Forum

Hierarchic VTS

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The paper proposes a hierarchic vessel traffic service (VTS) system that would ensure a safe and cost-effective flow of traffic in congested areas. Job division among the blocks of the system is proposed and methods of data processing for each put forward.

1. INTRODUCTION. Vessel traffic management is multi-central and multi-criterial. According to the International Maritime Organization (IMO)[1] a VTS authority may be constituted by a government maritime administration, a port authority, a pilotage authority, or any combination of the three. Fujii *et al.*[2] have noted that for the Coast Guard, for example, safety is likely to be the governing factor whereas port authorities will pay more regard to cost benefits. Fujii also notes that shipmasters, for example, prefer a minimum of external control. Meanwhile the problem of the division of authority and responsibility between the master, the pilot and shore-based personnel remains open and, as Dunning has pointed out,[3] can only be solved with the help of specialists in marine traffic problems.

The IMO document referred to gives priority to data collection, data evaluation, information service and navigational advice. 'Traffic Organization Service' which includes scheduling a vessel's movements through special areas, requiring her to remain or proceed etc., is placed very low on the list. Any interference with the shipmaster's job is made dependent on 'special circumstances' and is not considered in its legal aspects.

According to IMO the functions of VTS are (1) the safety and efficiency of traffic and (2) protection of the environment. But it is by no means clear what is meant by efficiency. Rarely is the word used to apply to financial losses caused by ships being forced to idle in congested areas or, more specifically, unnecessary delay in entry because of wrong scheduling. Holt[4] has shown how serious this problem can be and suggested the idea of 'directed traffic' as a solution.

In the discussion which follows the case will be considered where there is a permanent risk of congestion (predictable from the development of world sea transport) and where traditional modes of coordination have become inadequate and where, thus, the relationship between the shipmaster and the VTS centre begins to resemble that between the driver and the policeman.

2. VTS AS A SYSTEM OF CONTROL. If a flow of vessels is subject to control and at the same time has great density and high average speed, it is clear that there is not going to be much freedom to manoeuvre. The effectiveness of control, too, may be modified by factors such as incomplete radar coverage due to shadow sectors, the discipline of some masters and so on. In that case because the situation is continuously changing, control must evolve from mental to automatic processes which rely on a good model and an effective algorithm of control.

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TABLE 1. CONCEPT OF HIERARCHIC VTS

	Data input	Methods	Product
H-level (strategic)	(1) Register of: hydro-meteorological conditions vessel's characteristics and movements (2) Current hydro-meteorological conditions	(1) Statistical analysis and Queuing Theory (2) Simulation with *probabilistic model*	(1) Decisions concerning: development of VTS equipment localization of VTS facilities closed areas lights and signals (2) And for each class of vessel: safety criteria (i.e. size of *domain*) route (recommended or compulsory)
I-level (operational)	(1) For each vessel: ETA, duration of berthing and berth occupancy, size, berths recommended, danger of cargo *coefficient of cost* caused by waiting for entry/as a compromise among the interests of the owner, shipper, forwarder, broker, harbour authority etc. (2) H-level decisions	(1) Job-shop scheduling theory (2) Simulation with *deterministic model*	(1) Compulsory routes (2) Optimal schedule of entries and services *Objective* Minimizing the sum of costs for idle time (for ships) consider *coefficients of cost* with respect H-level decisions
L-level (direct control)	(1) For each vessel: exact position state (approach, waiting, berthing, berth occupancy, departure) (2) Activities of supporting vessels (3) H- and I-level decisions	(1) Surveillance (radar, TV, etc.) (2) Radar data processing (prediction of collisions or groundings) (3) Traffic data processing (i.e. establishing the level of risk) (4) Communication	(1) Optimal traffic plan *Objective* Maximizing the safety (i.e. minimizing the sum of 'collisions' between *domains*) with respect to H- and I-level decisions (2) Hence, for each vessel: messages, warnings, alerts orders (velocity, direction) approvals to proceed (3) Orders for supporting vessels (4) Registered data for H-level

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The aggregate model which would take into account both safety and efficiency would be highly complex and thus (because of research and implementation) probably very expensive. Although Buller[5] maintains that in general there is no 'safety versus efficiency' problem because '...the shorter the queue of waiting ships the lower the danger of collision'; and, inversely, each disaster will produce a financial loss, in practice a compromise between conflicting interests must, in the real world, be reached.

One way of simplifying a model is to break it up into independent blocks and select a relevant task for each. Table 1 suggests a breakdown for VTS based on the Vessel Reporting System Required Clearance (VMCL) concept formulated by Fujii and Yamanouchi.[6]

3. THE HIGH LEVEL. Since general social interests outweigh particular economic effects, the highest level in the strategic VTS hierarchy will be reserved for traffic organization in the widest sense of ensuring safe vessel traffic. Thus the task of this block will be to make the proper decisions regarding traffic separation schemes, the locality of anchorages and limited access areas, the locality of lights, signals and other VTS facilities as well as the development of VTS equipment. Some of these decisions would become obligatory data for the block responsible for maximising the economic effect. A special task at this highest level would be establishing the size of ship domains which are an important coefficient in the calculation of risk of collision at the lowest (direct control) level.

