Thinking Safety

Bridge Resource Management and Engine Room Resource Management

Index

Chapter 1 Introduction

Approximately 20 years have passed since the introduction of Bridge Resource Management (BRM) for ocean-going vessels in the mid 1990s.
Proposals for revision of the STCW Convention as related to Engine Room Resource Management (ERM) were adopted at the IMO Conference in Manila in June 2010. One of these proposals related to the addition of 'Requirements for ERM' added to the engineers' abilities requirements list.

While BRM and ERM are understood as an effective means of achieving safe operation of vessels, when actual implementation is attempted, the word from those on-site is "we can't get it to work properly''.

To ensure effective operation of BRM and ERM, it is important to raise awareness of crews on-site through improved understanding of the overall concept, and in understanding component elements.
In other words, it is necessary that all members of the team engaged in operation of the bridge and engine room have a shared awareness, and that this awareness is not limited to specific crew such as captains and chief engineers.

The following explains the methodology for effective use of BRM and ERM from the point of view of those on-site.

BRM: Bridge Resource Management

ERM: Engine Room Resource Management

Chapter 2 Thinking Safety

The following refers to series of publications for the '80th Captains Educational Lecture (Safety in a Proud Occupation, by the late Professor Isao Kuroda of the Japan Institute of Human Factors Institute) held by the Japan Captains Association on July 31st, 2000.

Expressions such as 'Safe Operation' and 'we pray for your safe voyage' are heard frequently, however before explaining BRM and ERM, it is important to consider 'what exactly is safety?'

* 2-1 What is Safety?

If we consider safety from the point of view that, not only the captain and chief engineer, but also the entire crew, comprise a collection of technicians, there are many who view safety as being at the leading edge of technology, and an extension of technology itself.
In other words, many are of the opinion that 'as vessel technology is improved, it automatically maintains safety'.
It must be simply stated that this thinking is incorrect and dangerous.
In the words of Professor Kuroda, 'Safety must be thought of as being a social value beyond technology, a dimension beyond technology'.
Technologies are specific to various fields, for example, and technology employed in operating vessels, in operating railways, each being simply a methodology with which our lives are made more plentiful.
Thus, it is necessary to consider that, unless the crew at the frontline of safety in operating the vessel separate safety and technology, unless they have a different dimension to safety, safety cannot be maintained.

However, when an accident occurs, the focus is on preventing reoccurrence, and there is a strong tendency to analyze from a technical perspective, and to develop measures against reoccurrence in technical terms.
For example, a Maritime Accident Inquiry is held following a collision accident, and the vessel is found to be in contravention of Clause XX of the Maritime Collisions Prevention Act.
In consequence, the accident is the responsibility of the person in contravention of the legislation, and that person is then subject to suspension of his/her license for a specified number of days. In other words, the focus is commonly on 'who was responsible', and **the person in question is punished, and everyone moves on**.
However, this approach does not investigate and analyze in practical detail **'why the accident occurred'.** As a result, the measures developed to prevent reoccurrence become simply a patch on the problem, and a similar

kind of accident is likely to reoccur.
Professor Kuroda referred to this as the 'grave-post type' of safety measure, i.e. a safety measure which commemorates the accident, calls an end to it, and moves on, without any connection to preventing reoccurrence.
In fact, what we should really consider are social considerations, for example, ensuring that no lives are lost, or that no pollution occurs. It is necessary to consider safety from the point of view of preventative measures to ensure that the accident does not reoccur.
Professor Kuroda referred to this as the 'preventative type' of safety measure.

An accident-free site, that is, a safe site, is always sought, but is there such a thing as 'safety'? The English psychologist Reason defines safety as 'having resistance to danger to which an organization is constantly exposed'.
When we consider operation of a vessel, we focus on existing dangers for example, the dangers of a collision, the dangers of a cargo accident, the dangers of damage to harbor facilities, and the dangers of an engine failure. We therefore see 'how to avoid these dangers' as being associated with safety. As human beings, we face these dangers, and engage in activities to avoid them.

When proposed measures to prevent reoccurrence are not of the preventative type, many are in the form of guidelines in the SMS manuals and in Safety Management Regulations for the purpose of preventing reoccurrence of accidents. Checklists are probably one form of the guidelines. However, implementation of safety management in these guidelines requires human actions, and thus considerable energy is required. People who lack sufficient energy will therefore necessarily take the easier path. In operation, there is a tendency to 'check without confirmation', even though a checklist has been prepared, and this may be a background factor in reoccurrence of the same type of accidents.
Furthermore, the common personality traits of personnel with high levels of skill such as the captain, chief engineer, navigator, and engineer conflict with these guidelines, and as a result, it is undeniable that the proposed safety management becomes a mere shell of the original in a very short space of time.
A considerable amount of study is required of seamen, in particular, in order to obtain a seamen's license. The true meaning of this study becomes effective when qualifications are obtained and they commence working on a vessel. However, in practical terms, the majority of seamen, once acquiring qualifications, exhibit a tendency to simply perform daily duties without expending effort in further study. Furthermore, while participation in training on days off is common, if we think of the true meaning of 'study', it is unsatisfactory to refer to simply showing up 'education and training'.

Safety in the true sense requires raising one's awareness, and improving the safety management culture in the organization.
BRM and ERM, and SMS manuals and Safety Management Regulations, are tools for the purpose of improving safety.

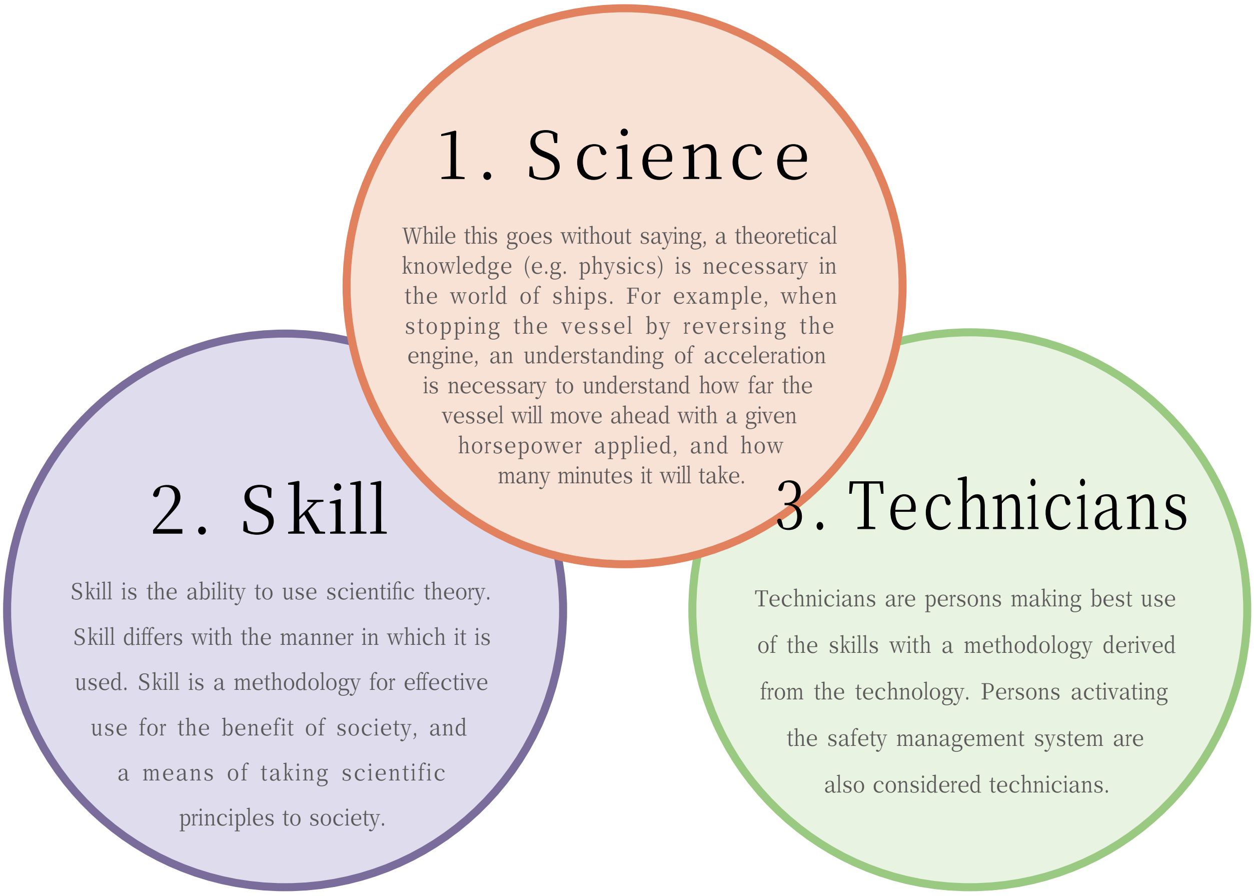
Important

Improving one's awareness, and improving safety management culture

BRM is one way of achieving these goals

* 2-2 Safety and Culture

As described above, considerable energy is required to activate the system developed within safety management. This energy must be seen and derived from the safety culture. When we consider this culture, we must see it in terms of the following three components.



* 2-3 Technicians

Electronic charts, GPS, and AIS have been introduced at a rate hitherto unimaginable, and provide a much greater volume of information than previously in visual format.
These technologies are integrated on the radar screen to provide digital displays of information such as movement of vessels, vessel names, and closest point of approach. Technology is available to issue alarms for vessels which are at a collision risk via ARPA (Automatic Radar Plotting Aid).

