普通高等教育“十一五”国家级规划教材

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DALIAN MARITIME UNIVERSITY PRESS

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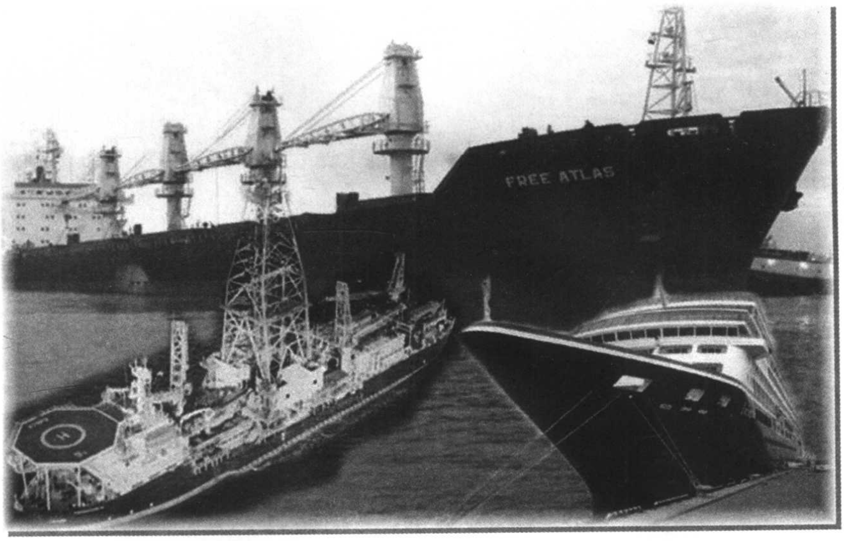

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内容提要

作者选择了国内外典型的研究成果，用英文介绍了海上交通工程学的基本原理、方法、主要研究成果及应用。主要内容有海上交通要素、海上交通调查与分析、海上交通事故调查与分析、海上交通危险管理、海上交通模拟、海上交通管理。

本书可作为海事管理专业及其他相关专业的双语教学教材，并可供海事管理人员、港口工程技术人员和船员参考。

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Preface

Marine Traffic Engineering is a new branch of learning developed during the last forty years. Its objective is to improve the safety and efficiency of marine traffic, especially in congested sea areas. The basic concept is to solve marine traffic problems in a systematic way considering the influencing factors of ships, mariners, traffic management, navigable waters and environment. Marine traffic survey and experiment with real ship or ship model have been used as traditional technical methods. Nowadays, off-line traffic simulation with computer and on-line traffic simulation using ship simulator are playing active roles in this field. Ships' routeing system, ship reporting system, vessel traffic service and traffic regulation have proved to be important measures of marine traffic management. Y. Fujii synthesized this kind of knowledge and published the first book in Japanese in 1971, which was entitled *Marine Traffic Engineering*. This title has been adopted by the Chinese maritime community since the 1980s. In Europe it is often called "Marine Traffic Studies".

As China has developed to be a large shipping nation, and marine traffic volumes in some areas have increased quickly that it is necessary for marine traffic engineers and administrative officers to have systematic knowledge and effective technology to deal with the complicated marine traffic problems concerning safety and efficiency. From 1989, a course in marine traffic engineering was given to the students specializing in maritime safety administration at Dalian Maritime University using a Chinese textbook written by Prof. Wu Zhaolin. In December 2001, the author of this book published a restricted book in English entitled *Marine Traffic Engineering* and started using it as the textbook of bilingual teaching in Dalian Maritime University. In August 2006, this book was approved and recommended as one of the textbooks in the eleventh-five-year national higher education textbook plan. Therefore, the author revised it. As this is a textbook for a 40-hour course for the students specializing in maritime safety administration, it is impossible to include all the findings and attend each and every aspect in this field. Having reviewed some typical studies published in this field, the author tried to introduce the fundamentals, methods, major research findings and applications of marine traffic engineering in English.

The author would like to thank Professor Wang Fengchen of Dalian Maritime University for his reviewing the book, and would also like to thank Professor Shashi N. Kumar of Maine Maritime Academy, the USA, for his proofreading the English of some parts of this book.