The work of this block is entirely 'off-line' and thus it uses for the most part recorded data concerning sea and weather conditions and vessel characteristics and movements. The methods of decision making designated for the high level (statistical analysis, queueing theory, simulation with a probabilistic model) are sufficient for extensive long-term control at this level.

4. THE INTERMEDIATE LEVEL. Let us consider financial loss caused by the waiting time of ships in the VTS area. For various reasons the arrival of vessels will be irregular and unless the efficiency of the port loading system is infinite, waiting for entry will be unavoidable. The principle of first-come, first-served (FCFS) can lead to a paradoxical situation when a vessel with a cargo that must be quickly unloaded and a short time of berth occupancy has to wait for the departure of a ship which could be held back without undue loss. In the conditions considered earlier there will be no time for discussions or disagreement in the Ship–Ship–VTS realm. There must be clear, simple criteria for determining the schedule of ship entries; otherwise there will be little chance of finding better traffic rules than FCFS.

Let us suppose that there are certain coefficients selected for each vessel in a VTS area and that the agreed cost of a ship's waiting time will be the arithmetical product of this coefficient and the waiting time. The task then becomes that of minimizing the amount of this product over a period of time. The necessary data for each vessel will be ETA, duration of berthing and berth occupancy, size, and recommended berth. Some decisions made at the high level (closed areas, recommended or mandatory routes, etc.) will be treated as constraints. At this level a deterministic model of traffic is required and contemporary or future developments of job-shop scheduling theory should be able to indicate the optimal solutions.

There remains the problem of establishing the coefficients. They should reflect in the first place a compromise between the interests of the owner, shipper, broker, harbour authority and so on. It is even conceivable that the coefficients will depend on payment by the owners of cargo. It is difficult to predict at this stage which solution will be favoured by the shipping community.

5. THE LOW LEVEL. This block, which is immediately responsible for the safety of the traffic, is the VTS centre proper. It works 'on-line' and maintains direct contact with vessels. The best contemporary VTS systems have the capacity to predict congestion in the controlled area (see Bleekrode *et al.*[7]). An ideal system would generate an optimal traffic plan and thus ensure control of the degree of congestion and minimize the probability of accidents. The criterion of optimality could be a function of the number and depth of 'collision' between ship domains, the size of which had been laid down by the high level. The process of finding an optimal traffic plan could be handled by a specially adapted version of radar data processing or traffic data processing. Optimization procedures adopted at the intermediate level would be considered as obligatory data for the low level.

6. CONCLUDING REMARKS. For this discussion to make any sense there are two basic requirements: a high quality of surveillance (by radar, TV, communication, etc.) and, even more important, a legally guaranteed certainty that shipmasters will execute VTS directives, even as to course and speed.

This discussion is offered as a contribution to vessel traffic studies with particular reference to cost-benefit analysis. The notion of breaking down the VTS system as proposed derives from the concept of vessel traffic management oriented towards both safety and efficiency defined in terms of the minimum financial loss caused by the waiting time of ships. The future VTS envisaged suggests an expansion of the science of the subject by the addition of new elements from operational research such as job-shop scheduling theory.

REFERENCES

[1] IMO (1984). *Guidelines for Vessel Traffic Services*, Nav 30/11, Annex 8, 30th session of sub-committee on Safety of Navigation.

[2] Fujii, Y., Yamanouchi, H. and Matui, T. (1984). A survey of vessel traffic management systems and brief introduction to marine traffic studies. *Electronic Navigation Research Institute Papers*, **45**. Tokyo.

[3] Dunning, R. M. (1984). Vessel traffic systems – legal liability a preliminary survey. *Dock and Harbour Authority*, **765**, 99.

[4] Holt, J. A. (1978). Port traffic management systems: alternatives and optimization. *Proceedings of the Third International Symposium on Marine Traffic Services, Liverpool.*

[5] Buller, A. (1984). The conception of progressive computerization of decision process in vessel traffic control. *Proceedings of the Fifth International Symposium on VTS*, 203–6. Marseille.

[6] Fujii, Y. and Yamanouchi, H. (1978). A semiquantitative analysis of marine traffic management systems. *Electronic Navigation Research Institute Papers*, **20**. Tokyo.

[7] Bleekrode, R. K., Noe, P. P. and Veldhuyzen, W. (1984). How to develop an integrated vessel traffic management system. *Proceedings of the Fifth International Symposium on VTS*, 43–56. Marseille.