At the same time, technicians are responsible for setting the point at which alarms are issued, and for the decision as to whether or not to use the various information displayed. These devices do not automatically control the vessel to avoid dangers in navigation. Until the development or the robotic vessel of the future, the captain and chief engineer as technicians, will conduct an overall evaluation of the provided information and control the vessel accordingly. In addition, vessels employing M0 operation are increasing in the engine room, and a considerable proportion of operation is now automated. However, even if operation of individual engines can be automated, the captain and chief engineer as technicians view the entire engine room as plant operated using the five senses to prevent problems, are still necessary.

Technicians are therefore required to acquire knowledge and skills for safe operation of the vessel and devices to ensure safety, and obtain a seamen's license as evidence of having such knowledge and skills. In other words, safe operation of the vessel and devices is extremely complex and difficult. There are therefore considerable differences in decision-making and discretion involved in this work, and the seamen's license can be considered as providing the necessary authority.

'Safe operation of the vessel and devices' is the subject of much expectation from the wider society, and from this point of view, the following are required.

Important

Required: Ability to predict accurately

Evaluation of information provided, and prediction to avoid associated dangers.

Means to achieve these requirements: Experience

Experience is important in improving the ability to predict

However, the question arises as to why technicians holding a seamen's license cause the same type of accidents. To answer this question, it is relevant to point out that highly skilled captains and navigators, and chief engineers and engineers, share common characteristics as noted below.

1. Pride and confidence in one's work and skills.
2. When hearing of an accident, they have a strong conviction that 'I would never cause an accident like that'.
3. Behind this there is the assumption that safety comes naturally if one has a high level of skill.
4. Feel offended by imposition of Safety Management Regulations and SMS manuals etc. from the management division.
5. Occlusive. Protect each other, particularly in the case of an accident.
6. Mistakes are matters of acute embarrassment, and concealed.

Many readers of this document will undoubtedly be in agreement with the above. It has occurred to me that all six points apply to me personally! As an aside, a few years ago, I was aboard a 330m container vessel of approximately 80,000 G/T. After avoiding anchored vessels and fishing boats while navigating to the specified anchorage prior to passage through the Suez Canal, the anchor was lowered precisely at the specified location. Furthermore, large changes in course were made in the Singapore Straits etc. without deviating from the planned course on the electronic chart, and the resultant track of the vessel was able to be displayed.
However, I regularly told my navigators to 'steal skills to learn', but none appreciated my guidance. Only the Chief officer's wife, the family member on board, graciously commented that my skill in comfortably navigating such a large vessel was admirable. This appreciation brought a tear, and left me without words.

Within the context of the modern world in which technology changes from day to day, the mission of a technician is one of lifetime study. It is also necessary to improve awareness through a calm appreciation of one's own personality. Awareness in prevention and prediction to guard against accidents, creation of one's own technical framework (or use of an existing technical framework), its implementation, and constant consideration of what is the most important in its use, is constantly required.

Important

- Lifetime study
- Calm evaluation of one's own personality
- Constant awareness in prevention and prediction to guard against accidents

▶ **Increased awareness in everything!**

* 2-4 Human Factors and Human Error

Maritime accidents have many causes. In the case of collisions, 80% - 90% are said to be due to insufficient watch-keeping, that is, human error. Furthermore, most accidents are due to a chain of errors, rather than a single error.
If we assume that 'humans are error-prone', preventing the chain of human error is a matter of BRM and ERM **designed to achieve safe vessel operation** by raising awareness of bridge and engine room teams.
Let's consider 'human factors' and 'human error' in this context.

Human factors

The study of human factors is the study of the skills and the limitations, and characteristics of persons necessary to ensure that systems comprised of machinery and technology function safely and effectively.

Human error

Human error is defined as **'behavior against expectations'** which is an unintentional departure from the target to be achieved.

When an accident occurs solely due to human error, the person directly responsible and those in the vicinity are able to ask 'What was the mistake?' and consider the cause on that basis. In most cases, the immediate matter is considered and a caution given, or in some cases punishment is applied. However, this is the grave-post type of safety measure, and can be considered as of no use at all in preventing reoccurrence.

Rather, the preventative type of safety measures are necessary in which we ask why the accident occurred, and what was the background to the accident, and consider the best means to prevent reoccurrence.
Nobody operates a vessel or an engine with the expectation of causing an accident. We must be aware that the human brain does not possess a 'voluntary error generation mode', and that investigating 'causes which inhibit human abilities' is associated with preventing reoccurrence.

* 2-5 Causes Which Inhibit Human Abilities

This section considers the mechanism which gives rise to errors inhibiting human abilities.

1. Human Characteristics

Human characteristics as viewed in terms of the information processing process are as shown in Fig. 1. A large amount of information exists in the surroundings. We evaluate which information to use and the criteria for this evaluation are our past experience and the results of our training.
Humans make an overall evaluation of the various information available and take action. New information appears as a result of this action. This process is then repeated.

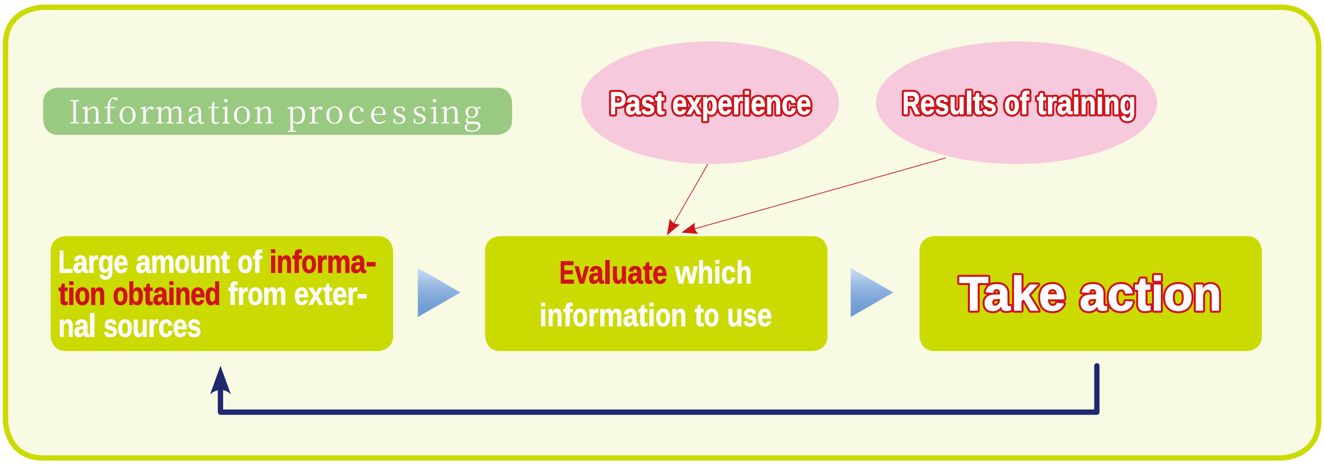


Fig. 1

The process of deciding which information to use is shown in Fig. 2. Approximately 80% is not through individual evaluations but through our daily activities. As a result, unconscious errors occur, leading to honest mistakes. With BRM and ERM, an accident occurs if this error chain continues.

Fig. 2

Causes which inhibit human motion characteristics are as follows. (from Nihon VM centte "Anzen no Komado" No.18 30/6/2002)

Twelve human characteristics

1. Human beings sometimes make mistakes
2. Human beings are sometimes careless
3. Human beings sometimes forget
4. Human beings sometimes do not notice
5. Human beings have moments of inattention
6. Human beings sometimes are able to see or think only one thing at a time
7. Human beings are sometimes in a hurry
8. Human beings sometimes become emotional
9. Human beings sometimes make assumptions
10. Human beings are sometimes lazy
11. Human beings sometimes panic
12. Human beings sometimes transgress when no one is looking

If we consider the above, it appears that human beings are nothing but a collection of defects and shortcomings. However, from another point of view, 'human beings have wonderful abilities'.

❶ Attention dispersal model	⇔	Simultaneously perform multiple tasks effectively
❷ Evaluate and act on assumptions	⇔	Able to make overall decisions
❸ Make decisions on limited information	⇔	Able to make decisions efficiently
❹ Haphazard behavior	⇔	Able to make flexible responses to suit the conditions

Human beings have a wide range of information input systems, with a single processing system. This system is easily interrupted, and the focus easily switched.

Furthermore, human beings tend to seek the comfortable option, to have real intentions and stated reasons, to be sleepy in time zones, and to find work harder as they become older. These problems are controlled with 'attentiveness' and 'awareness' as information processing sources, however they are limited and become causes of an inability to avoid errors.

For example, investigation of the time zones in which vessel collisions occur show that it is most common between 2am and 6am, and 2pm and 4pm, which is likely due to these factors.

2. Human behavior patterns: Rasmussen's SRK behavior pattern

When human beings initiate any kind of behavior, this behavior is processed in a number of steps depending on the details of the behavior.

Rasmussen, a Danish cognitive scholar, described this simply with his SRK model in which human behavior can be considered in terms of three patterns (S, R, K).