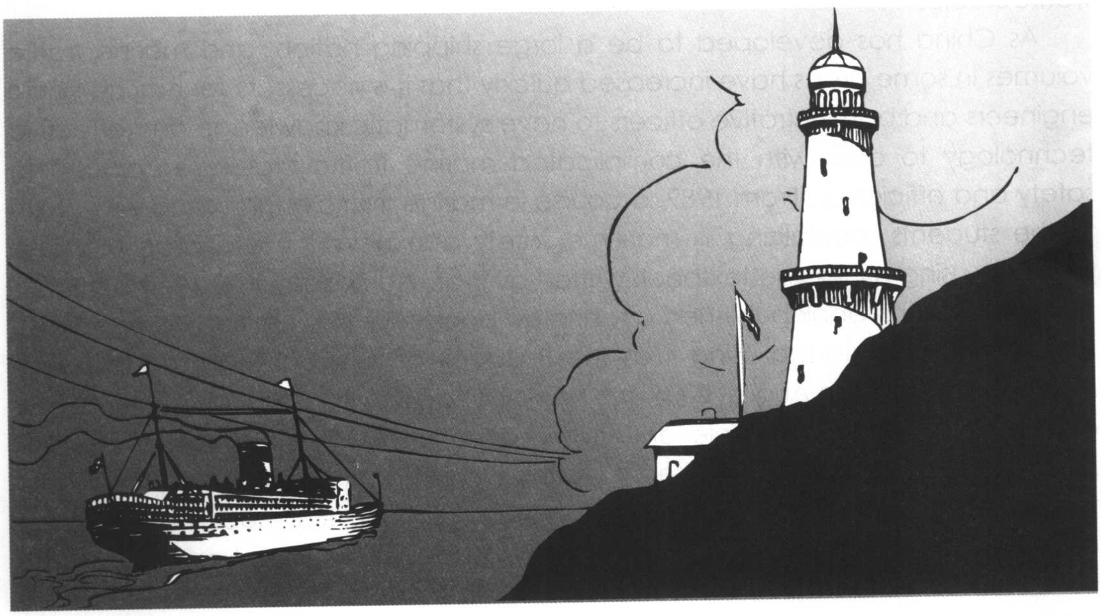
The Author

October 2006

Summary

Having reviewed some of the typical studies, the author introduces the fundamentals, methods, major research findings and applications of marine traffic engineering in English. The main contents are marine traffic elements, marine traffic survey and analysis, marine traffic accidents investigation and analysis, marine traffic risk management, marine traffic simulation and marine traffic management.

This book can be used as a textbook for the bilingual teaching of maritime safety administration students and the students of other specialties concerned, and as a reference book for maritime safety administrative officers, harbor engineers and seafarers.



Contents

1 INTRODUCTION

1.1 Definition and Scope

Marine traffic engineering is a new branch of learning. In Europe, it is called marine traffic studies. Although it is studied as a branch of learning, its scope is changing with the development of the studies, and the definitions of marine traffic engineering given by scholars are not uniform.

A. Wepster of Netherlands Maritime Institute defined the marine traffic as the combination of individual ship movements in a specified area.

Y. Fujii of Japan described the marine traffic as "ship behaviours as a mass". He defined the marine traffic engineering as the investigation of marine traffic and the application of the results of the investigation to the improvement of port and fairway facilities, and to traffic regulation. Fig. 1.1 shows the scope of this new branch of learning.

1.2 Evolution of Marine Traffic Studies

The development of marine traffic studies in the early ancient times was very gradual. It was after the introduction of steamship that some activities in this field increased especially after the Second World War. In this section, the evolution of marine traffic studies is briefly introduced.

1.2.1 Legislation

For several hundred years there have been rules in existence for the purpose of preventing collisions at sea, but there were no rules of statutory force until the 19th century. In 1840 the London Trinity House drew up a set of regulations which were enacted by Parliament in 1846. A completely new set of rules drawn up by the British Board of Trade, in consultation with the French Government, came into operation in 1863. Until the end of 1864 these rules had been adopted by over thirty maritime countries. The British introduced mandatory lights for vessels in 1854, but were behind American with visual and sound signals in 1878. However, with the change over from sail to mechanical propulsion between 1860 and 1900, the Steering and Sailing Rules were codified, the *International Regulations for Preventing Collisions at Sea* came into force in 1910 after a conference in Washington in 1889. The Regulations were amended several times at the Safety of Life at Sea Conference and now the 1972 Collision Regulations is in force.

