each ship
(5) Determine the steering instruction according to the each ship task as well as target ships' positions and behaviours
(6) Calculate ship position according to the instruction
(7) Increase one time step
(8) Repeat item (2) to (7) until the end of the simulation time

### 4.3 *Marine Traffic Simulation in Osaka Bay*

In this paper the simulation is applied for Osaka Bay. Osaka Bay is one of the most congested areas in Japan and in the world as well as Tokyo Bay. In Osaka Bay, there are many small ports. Authors have limited these ports to 6 categories for simplification. The statistical data of Osaka Bay was collected in various surveys for long term by the Kobe Marine Accidents Inquiry Agency.

The arrival time was determined from two reports (Third District Port Construction Bureau, 1980), (Center for Environemntal Care of Broad Coastal Area in Osaka Bay, 1983). Routes and waypoints are determined from (Japan Hydrographic Association, ?) and (Safety Navigation Forum, Hanshin Branch, Japan Captains' Association, 1985). Figure 2 shows Osaka Bay used in simulation with waypoints. Table 1 shows the OD table for ships departing from West Kobe and Suma ports. For

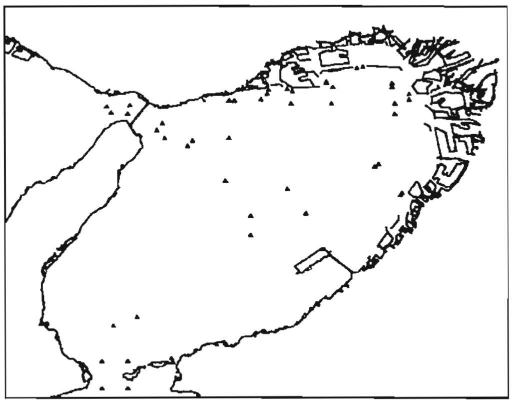

Fig. 2. Configuration of Simulation Area in Osaka Bay with Pre-fixed Waypoints

other departing points similar tables are prepared. In the table, ship type are defined as follows.

- Ship Type A: 5 – 100 GT, $L_{PP} = 20$m
- Ship Type B: 100 – 500 GT, $L_{PP} = 40$m
- Ship Type C: 500 – 1000 GT, $L_{PP} = 60$m
- Ship Type D: 1000 – 3000 GT, $L_{PP} = 90$m
- Ship Type E: 3000 – 1600 GT, $L_{PP} = 115$m
- Ship Type F: 6000 – 10,000 GT, $L_{PP} = 145$m
- Ship Type G: over 10,000 GT, $L_{PP} = 220$m

where GT is gross tonnage and $L_{PP}$ is ship length between purpendiculars.

The steering and speed characteristics are represented by 1st-order differential equations. Once ship type was chosen, the $L_{PP}$ was determined by normal distribution from the above 'standard value'. The parameters of steering and speed characteristics are determined according to the ship type and $L_{PP}$.

Figure 3 shows a snapshot during the simulation.

### 4.4 *Example of Application*

As an example of applications of the Marine Traffic Simulation System, 24-hour simulation was done to check the number of AIS reports in Osaka Bay. Figure 4 shows total number of reports and ships in time. The following points were drawn from this simulation.

- The effect of course changes into the report number is not so significant.
- Total number of reports is almost 5 times than that of ships. It has closely related to the fact that report number below 14 kts is 5 per minute.
- The most peak value of the reports is 1200 per minute. It satisfies the IMO criterion (2000 reports per minute).

Several other tasks are also done.

- Database accessed by GPS equipped clients
- Unification of Marine Intelligent Traffic System with the GPS clients

## 5. CONCLUSIONS

The concept of Marine Intelligent Traffic System using Virtual Vessel Traffic Service (V-VTS) was introduced. The simulation system of V-VTS accessing AIS was shown and as an example of the applications, AIS capacity was estimate in Osaka Bay to confirm whether it satisfies IMO standard. The main conclusions will be drawn as follows.

- Concept of V-VTS using AIS is described.
- Simulation was done to estimate AIS report capacity.
  - The number of AIS reports in Osaka Bay satisfies the IMO standard.
  - The report number is almost 5 times of the number of ships.
  - The effect of course changes is not so significant.