1	Intuitive behavior bypassing the information process, behavior at the reflex level	(S : Skill-base)
	For example, when climbing stairs, we climb without verifying the height in centimeters of each step. Behavior repeated daily in which we intuitively know the height of each step. Such behavior is mostly unconscious and automatic, and not determined by verification against memory and knowledge acquired through past experience and the results of training. Errors such as tripping occur on stairs of unfamiliar height.	
2	Behavior at the rule level	(R : Rule-base)
	Not to the same extent as the reflex level above, but behavior in accordance with habits and rules learnt in work in which one is comparatively experienced. A short period of time is required in comparison to reflex level behavior. Errors due to mistakes of fact, mistakes in selection of rules, and mistakes in application of procedures.	
3	Behavior at the knowledge level	(K : Knowledge-base)
	Behavior when responding to situations not normally experienced. Behavior with which problems must be resolved with one's own knowledge when responding to difficult matters and malfunctions which occur rarely etc. An evaluation is made that something has occurred, the objective defined, measures developed based on one's own knowledge of what to do, a procedure planned, and behavior initiated. In some cases, a new investigation must be conducted to obtain the appropriate information, and a response initiated. Requires more time than behavior at the rules level. Errors are induced through misunderstanding of fact, lapses of memory, and misapplication of knowledge.	

These three behavior patterns are affected by stress, fatigue, the content and volume of information, and the personality of the individual, and these factors affect the frequency of the induced errors.

For example, even an experienced veteran sometimes acts unconsciously when distracted, due to a desire for something, or under external pressure.

* 2-6 Accident Examples

The following are two examples in a consideration of measures to prevent an accident reoccurring.

Accident example (1)

The first example relates to a collision between a container vessel (9,977 G/T) and a fishing vessel (8 G/T) at Genkainada in off-Hakata port. Movement of both vessels prior to the collision is shown in Fig. 3 and Table 3 (source: Judgments on the Maritime Accident Inquiry Tribunal website).

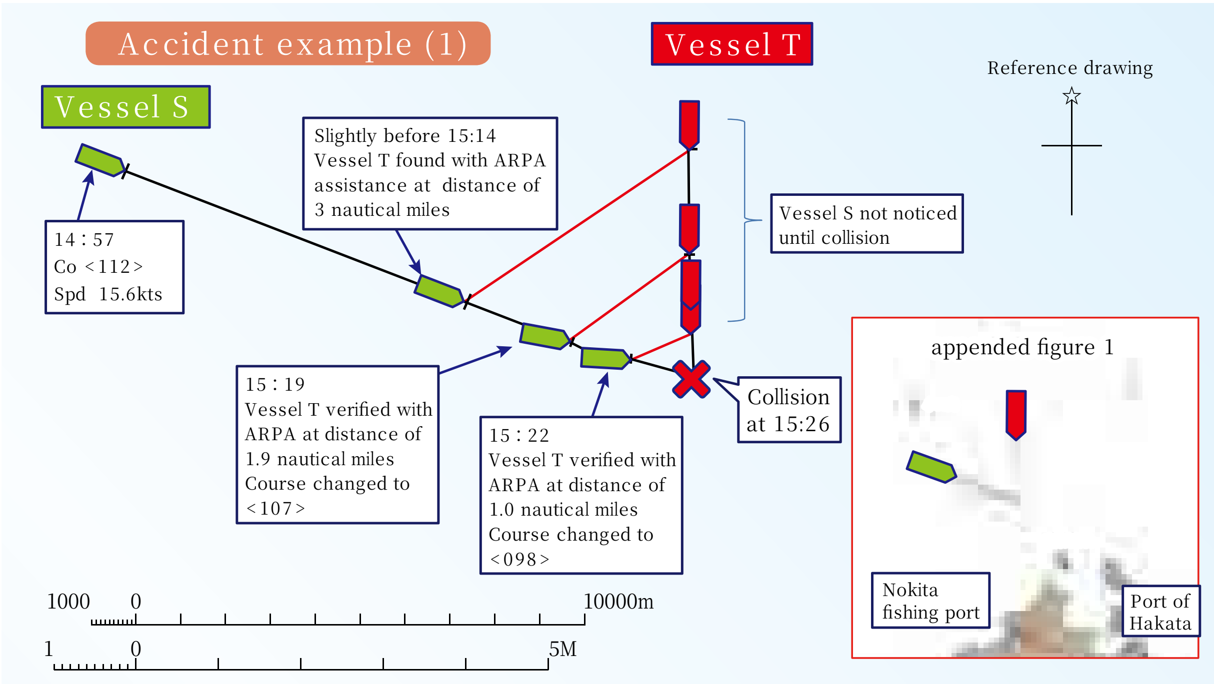


FIg.3

Collision example (1) location: Genkainada weather: cloudy SE wind, wind strength 2, good visibility

Time	Distance to other vessel (nautical miles)	Vessel S Vessel S, 9,977 G/T, container vessel, with 18 Chinese crew. From Port of Qingdao, China bound for Port of Hakata. Original course <112> Speed 15.6 Kts Second mate and able seaman on duty.	Vessel T Vessel T, 8 G/T, fishing vessel, with 2 Japanese crew. Returning from Genkainada to Nokita fishing port. Original course <180> Speed 15.0 Kts Captain on duty.
Slightly before 15:14	3.3	Vessel T verified at range of 3 nautical miles (off center) on radar, supplemented with ARPA.	Determined that no other vessels were in vicinity, and switched to automatic steering. Commenced processing catch with deck crew.
15:19	2.0	Based on ARPA information, thought vessel T was cutting across bow, changed course 5º to port to course of <107>.	Continued above work. Did not notice vessel S.
15:22	1.0	Based on ARPA information, thought CPA was 0.1 nautical miles crossing ahead, changed course 9° to port to course of <098>. No warning signal and no joint action	In situation in which vessel S was visible, however, continued with above work.
15:26	Collision	Turned full to starboard immediately before collision. Insufficient. Collided with bow when turned to <114>. Grazing marks amidships on port side.	Did not notice until collision, continuing on same course and speed. Crushing of bow plating, no injuries. Returned to Nokita fishing port under TOW by consort.

Table 3

+ Maritime Accident Inquiry Judgment - main points +

The judgment of the Maritime Accident Inquiry is summarized as follows.

1 **Principal text** License of captain of vessel T suspended for 1 month.

2 **Applicable legislation** Clause 15(Crossing Situation) of COLREGS
– International Regulation for Preventing Collision at Sea

Note: Clause 15.1(Crossing Situation) of COLREG

When two power-driven vessels are crossing so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way and shall, if the circumstances of the case admit, avoid crossing ahead of the other vessel.

3 Outline of accident

After completing fishing, the fishing vessel T (8.0 G/T) headed for the fishing port of Nokita in Fukuoka Prefecture. After determining that no other vessels were in the vicinity, the vessel was switched to automatic pilot. The bridge was left unattended and the captain commenced processing the catch with the deck crew. Vessel S was unnoticed until the collision.

Vessel S verified the image of vessel T on radar, assisted by ARPA, at a distance of 3.3 nautical miles approximately 15 minutes before the collision, however movement was not verified. The vessel was further verified again visually 7 minutes before the collision, however it was thought that it would continue to cross the bow of vessel S, and course was altered 5º to port to ensure sufficient distance for avoidance. Change in heading was subsequently not verified, and course again altered 9º to port 4 minutes prior to the collision. Turned full to starboard immediately prior to the collision, however this action was insufficient, resulting in the collision.

4 Cause of accident

Primary cause Insufficient watch-keeping by vessel T

Secondary cause Vessel S did not issue warning, and no joint action (action as will best aid to avoid collision) was taken.

5 Discussion of causes

Vessel T Vessel should have been under control of one crew on watch. Avoiding action could have been taken if a crew member was on watch.

Vessel S The possibility of collision would have been apparent if watch-keeping or look-out were sufficient and crew had not relied solely on the ARPA signal.

+ Transport Safety Board Report – main points +

The Transport Safety Board report is summarized as follows based on causes and measures to prevent reoccurrence.

1 Causes

The 2 crew of vessel T were busy processing the catch and ignored watch-keeping or proper look-out. The second officer of vessel S assumed that vessel T would take avoiding action.

2 Reference (measures to prevent reoccurrence)

- Sound horn as necessary, and signal to attract attention.
- The most appropriate joint action is necessary when it is apparent that the burdened vessel is unable to avoid collision solely by adjustments to course of the give-way vessel.
- Do not leave the wheelhouse unmanned while under way, and maintain a sharp look-out on the surroundings as appropriate.

Accident example (2)

The second example relates to a collision between a container vessel (44,234 G/T) and fishing vessel (18 G/T) in Katsuura Light House off Chiba Prefecture. Movement of both vessels prior to the collision is shown in Fig. 4 and Table 4 (source: Judgments on the Maritime Accident Inquiry Tribunal website).