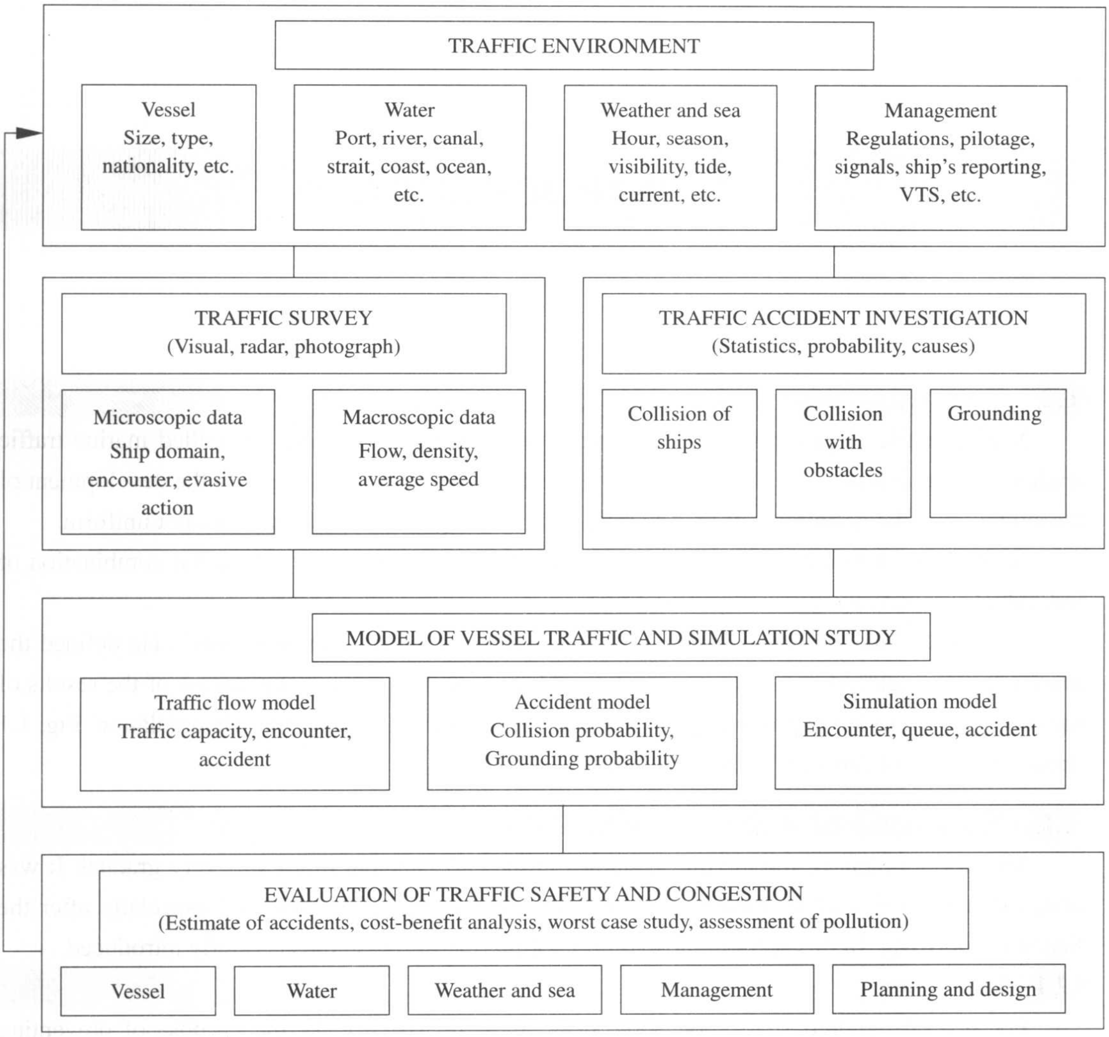


Fig. 1.1 The scope of marine traffic engineering

1.2.2 Ships' Routeing

(1) Ocean Weather Routeing

The first organized attempts on ships' routeing at sea were for weather routeing. In 1847, Lieutenant Maury produced a *Wind and Current Chart for the North Atlantic* based on U.S. Navy logs and on a special abstract log made available to ships of all nations, and this was soon followed by his *Sailing Directions*. The first shipmaster following his routes completed the round trip from New York to Rio in exactly half the previous time.

(2) Ocean Traffic Separation

The first proposals for traffic separation were made to Lieutenant Maury in November 1854 by

Mr. Walter R. Jones from New York. This initiative followed the disastrous collision between the U.S. mail steamer "Arctic" on passage from Liverpool to New York and the French steamer "Vesta", in thick fog some 40 or 50 miles to the east of Cape Race, over 300 passengers and crew were lost. Maury at once recommended separate steam lanes and in January 1855 a number of Boston ship owners, underwriters merchants and others asked Maury to prepare separate routes for westbound and eastbound steamers. By the following month, Maury had carefully planned Atlantic steam lanes between the ports of New York, Philadelphia and Halifax on the one side and the areas of Cape Clear and the Scilly Isles on the other.