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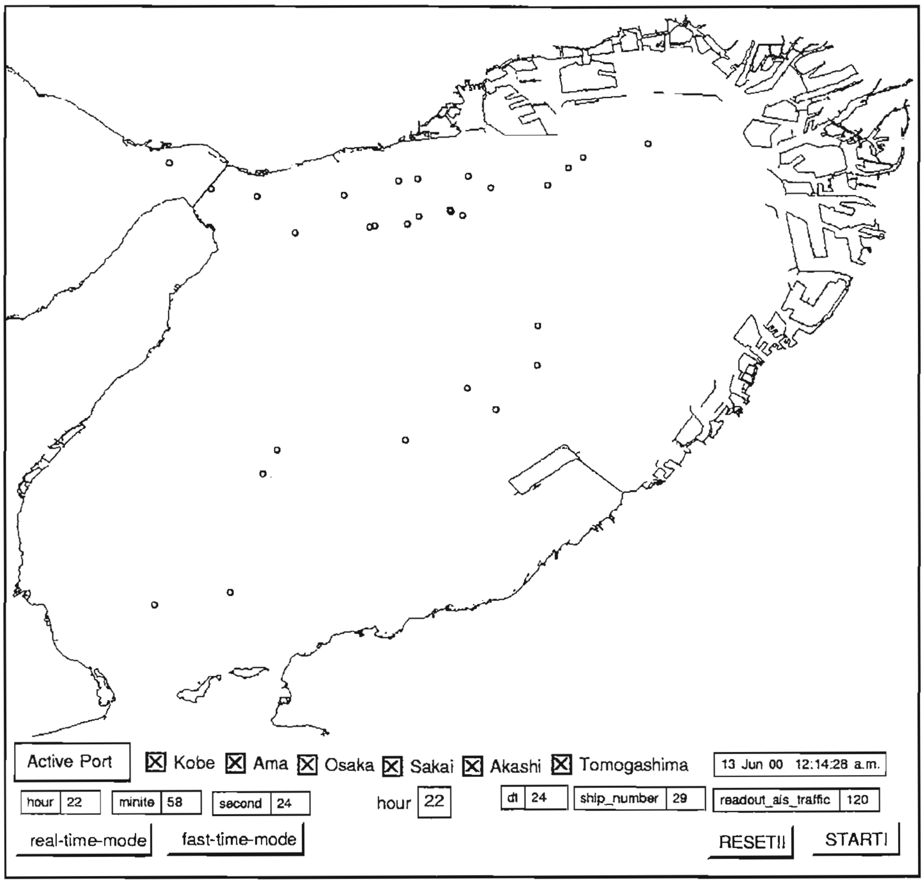