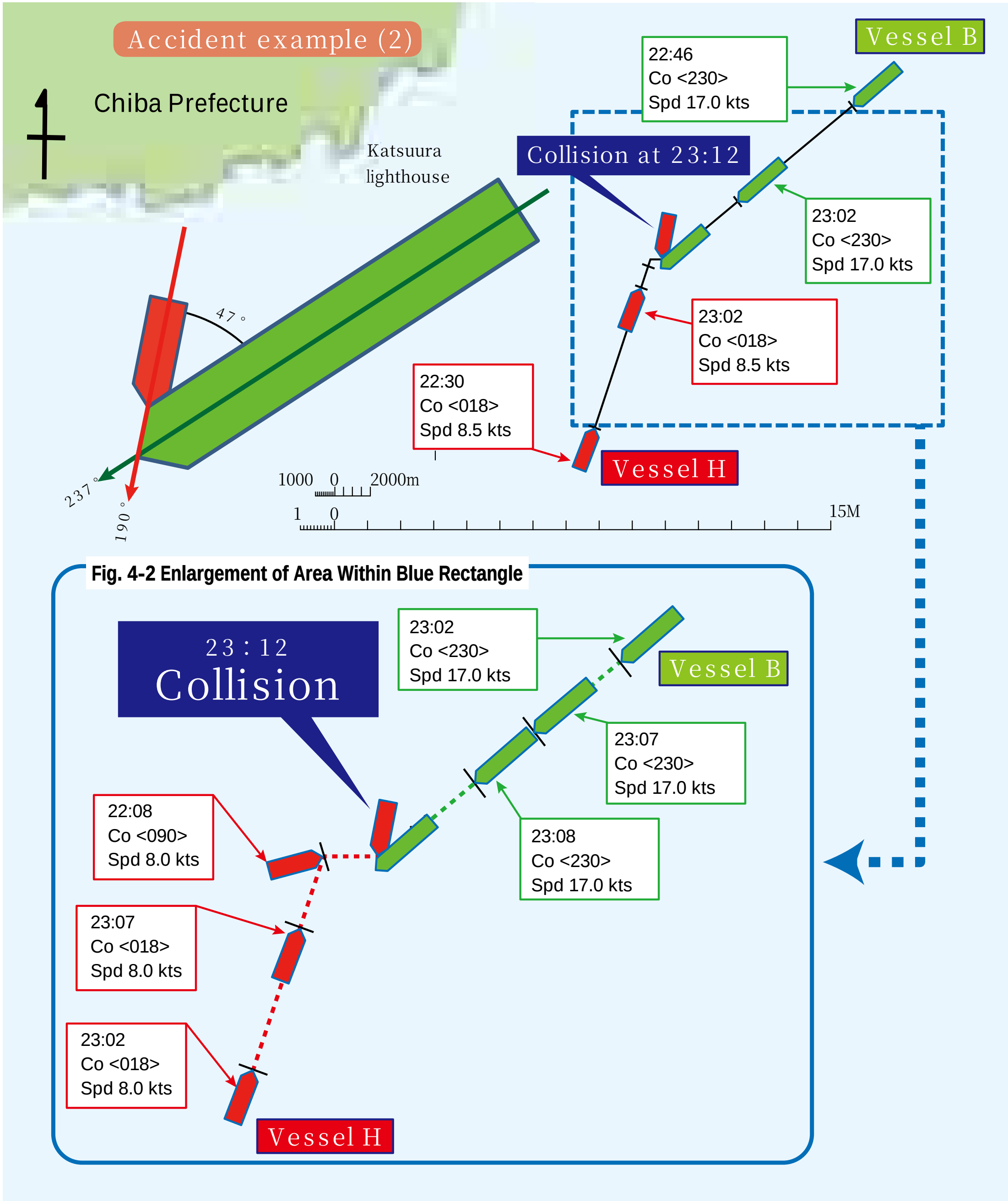


Fig 4-1

Accident example (2) location: Katsuura Bay off Chiba Prefecture weather: rain wind NNW, visibility 7-8 nautical miles

Time	Distance to other vessel (nautical miles)	Vessel B Vessel B 44,234 G/T container vessel with 21 Filipino crew Bound for Tokyo from Oakland USA Original course <230> Speed 17.0 Kts Third mate and able seaman on duty	Vessel H Vessel H 18 G/T fishing vessel with 3 Japanese and 3 Indonesian crew Returning to the port of Choshi from fishing grounds 410 nautical miles south of the port of Chosi off Chiba Prefecture. Original course <018> Speed 8.5 Kts Captain on duty alone
22:30	14.7 (approx)	—	Course <018>, 8.5 Kts full speed ahead. Sitting in chair watching radar.
22:46	10.5 (approx)	Course <230>, speed 17.0 kts. General conversation with able seaman continued until 23:08. Radar range set to 12 nautical miles.	—
23:07	2.0	Situation allowed vessel H to be recognized approaching Northwards at distance of 2.0 nautical miles 7.5° <237.5> off starboard bow, however it was not noticed. Communications of other vessel monitored on VHF.	Radar set to 3 nautical miles range. Recognized vessel B on radar at a distance of 2.0 nautical miles 37.5° <055.5> off starboard bow. Not supplemented with ARPA. Situation allowed mast lights and green light of vessel B to be verified visually, and passage on vessel B's heading was able to be verified, however it was not verified visually.
23:08	1.4	Vessel H proceeded further on the same heading. The situation allowed recognition of the other vessel at 15.5° <245.5> on the starboard bow at a distance of 1.4 nautical miles, however it was not noticed.	Able to pass starboard-to-starboard at 6.3 cables on a heading of 47.5° <065.5> off starboard bow at a distance of 1.4 nautical miles, however attempted to pass port-to-port without ARPA assistance. Furthermore, gave rise to the danger of another collision with a course of <090>.
23:11	0.6	The able seaman discovered vessel H to starboard at 0.6 nautical miles and reported it to the third mate, however after changing the radar range to 6 nautical miles and checking the image, was unable to find the vessel.	—
23:12	Collision	The mast lights and red light of vessel H were recognized as a danger 27° <257> on the starboard bow at a distance of 0.3 nautical miles. A long blast was sounded on the horn and the wheel turned hard to starboard, however it was too late and the collision occurred as the bow was turned to <237>.	Vessel B recognized on radar at a distance of 0.3 nautical miles 13° <077> off port bow and turned hard to starboard, however it was too late and the vessel collided with the bow of vessel B as the bow was turned to <190>. The vessel sank, however all crew were rescued by vessel B.

Table4

+ Maritime Accident Inquiry Judgment - main points +

The judgment of the Maritime Accident Inquiry is summarized as follows.

1 **Principal text** License of captain of vessel H suspended for 1 month.

2 **Applicable legislation** Since vessel H turned to starboard after passing in the bow direction of vessel B, giving rise to the danger of a collision, no regulation exists in legislation. This case is therefore judged in accordance with Clause 38 and 39 (normal duties of seamanship) of the Japan Maritime Collisions Prevention Act.

Note: Clause 38 of the Japan Maritime Collisions Prevention Act (special situations associated with dangers in approach)

In construing and complying with these Rules due regard shall be had to all dangers of navigation and collision and to any special circumstances, including the limitations of the vessels involved, which may make a departure from these Rules necessary to avoid immediate danger.

Note: Clause 39 of the Japan Maritime Collisions Prevention Act (responsibility for negligence)

Nothing in these Rules shall exonerate any vessel, or the owner, master, or crew thereof, from the consequences of any neglect to comply with these Rules or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

Note: Statutory interpretation of normal duties of crew: From description of the Japan Maritime Collisions Prevention Act.

'Normal duties of crew' is commonsense to all those associated with maritime matters, and covers 'the knowledge, experience, and practices of seamen'. Scope is wider since it is not limited to 'operation' as in 'Appropriate practices for operation of vessels' (Clause 8.1). A typical example is the avoidance of anchored vessels by vessels underway.

Note: Clause 8(a) of the Maritime Collisions Prevention Act

(a). Any action to avoid collision shall be taken in accordance with the Rules of this Part and shall, if the circumstances of the case admit, be positive, made in ample time and with due regard to the observance of good seamanship.

3 Outline of accident

Vessel H was proceeding north with vessel B underway on a south-easterly heading to starboard as required when there is a danger of collision. The captain of vessel H was sitting in the chair watching the radar (set to 3 nautical mile range), and recognized vessel B on the radar at a distance of 2 nautical miles (not assisted by ARPA). At this point, the vessel passed in the bow direction of vessel B, however no visual check was conducted. The image on vessel H's radar shows 47.5˚ to starboard at a distance of 1.4 nautical miles. Attempted to pass port-to-port on a course of <090>, however vessel B had already passed in the bow direction of vessel H, and the heading for a collision was set.

The navigator on duty on vessel B was busily engaged in conversation with the able seaman, and neglected to watch the radar and conduct visual checks. Although he was monitoring VHF communications of the other vessel, he neglected watch-keeping. The able seaman first noticed vessel H at a distance of 0.6 nautical miles and reported it to the navigator on duty, however the navigator continued trying to find vessel H on the radar without conducting visual checks. The only measure taken was to switch the radar from 12 to 6 nautical mile range, and since the STC (Sensitivity Time Control circuit), used to eliminate sea clutter) was applied to a high degree, vessel H was not found.

4 Cause of accident

Primary cause Vessel H placed vessel B (ready to pass without problems) in a new danger of collision.

Secondary cause Vessel B neglected to watch the surroundings sufficiently, did not issue a warning, and did not take action to avoid collision.

5 Discussion of causes

Vessel H

- Had the duty to sufficiently monitor and issue caution of movement of vessel B to ensure that a new danger of collision did not occur.
- Should have used ARPA assistance, radar plots, and visual verification.

Vessel B

- Should have kept watch and sharp look-out by radar and visual observation.

+ Transport Safety Board Report – main points +

The Transport Safety Board report is summarized as follows based on causes and measures to prevent reoccurrence.

1 Causes

Vessel H

- Turned to starboard without monitoring the movement of vessel B sufficiently.
- Assumed that when turning to starboard, the other vessel must be avoided by passing port-to-port.
- Did not appropriately monitor movement of the other vessel using the electronic cursor on the radar, and ARPA.