(3) Evasive Routeing for Ice

In 1875 the problem of ice caused the Cunard Line to adopt an evasive routeing system of tracks for different seasons, the southern ones for the ice season being south of the normal ice limits in the North Atlantic. Following the loss of the Titanic in a collision with an iceberg in 1912, the International Ice Patrol was instituted at the SOLAS meeting in 1914 through the cooperation of 13 nations.

(4) Routeing in the Great Lakes

Following the disastrous loss of 22 vessels in collision from 1900 to 1910, a much more significant but less publicized step was taken in 1911 by shipping companies represented by the Lake Carriers Association when they prescribed separate routes for navigation on Lakes Superior and Huron. The L. C. A. and the Dominion Marine Association of Canada followed these pioneering schemes on Lake Michigan in 1926, on Lake Erie in 1947, and on Lake Ontario in 1949. These separate routes, over a sailing distance of 1,225 n mile, have been shown on U.S. charts since 1947.

(5) Minesafe Route

Minesafe routes were introduced during the First World War, principally by the British and German. Swept routes through declared danger zones due to mines were introduced, in the Second World War and afterwards, on a large scale by naval authorities. They are of special routeing interest because those in Europe like NEMEDRI (Northern European and Mediterranean Routeing Instructions) form parts of the routes in use today.

(6) Routeing in Congested Waters

The first protagonist of traffic separation in the radar era was the Spanish navigator, Rear Admiral. J. Garciafrias. In 1956 he proposed a rather complex traffic separation scheme for the Strait of Gibraltar and its approaches, which embodied what are now known as one-way traffic lanes with separation zones between lanes. His proposal did not receive attention at the time. Afterwards, Captain De Fregate L. Oudet of France, Commandant J. H. Poll of Belgian did further studies.

In May 1961, the British, French and German Institutes of Navigation agreed at Dusseldorf to form a joint working group to study traffic separation in the Dover Strait. Captain Wepster of

Holland, through the Royal Netherlands Shipowners Association received over 500 replies to a questionnaire sent to masters of Netherlands ships. By January 1962, he was able to report 90 percent in favor of routing. A report drafted by Richy, was published in October 1962 and proposed some technical recommendations. This report was forwarded to IMCO (Inter-Govermental Maritime Consultative Organization, the former name of IMO before 1982), and in April 1964, its Maritime Safety Committee decided to accept the recommendations.

On 1 June 1967, the scheme was announced by Notices to Mariners. From then on ships' routeing was developed through out the world. In 1970, IMCO published *Ships' Routeing* and the General Provisions was included in it in 1971.

A new traffic management concept being introduced in Tokyo Bay in 1978 was a circular system, in which the traffic circulates around the bay anti-clockwise in a ring, keeping opposing streams of traffic widely separated. Other routeing measures, such as deep-water route, in shore traffic zone, etc were established some where in the world.

1.2.3 Vessel Traffic Services

The port of Liverpool was probably the pioneer of European VTS in 1948. A radar station was set up at this port in order to facilitate the boarding of pilots from the pilot boat. In 1951, Long Beach in California established a radar and VHF to facilitate port operations. Le Havre established another system and so, gradually, other ports followed. At this time, commercial radar was comparatively new, and made it possible for the first time, under almost all weather conditions, to observe vessel traffic from the shore. In combination with VHF radio, traffic surveillance system was achieved and real time information exchange between the shore and ships became possible. Nevertheless, it was not until 1985 that the role of VTS in connection with navigation safety, traffic efficiency and environmental protection gained international recognition. This recognition is contained in an IMO resolution, which constitutes the VTS guidelines.

In 1971, an experimental coastal surveillance system was operated in the English Channel. The French followed in August 1973 with a French speaking service for the Pas de Calais and also an English speaking service in 1974.

There have been a number of European research projects encompassing VTS. One of the earliest projects was COST301, set up in 1983, which lasted for about three years. The objectives were to assess the potential benefits, which VTS would bring to the safety and efficiency of traffic and the reduction of pollution risk in European waters, and to make recommendations on a coordinated European approach to VTS based on results obtained from this assessment.