Fig. 3. Snapshot of Marine Traffic Flow Simulation in Osaka Bay

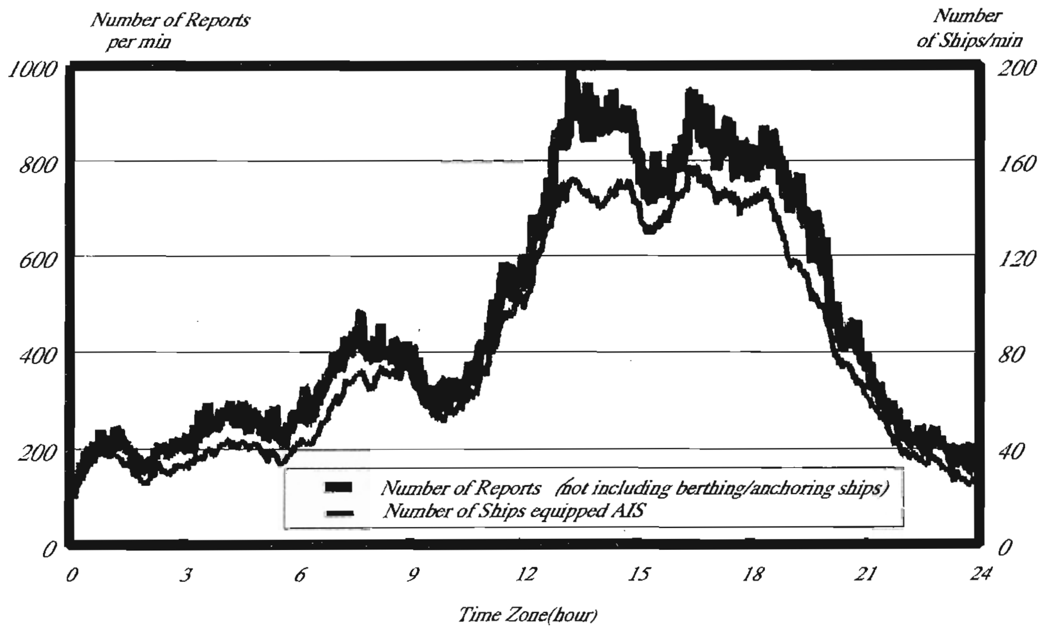


Fig. 4. Number of AIS Reports in Osaka Bay (Simulation)

Table 1. OD Table for West Kobe and Suma, and Lane No. 1

| OD | | Ship (%) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Origin | Destination | Type A | Type B | Type C | Type D | Type E | Type F | Type G |
| West Kobe and Suma | West Kobe and Suma | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Lane No. 1 | 0.4 | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Lane No. 2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Lane No. 3 | 0.2 | 0.2 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 |
| | East Lane of Mole No. | 0.2 | 0.2 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Amagasaki Lane | 3.1 | 3.5 | 3.9 | 0.5 | 0.0 | 0.0 | 0.7 |
| | North Lane | 5.2 | 1.9 | 4.1 | 5.9 | 0.0 | 0.0 | 0.0 |
| | Main Lane | 12.5 | 9.3 | 6.5 | 12.9 | 6.9 | 5.6 | 2.9 |
| | South Lane | 5.3 | 1.6 | 1.1 | 2.7 | 0.0 | 0.0 | 0.7 |
| | Sakai Lane | 22.5 | 2.7 | 3.9 | 0.5 | 0.0 | 0.0 | 0.0 |
| | Hamadera Lane | 7.9 | 2.0 | 2.2 | 0.2 | 0.0 | 0.0 | 0.7 |
| | Izumiohtsu Lane | 14.7 | 1.7 | 0.4 | 0.2 | 0.0 | 0.0 | 0.0 |
| | Ohtsu Minami Lane | 3.7 | 0.7 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Kishiwada Lane | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Hannan Minami Lane | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Akashi Straits | 20.1 | 53.9 | 35.4 | 34.6 | 24.1 | 27.8 | 20.1 |
| | Yura Seto | 0.8 | 8.8 | 35.4 | 40.1 | 69.0 | 66.7 | 74.8 |
| | Kata Seto | 3.4 | 12.7 | 5.6 | 2.5 | 0.0 | 0.0 | 0.0 |
| | TOTAL | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Lane No. 1 | West Kobe and Suma | 0.5 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Lane No. 1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Lane No. 2 | 0.3 | 0.1 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Lane No. 3 | 0.7 | 1.0 | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| | East Lane of Mole No. | 0.9 | 1.0 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Amagasaki Lanc | 2.9 | 3.2 | 3.0 | 0.3 | 0.0 | 0.0 | 0.0 |
| | North Lane | 5.2 | 1.9 | 3.9 | 5.9 | 0.6 | 0.0 | 0.0 |
| | Main Lane | 12.5 | 9.6 | 5.8 | 12.8 | 7.0 | 3.7 | 0.0 |
| | South Lane | 5.3 | 1.7 | 0.9 | 2.8 | 1.2 | 1.2 | 0.0 |
| | Sakai Lane | 21.7 | 2.7 | 5.8 | 0.9 | 0.0 | 0.0 | 0.0 |
| | Hamadera Lanc | 7.6 | 2.1 | 3.2 | 0.6 | 0.0 | 0.0 | 0.0 |
| | Izumiohtsu Lane | 14.2 | 1.7 | 0.9 | 0.3 | 0.0 | 0.0 | 0.0 |
| | Ohtsu Minami Lane | 3.5 | 0.7 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Kishiwada Lane | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Hannan Minami Lane | 0.4 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Akashi Straits | 19.1 | 52.6 | 31.1 | 34.6 | 22.2 | 27.2 | 0.0 |
| | Yura Seto | 0.9 | 8.6 | 36.9 | 39.3 | 69.0 | 67.9 | 0.0 |
| | Kata Seto | 3.9 | 12.5 | 5.8 | 2.5 | 0.0 | 0.0 | 0.0 |
| | TOTAL | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

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