Vessel B

- The third officer did not pay appropriate look-out to radar and visual checks.
- Attention was directed to conversation and communications of the other vessel, and not to appropriate watch-keeping.

2 Reference (measures to prevent reoccurrence)

- Do not allow conversation to interfere with watch-keeping and look-out.

- Ensure that radar is watched appropriately.
- Ensure that changes in heading of the other vessel are carefully measured with the radar cursor and ARPA, make accurate decisions on the possibility of collision, and maintain a safe distance while passing.

Major revisions were made to the Japan Maritime Accident Inquiry Act in May 2008, and causes of accidents are now clarified as follows by the Transport Safety Board.

Before and after comparison of Maritime Accident Inquiry Act

Previous Japan Maritime Accident Inquiry Act (Before)		Revised Maritime Accident Inquiry Act (revised May 2nd, 2008) (after)
Clause 1 This legislation is designed to clarify the causes of maritime accidents through inquiry by the Marine Accidents Inquiry Agency, and to contribute towards preventing their reoccurrence.	→	Clause 1 This legislation determines procedures for inquiry at the Maritime Accident Inquiry Tribunal established in the Ministry of Land, Infrastructure and Transport for the purpose of providing disciplinary punishments for maritime accidents caused by intentional or unintentional neglect of duty by maritime technicians, small vessel operators, or pilots, and to contribute towards preventing their reoccurrence.

Clarification of causes of maritime accidents

Transport Safety Board Establishment Act (revised May 2nd, 2008)

(Purpose)
Clause 1
This legislation establishes a Transport Safety Board to accurately conduct investigations to clarify the causes of air accidents, railway accidents, and maritime accidents, the causes of damage arising from such accidents, and to seek implementation of the necessary policies and measures by the Minister of Land, Infrastructure and Transport and persons associated with causes based on the results of these investigations, and to contribute to preventing such accidents, and to alleviating damage arising from such accidents.

The Maritime Accident Inquiry touches on the causes of accident when determining disciplinary punishments for maritime technicians etc., however the primary task of clarifying causes is the work of the Transport Safety Board. In the case of collisions, lawyers for both parties negotiate the division of responsibility based on the judgment of the Maritime Accident Inquiry and the Transport Safety Board, however in some cases it appears that causes as noted by the Maritime Accident Inquiry and as investigated by the Transport Safety Board differ.

* 2-7 Basic Considerations for Preventing Reoccurrence of Accidents

Consideration of the causes of the two accident examples introduced above, and points common to parts related to preventing reoccurrence, are as follows.

+ Maritime Accident Inquiry +

In accordance with the New Maritime Accident Inquiry Act, Japanese holders of a seamen's license are subject to punishment by suspension of license for a period of one month, and responsibility for the cause of the accident, the reason for punishment, is sought in terms of crew negligence.

+ Transport Safety Board +

It refers to enforcement of watch-keeping and look-out, cooperative action by burdened vessels, and failure to issue warning signals, however the point of 'why was that action taken?' appears not to have been touched.

Grave-post and preventative types of measures have been explained above. In the following, human characteristics, factors which inhibit these characteristics, and the occurrence of human error will be considered in relation to **reoccurrence of the same accidents if preventative measures are not developed.**

In other words, most accidents are caused by human error. From the Accountability type of measure in which the person is investigated to determine what mistakes were made, responsibility apportioned, and the curtain drawn, it is necessary to change our awareness to the pursuit of background factors of human error, investigating 'why it happened', and the development of valid measures of the Countermeasures-oriented type.

! Important

A change in awareness from the Accountability type to the Countermeasures-oriented type

If we return to the point of view of preventing reoccurrence of the same type of accident, we need to change our consideration of accidents and phenomena.
As noted above, no one undertakes a task, or pilots a vessel, with the intention of causing an accident. Furthermore, if we consider the matter in terms of human factors, punishment of the person involved has no suppressive effect, and makes no major contribution to preventing reoccurrence.
In other words, when developing preventative measures, an analysis in terms of the following points is necessary.

1. Analyze the accident from the point of view of the person involved.

Analyze the phenomena occurring up to the accident in terms of 'what would I have done if it had happened to me?'.

2. Consider human characteristics

Consider why human error occurred, and the background factors, in terms of 'Human Characteristics' in 2-5.

3. Based on a consideration of causes

Analysis results in terms of 'should' and 'should have' simply conclude with seeking responsibility of the person involved, and are meaningless from the point of view of preventing reoccurrence. It is necessary to return to the origin and consider that matters collapsed, giving rise to the accident.

Use of the M-SHELL model, an element in **Bridge Resource Management** explained in Chapter 3 results in the following.

As shown in Fig. 5, the person at the center (L :Person responsible for the accident) is surrounded by those resources such as: ' H :Hardware: ', ' S :Software', ' E :Environment', and ' L :Persons other than the person responsible for the accident.' Each resource is always in a state of change. This situation can be shown in terms of quivering rectangles. Here, if communication and cooperation between the person ' L ' and those resources are insufficient, ' L ' is unable to have sufficient contacts with others and human error occurs; in consequence, safety is no longer assured.

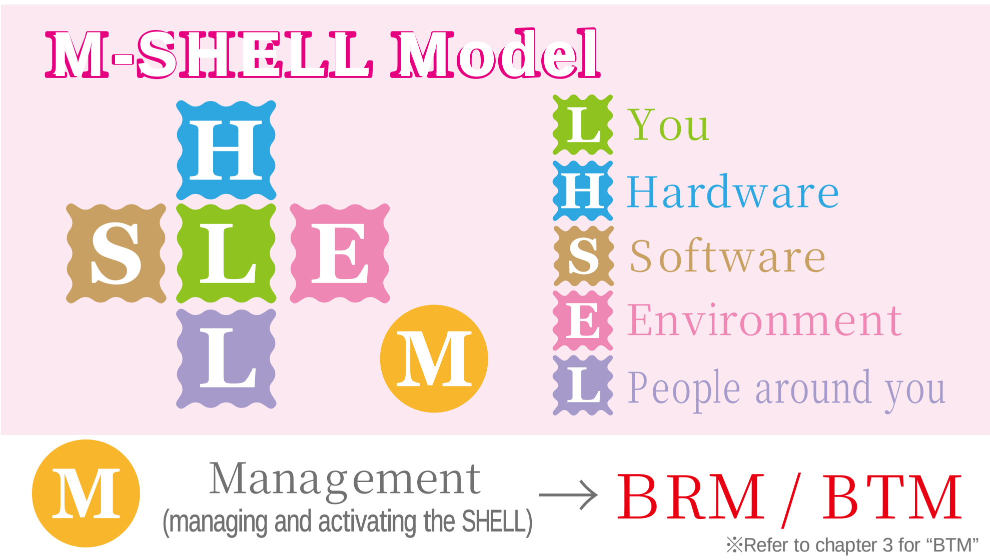


Fig. 5

The accident example has been summarized in Fig. 6 and Table 6 by evaluation against human characteristics and analysis using the M-SHELL model.

+ Accident example (1) +

Human Characteristics and Comparison of Behavior of Persons Involved

	Human characteristics	Vessel S 2/O	Behavior	Vessel T captain	Behavior
①	Human beings sometimes make mistakes	〇	Turned to port despite being stand-on vessel.	×	—
②	Human beings are sometimes careless	×	—	〇	Aware of need for watch-keeping, however intervals were too long.
③	Human beings sometimes forget	〇	Ignored Maritime Collisions Prevention Act.	〇	Ignored Maritime Collisions Prevention Act.
④	Human beings sometimes do not notice	×	—	〇	Did not notice other vessel.
⑤	Human beings have moments of inattention	〇	Verified only with ARPA.	〇	Aware of need for watch-keeping, however did not execute.
⑥	Human beings sometimes are able to see or think only one thing	×	—	〇	Busy processing catch.
⑦	Human beings are sometimes in a hurry	×	—	〇	In a hurry to return to port.
⑧	Human beings sometimes emotional	×	—	×	—
⑨	Human beings sometimes make assumptions	〇	Assumed other vessel would take avoiding action.	〇	Thought all was normal, and no problems.
⑩	Human beings sometimes lazy	〇	Did not issue warning signal or take appropriate action.	〇	Aware of need for watch-keeping, however did not execute.
⑪	Human beings sometimes panic	×	—	×	—
⑫	Human beings sometimes transgress when no one is looking	×	—	〇	Nobody on-site to call attention to insufficient watch-keeping.