In November 1997, the IMO adopted Resolution A. 857(20), Guidelines for Vessel Traffic Services and its associated Annexes, namely: Guidelines and Criteria for VTS; and Guidelines on Recruitment, Qualifications and Training of VTS operators. These Guidelines are associated with SOLAS Regulation V/8-2, and together with the Annexes, set out the objectives of a VTS, outline the responsibilities and liability of the governments involved, and give guidance for planning and implementing a VTS as well as recruiting and training of VTS operators. The Guidelines note that a

VTS is particularly appropriate in areas that include such characteristics as high traffic density, traffic carrying hazardous cargoes, conflicting and complex navigational patterns and difficult hydrological and meteorological elements.

1.2.4 Marine Traffic Studies in Japan

The first systematic survey of marine traffic in Japan was made by the Nautical Society of Japan in cooperation with the Japan Association for Preventing Sea Casualties in 1963. A. Yamaguchi and others undertook a year-long survey of traffic in the Akashi Channel near Kobe from 1 June 1963 to 31 May 1964. This included visual observations as well as radar recording for 365×24 h. The main items covered by their report are traffic volume, ship tracks, the influence of weather condition on traffic volume, and number of fishing vessels. K. Hara examined the number of ship arrivals in unit time and concluded that the distribution of this random variable approximately fits the Poisson Distribution. Ichinose reported that the mean speed of vessels in the Akashi Channel is not influenced much by poor visibility. Y. Fujii and others made the first approach to traffic capacity. Afterwards researchers at several sea areas in Japan made many traffic surveys. Makishima studied overtaking and Hara analyzed statistically the number of avoiding motions of a large tanker in the open sea as well as in confined waters. Sakaki studied the relation between linear density of ships and collision rate. Y. Fujii treated the collision problem by a model analogous to the kinetic theory of gases and showed that the collision rate and the frequency of avoiding action can be treated by the same procedure. The design of fairways is another important topic in traffic engineering. Toyoda reported a survey on the width of fairways in harbours. Sugisaki studied the fundamentals of fairway design and showed the usefulness of mathematical simulation, particularly for the analysis of traffic capacity and crossing area. K. Inoue, A. Nagasawa, et al tried to develop a toolbox and indexes for the assessment of vessel traffic engineering. Many researchers studied marine accidents statistically. In recent years, computer-based simulation technology has been employed in marine traffic studies. In 1999, Kinzo Inoue published the technical terms in marine traffic engineering.

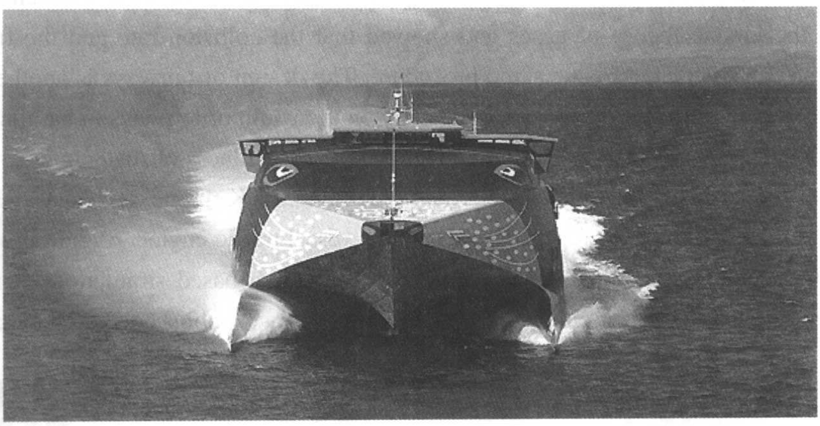
1.2.5 Vessel Traffic Studies in China

Vessel traffic studies in China have a long history. It is reported that canal traffic was controlled using simple signals 1,400 years ago. Vessel traffic studies are necessary in harbour construction. In planning and design of harbours, Chinese researchers use both real vessel and scale model to do experiment and collect data. They also do statistical studies and synthesize domestic marine traffic data and the data of foreign countries. From the late 1970s, researchers tried to establish shore based surveillance radar to keep watch on the harbour traffic. In the 1980s, VTS systems were established at the ports of Beilun, Dalian, Qinhuangdao, Lianyungang and Shanghai. By the end of 2000, more than twenty VTS systems had been established or were under construction. Ships' routeing systems at the sea area off Chengshanjiao, the approach and the fairway of Changjiang River, Dalian Bay, Laotieshan Channel and the approach to Zhujiang River have been carried out so far. The routeing system in the Taiwan Strait is now under discussion. Ship reporting systems have been established in most of the coastal harbours, some sea areas and inland waterways, which provide necessary traffic information to the local Authorities. Traffic regulations are laid down and implemented. harbour Researchers have studied safety assessment methods, ship collision avoidance behaviours, traffic planning and design using computer-based simulation technology, benefit and cost analysis for VTS construction and running, and the application of AIS in marine traffic survey. Several books about marine traffic engineering have been published in China and have played a positive role in spreading marine traffic engineering education.