Table 6

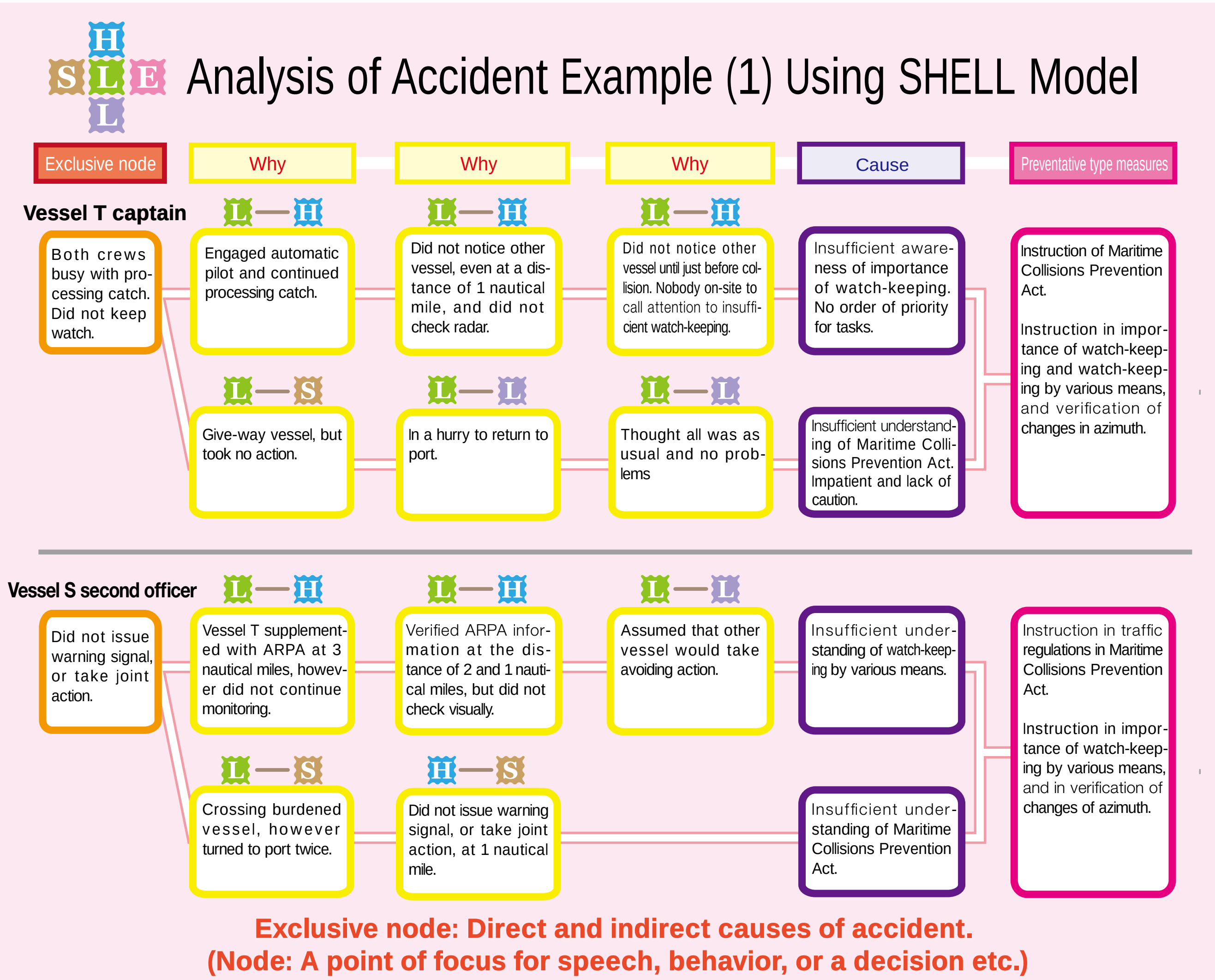


Fig. 6

5 of the 12 human characteristics apply to the second officer of vessel S, and 9 of the 12 apply to the captain of vessel T. An analysis using the M-SHELL model of why the behavior was taken in relation to these characteristics using is shown in Fig. 6.

In the examination of causes by the Maritime Accident Inquiry, and in reference to the Transport Safety Board (measures to prevent reoccurrence), associating primary causes and measures to prevent reoccurrence are associated as the exclusive node, and items verified against human characteristics as ‘why?’ in considering corresponding resources. Thus, the cause becomes apparent as a background factor, and preventative type improvement measures can be established for that cause.
In this accident example, ‘Reeducation of Maritime Collisions Prevention Act’ and instruction on the ‘importance of watch-keeping, watch-keeping by various means, and verification by change in bearing’ were established as measures for both vessels. These factors are considered as a commonsense result by the vessel operator.
Note: Exclusive node: Direct and indirect causes.
(Node: A point of focus for speech, behavior, or a decision etc.)

+ Accident example (2) +

Accident example (2) similarly summarized in Table 7 and Fig. 7.

	Human characteristics	Vessel B 3/O	Behavior	Vessel H captain	Behavior
①	Human beings sometimes make mistakes	×	—	○	Gave rise to another danger of collision.
②	Human beings are sometimes careless	×	—	×	—
③	Human beings sometimes forget	×	—	×	—
④	Human beings sometimes do not notice	○	Did not conduct watch-keeping.	○	Verified other vessel solely by radar.
⑤	Human beings have moments of inattention	○	Negligent in watch-keeping.	○	Verified other vessel solely by radar. No visual verification.
⑥	Human beings sometimes are able to see or think only one thing	○	Distracted by VHF and conversation.	○	Verified other vessel solely by radar.
⑦	Human beings are sometimes in a hurry	×	—	×	—
⑧	Human beings sometimes emotional	×	—	×	—
⑨	Human beings sometimes make assumptions	○	Thought that radar displayed images of all vessels.	○	Assumed that all crossing must be port-to-port.
⑩	Human beings sometimes lazy	○	Did not verify visually.	○	Sitting in chair concentrating on radar. Did not conduct watch-keeping by various means.
⑪	Human beings sometimes panic	×	—	×	—
⑫	Human beings sometimes transgress when no one is looking	○	Did not carry out captain's instructions (careful watch-keeping).	○	Did not conduct watch-keeping by various means.

Table 7

Verification against human characteristics shows six characteristics applicable to the third officer of vessel B, and 7 applicable to the captain of vessel H. Exclusive nodes can be taken as ‘did not notice other vessel until immediately prior to collision’ for vessel B, and ‘operation giving rise to a new danger of collision’ for the captain of vessel H.

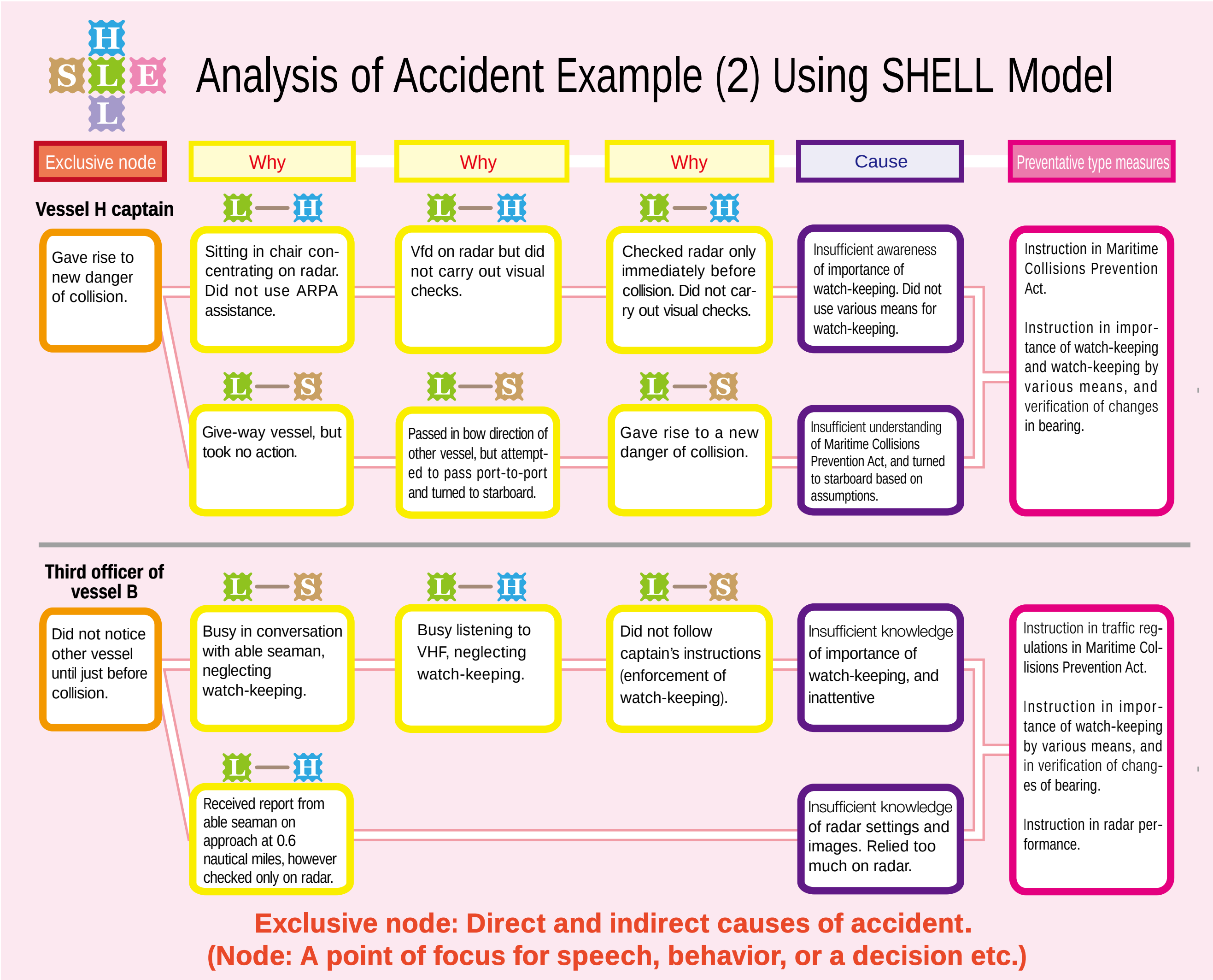


Fig. 7

In accident example (2), as with accident example (1), it can be seen that 'Reeducation of Maritime Collisions Prevention Act' and education on the 'importance of watch-keeping, watch-keeping by various means, and verification by change in bearing' were necessary. Additionally, for the third officer of vessel B, 'instruction in radar performance' was also necessary. The method of instruction for crew is described in Chapter 6.

Chapter 3 Bridge Resource Management (BRM)

This chapter describes the outline and history of BRM.

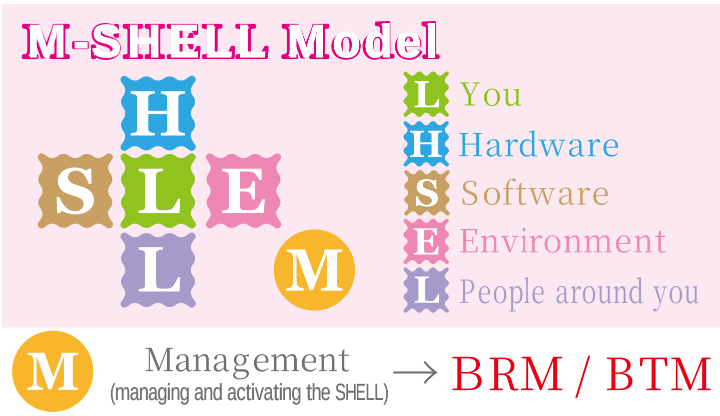
* 3-1 What is Bridge Resource Management (BRM)?

Bridge Resource Management is the effective use (M as in management) of the range of resources (R: personnel, objects, information) available on the bridge (B) for safe and efficient operation of the vessel. The term Bridge Team Management (BTM) has also come into use in recent years.
The following describes the difference between BRM and BTM.

As described above, the objective of BRM is the effective use of resources (including personnel) on the bridge, in particular the effective use of human resources for management functions which must be implemented by a leader of an organized team.
However, the achievement of safe operation is not simply due to the efforts of the leader, but it requires all members of the team to raise the level of their abilities. Improved functioning of all members of the team, including the leader, is essential. The function to achieve this, including management, is the BTM.
From the relationship between the two, the functions which must be achieved by the leader of the team are positioned as BRM, and since the leader is a member of the team, he/she must achieve BTM as a function to be executed as a member.

> **Important**
> **BTM is a function to be achieved by all members of the team.**
> **BRM is a part of BTM, and a function to be achieved by the leader.**

The following explains the situation before the introduction of the concept of BRM and BTM, and the difference between the two.
In terms of the work performed on the bridge, there is no difference in the work of watch-keeping, vessel positioning, external communications, and handling navigation equipment etc. However, if we combine resources and consider matters from an outline of human factors, BRM and BTM are intended behavior. Here it becomes the concept of the M-SHELL model.



As described above, L (You) at the center, and the surrounding resources, are never static. BRM and BTM act to ensure good communication with each resource, eliminate causes inhibiting the 12 motion characteristics of human beings, and suppress the occurrence of errors.

* 3-2 Physical Resources on the Bridge

How communication between physical resources on the bridge and human resources take place?

1. Hardware H

Hardware provides information available from various navigational equipments (radar, ARPA: Automatic Radar Plotting Aid, electronic charts). Binoculars are also an important item of hardware.

If visual information such as radar images and electronic charts is available, audio information emitted by ARPA etc. is also available. In particular, information for the prevention of collisions requires the operator's communication with the equipment to set ARPA alarms. Furthermore, work to obtain information by aligning the ARPA cursor on information on other vessels on radar images requires communication with the hardware.

Thus, the pilot is required to be skilled in the use of the hardware, and information set manually must be shared with the team. For example, even if the captain sets the CPA: Closest Point of Approach, and TCPA: Time to CPA, alarms in the ARPA settings, the officer on duty may sometimes change the alarm settings without the permission of the captain if the alarm is excessively loud. However, from the BRM point of view, this behavior gives rise to misunderstandings by team members in relation to alarm tones and further errors.

2. Software S

Software cover navigation regulations such as the Maritime Collisions Prevention Act and the Maritime Traffic Safety Act, and procedures determined in SMS manuals and safety management rules. Movement of stand-on vessels when crossing is regulated under Clause 17 of the Maritime Collisions Prevention Act (stand-on vessels) as 'unless such action is impossible, the stand-on vessel is required to turn to port'.

However, the second officer of vessel S in accident example (1) turned to port after evaluating only the ARPA information CPA and the vector, and did not visually check the change in bearing of the other vessel. Furthermore, for navigation in conditions of restricted visibility, Clause 19.5.1 of the Maritime Collisions Prevention Act regulates that ‘when other shipping is in a position abeam or forward of abeam (excluding the case in which one’s own vessel passes the other vessel), one’s own vessel changes course to port’ shall be followed unless such action is impossible. However, in conditions of restricted visibility, most collisions are due to one of the vessels not monitoring vessel movement sufficiently with radar etc. while turning to port. In such cases, the navigator on duty and the captain have ignored the requirements of the Maritime Collisions Prevention Act.

Many accidents can be prevented by simply following the procedures laboriously established in SMS and safety management regulations. In such cases, as well, it is necessary not only to determine the responsibility of the person on duty, but also to investigate causes in terms of why the regulations were not followed.

3. Environment E

Handled as environment in the SHELL model. The following information from external sources is relevant.

Information from External Sources

- Navigation information: For example, MARTIS information from the Marine Traffic Center.
- Weather maps and navigation alarms
- Communications with other vessels via VHF etc.
- Navigation alarms from the Maritime Safety Agency
- Various information from the company

In particular, with navigation under conditions of restricted visibility in congested sea areas and narrow channels, a careful examination of information obtained via VHF to identify valid and invalid information is necessary, however the priority of work must be clarified simultaneously before taking action. The third officer in example (2) was busy listening to the VHF communications from the other vessel, and engaged in conversation with the able seaman, neglecting watch-keeping, resulting in the collision.

Very few maritime collision accidents resemble motor vehicle collisions in which the two vehicles are head-on. Most reports indicate that the collision occurred despite the other vessel having been already recognized. In most cases, the Maritime Accident Inquiry and the Transport Safety Board Report indicate insufficient watch-keeping. However, most collision accidents can be prevented not only through awareness of the insufficient watch-keeping ‘exclusive node’, but also by breaking the error chain.

Fig. 8 shows the error chain up to a collision accident.

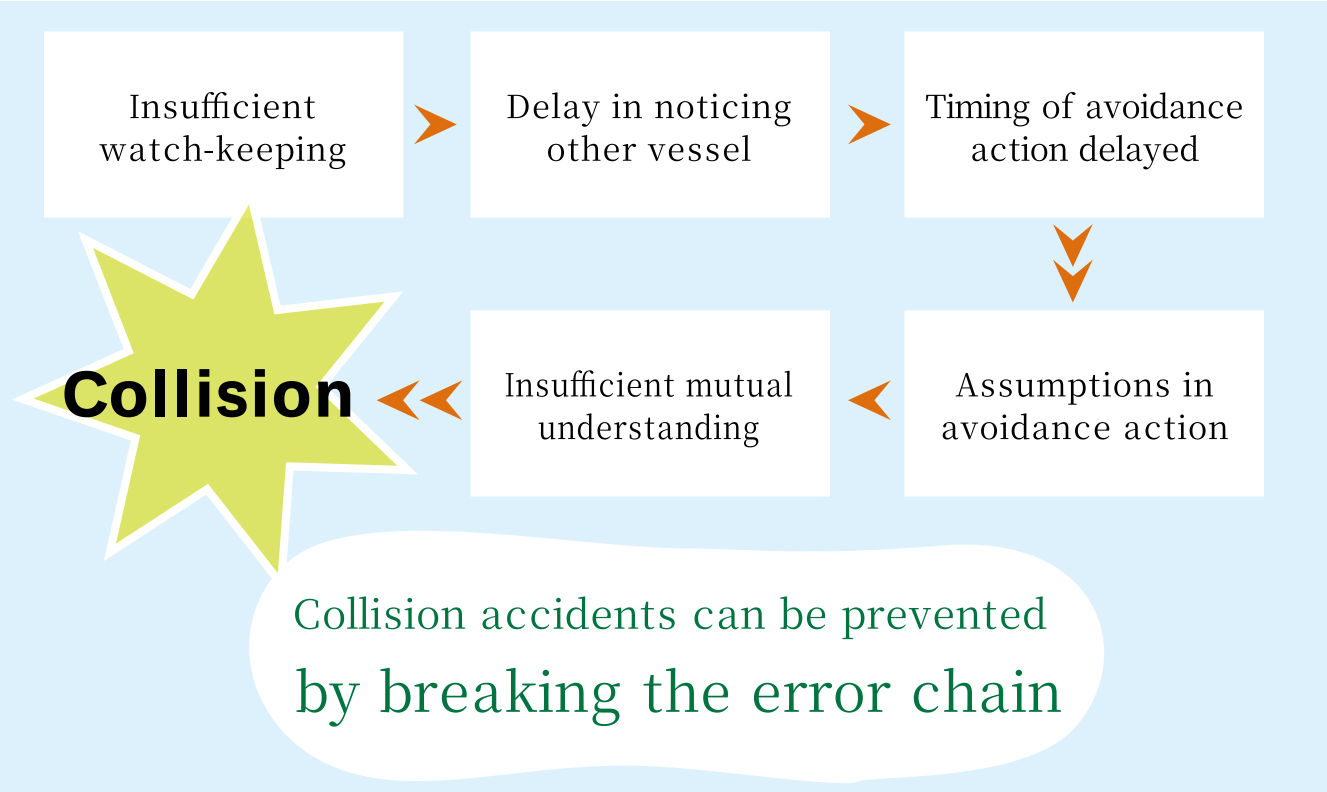


Fig. 8

The initial error chain was insufficient watch-keeping. This gave rise to a delay in noticing the other vessel, and as a result, the start of avoidance action was delayed. Then the assumption that the other vessel would take avoidance action was made without confirming the name of the other vessel in the AIS information in order to call it on VHF to verify each other's intentions; and a collision resulted. A collision could have been prevented by executing one or more of these five error chains.