Questions

(1) Describe the marine traffic in a specified sea area.

(2) Describe the scope of marine traffic engineering.



2 ELEMENTS OF MARINE TRAFFIC

2.1 Mariner

2.1.1 Physiological and Psychological Factors

(1) Vision

The eye is the most important sensory organ for mariners. The sensations produced by light waves on the retina enable an individual to judge size, shape and color, and to estimate distances and speed within the general perception of the external world. The images received are not always focused on the retina in the right plane. Where parallel rays are brought to focus in front or beyond the retina, the malfunction causes short or long sight. The two important types of retinal cell are cones and rods. The cones are distributed in greater numbers around the focal point and while they are light-sensitive, they are able to discriminate colors and fine detail. The eye has a remarkable ability to discern detail. With normal visual acuity and under good lighting and contrast conditions, an object subtending a visual angle of 1 minute can be seen. The rods, spread over the retina, are responsive to the lower levels of illumination but cannot discern color. Contraction and dilation of the pupil affects the amount of light admitted to the retina.

Because of the variation in types of cell in the retina, the ability to distinguish detail in the field of view falls for zonal areas located away from the focal point. While the total visual field for normal sight is approximately 180° horizontally and 145° vertically, anything outside the central 2.5° of the fore rapidly becomes indistinct, deteriorating towards the peripheral limits. However, the movement of objects or subjects of high stimulation are readily detected on the peripheral field, causing the eye to shift and focus on the point of activity.

Time is required by the mariner to scan the waterway and focus on points of detail within it. Situation appreciation is assisted by the depth of the visual field and color discrimination and, hence, visual performance at night is much reduced even without the impairment caused by light source glare. Vision is poor as the eye moves from one fixation point to the next and is also lost for about 0.3 s during blinking, which tends to increase with eye movements. Concentration reduces the normal blink rate of 5 per minute but results in eye fatigue.

Vision has adaptability when a person moves from bright to dark or from dark to bright. The former needs 30~40 min and the later about 1~2 min to resume the sight completely.

Vision is affected by movement, as speed increases, the peripheral view shrinks with a corresponding increase in the focal point distance. At 40 km/h these are 100° and 180 m, and at 100 km/h 40° and 500 m respectively. The waterway alignment and control devices must be revealed at distances ahead and within the visual cone compatible with the operating conditions.

(2) Hearing

The ear is the organ of perception, which locates and senses sounds. The sounds of whistle, wind, engine noise and buzz of warning are useful additional indicators, and particularly, with hearing organ, VHF communication plays an important role in navigation and traffic management. Sound waves cause oscillations in a taut membrane and these are transmitted by three small bones through a further membrane, to a fluid within a canal in the inner ear.

(3) Other Senses

The vestibular organs, located within the inner ear, are sensitive to acceleration orientation. Kinaesthetic senses are perceptual indicators of the relative spatial position of head and limbs, and important to ship control operation. Such emergency situations as fire and overheated engines may be first detected by smell, through the olfactory senses. The thermal senses respond to climatic and environmental conditions while the tactile sense is important in ergonomic design of control switches. Finally pain may have important effects on other senses.

(4) Perception

Events in the external world, of sufficient stimulus, awaken consciousness in the brain in a process of perception. Recognition and response to event stimuli are far more complex than the simple images projected on the retina or other unsifted sensory information. While objects are seen as a certain shape and size, through the experience of relating them by scale and position within a background, their interpretation is a complex association between the conscious physical and unconscious psychological world. Perception is thus dependent on introspection where psychological aspects, conditioning and acclimatization are very important aspects of experience.

An event (of stimuli) only impinges on the receptors at some minimum level, known as the absolute threshold. Thresholds are determined for an individual and vary according to many factors such as age and state of health and mind. If a mariner is presented with the same information repeatedly, the threshold condition can be determined.

(5) Other Psychological Factors

Motivation: Some important motivation factors are time-distance economy, comfort and convenience, desire for privacy, security from traffic accidents.

Intelligence level: Determines the speed and accuracy with which information is processed and decisions are reached.

Attentiveness: Some mariners are distracted by non-traffic events at the sea or on the shore, by worries, other people on the bridge, equipment or activities on board the ship.