* 3-3 History of BRM

The concept of human factors was first introduced at the Hawthorne plant of the US electrical manufacturer Western Electric between 1924 and 1930 in an effort to improve efficiency of work.

Subsequently, the idea that machines must be suited to human characteristics in order to obtain optimum results was taken up in the US in 1940 for the manufacture of military equipment during WWII.

A large number of aircraft accidents occurred in the 1960s, and while no major change occurred in the accident rate, the greater size and number of aircraft resulted in an increase in the number of casualties. It became apparent that if the accident rate continued, by the year 2000, an aircraft accident would occur every week somewhere in the world. A sense of impending crisis grew in the aircraft industry that the public would come to view an aircraft as an unsafe mode of travel.

In 1971, the training in 'Human Factors in Transport Aircraft Operation' commenced at Loughborough University in the UK. Voice recorders and flight recorders were then fitted to aircrafts, and the majority of aircraft accidents subsequently were considered to have resulted from human error.

The trigger for the training by the airline industry incorporating human factors was the accident at Tenerife described below.

Jumbo Jet Collision at Tenerife

This accident occurred in the island of Tenerife in the Spanish territory of the Canary Islands at 17:06 local time on March 27th, 1977 on the runway at Los Rodeos airport.
The accident involved two 747 Jumbo aircraft, one KLM, and one Pan American, the aircraft colliding on the runway after failing to visually identify each other. A total of 583 passengers and crews were killed, with 54 passengers and 7 crews surviving. The accident was the worst in the history of the airline industry.

Circumstances of the accident

The captain of the KLM aircraft released the brakes and began moving down the runway. The co-pilot noted that clearance had not been received, and a few seconds later checked and obtained clearance from the controller.
This clearance was only for ‘standby to takeoff’, and not for ‘takeoff when ready’. When the controller issued clearance he used the term ‘takeoff’, and it is thought that crew on the KLM aircraft understood this as permission for ‘takeoff when ready’. At 17:06:23 the KLM co-pilot, speaking with a Dutch accent, responded with either “We are at take off” or “We are taking off”. The controller was confused by this response, and in turn responded with “OK”, followed after a 2-second silence by “Stand by for take off. I will call you”. This ‘OK’ and the following 2-second silence subsequently became a point of contention.

The crew on the Pan Am aircraft were listening to this conversation, and immediately felt uneasy and warned that “No, we are still taxiing down the runway”. This silence from the Pan Am aircraft occurred immediately after the 2-second silence noted above, and on the KLM aircraft, the crew heard only “OK”, and transmission then became inaudible due to interference, and nothing was recorded.
On the Pan Am aircraft, the 2-second silence was interpreted as completion of the controller’s transmission, and the Pan Am crew then began transmission, however controller was still holding down the send button, resulting in the interference. Neither the controller nor the Pan Am crew noticed this interference.
Thus, the Pan Am crew thought that the warning had reached both the KLM aircraft and the controller, the controller thought that the KLM aircraft was waiting at the takeoff position, and the KLM crew thought that ‘OK’ meant that permission to take off had been issued, and opened the throttle for takeoff.

Due to the thick fog, the KLM crew thought that the Pan Am 747 was still on the runway, and were unaware that it was moving in their direction. Furthermore, personnel in the control tower were unable to see either aircraft, and even worse, no ground control radar was installed on the runway.

There was, however, one last chance to avoid the collision - only 3 seconds after the conversation noted above, the controller asked the Pan Am crew to “report when runway is clear”. The Pan Am crew responded with “OK, we’ll report when we’re clear”. The KLM crew heard this conversation clearly, and the KLM fight engineer feared that the Pan Am aircraft was on the runway. The conversation at this point was recovered after the accident from the cockpit voice recorder of the KLM aircraft.

KLM flight engineer :" Looks like it's still on the runway " .

KLM captain :" What! "

KLM flight engineer :" Looks like Pan Am is still on the runway " .

KLM captain/co-pilot :" We're OK "(in a strong voice)

The situation was that the KLM captain was not only the superior of the flight engineer, but also one of the most experienced pilots. It appears that in this context, the flight engineer clearly hesitated to push the point.

Since 1980, CRM (Cockpit Resource Management) has become a fixture, and the training is now conducted in the airline industry.
Currently, Crew Resource Management includes cabin staff, and thus includes all crew. In Japan, the training was introduced in 1985 triggered by the Osutakayama crash.

In the maritime world, BRM training was introduced in Europe and the US in the 1990s. In Japan, it was introduced by large shipping companies in 1998.

Chapter 4 BRM in Practice

* 4-1 BRM on the Bridge

BRM was introduced to ocean-going vessels almost 20 years ago. As described in Chapter 2-4 Human Factors and Human Error, BRM was introduced with the understanding that 'everyone makes a mistake' and 'there are limits to abilities', and to cover the weakness of human beings on the bridge with team work and information to ensure that errors do not lead directly to a threat to the safe operation of the vessel.

However, while the efficacy of BRM is understood, complaints to the effect that it cannot be put into practice on-site are heard. The following explains how to use BRM to ensure that it functions effectively.

* 4-2 Clarifying Division of Labor and Ship Handling

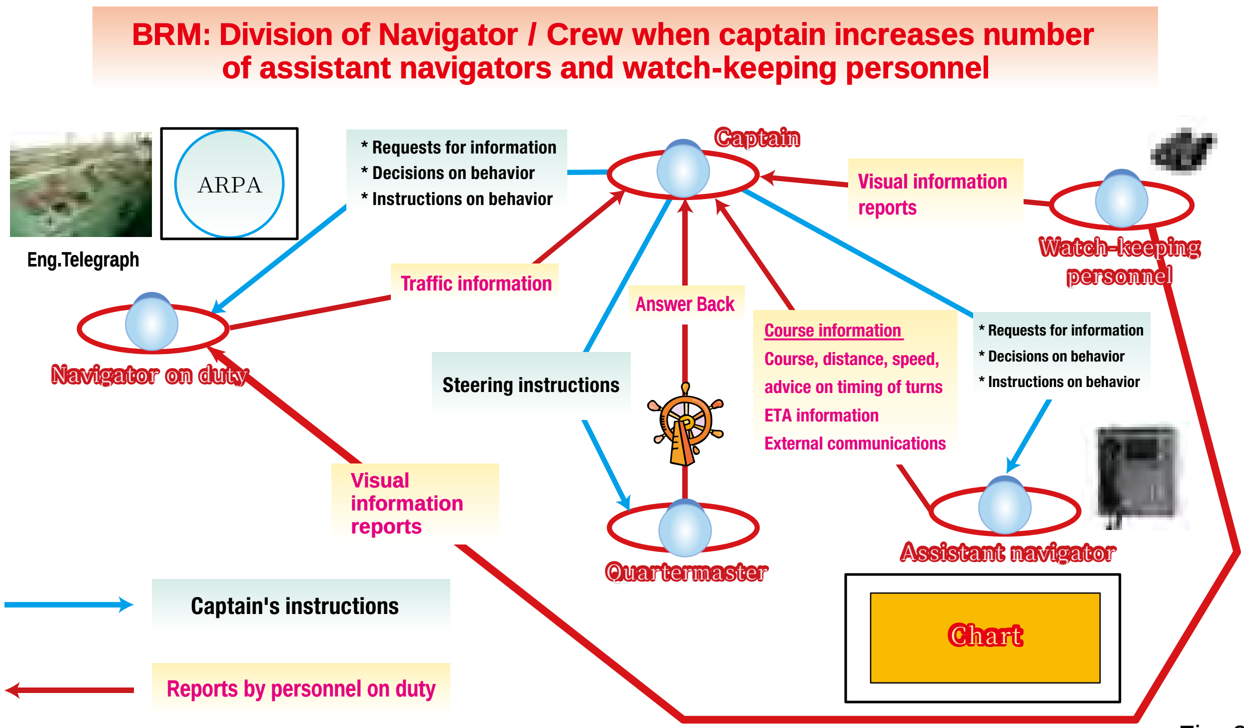


Fig. 9

Fig. 9 shows the command structure for steering of the vessel when entering and leaving port, in congested areas, and in narrow channels with increased numbers of assistant navigators and watch-keeping crew.

1 Captain

Takes command at the center of the bridge.
In particular, when giving instructions to change course and for engine control, it is important to explain the intentions to team members if sufficient time is available. For example, to change course and reduce speed to avoid another vessel, or course change towards the next turning point and increase or decrease speed to avoid another vessel. It is also necessary to clarify switching between manual and automatic pilot to the able seaman.