If there is insufficient communication and cooperation between the person responsible for the accident (L) and each resource, and if the team does not gel, this will create a gap and safety cannot be established when a human error occurs.

If the squares (H, S, E, L) are well aligned, then even when a person causes a human error (L), the resources surrounding him/her will be aware of it and will communicate this so that L is aware.

BTM and ETM training are effective methods that help us address communication issues, however, there are many who still say that it is difficult to carry this out in practice. The main reason has to do with the difficulty of communication. Figure 13 illustrates this.

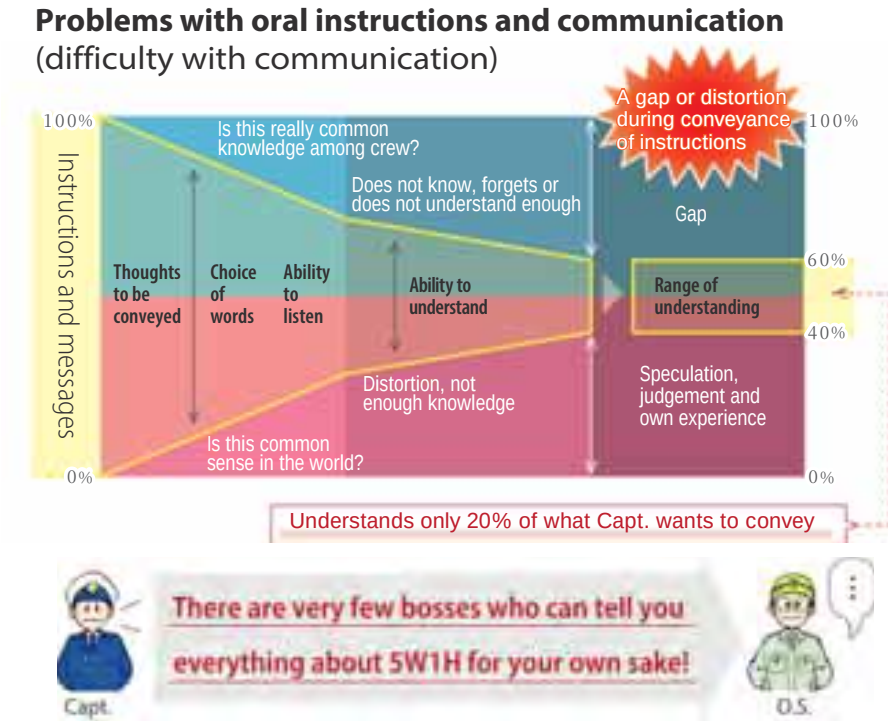


Fig. 13 Problems with oral instructions and communication (difficulty with communication)

The yellow coloured area on the extreme left shows what a Master intends to order or what message he intends to convey (Full understanding is shown as 100%). Even when the Master tries to relay information to an Ordinary Seaman (O/S), only 20% of the information may be understood due to a misunderstanding, a lack of understanding or knowledge that the O/S may think is common sense, a lack of communication, speculation or judgement on the part of the O/S, or he/she may compare what was relayed to their own experience. Why is this the case?

It seems most likely that the reason why information cannot be conveyed successfully is down to a difference in their level of understanding regarding technology. For example, if the Master tries to convey the same message to another Master, his message will be conveyed to the full (100%), because their technical backgrounds are almost the same.

§2 4M4(5)E Analysis

One preventive measure that we can use is the 4M4(5)E Analysis. This model takes into account lessons learned from similar past accidents. This is a countermeasure (method) that seeks to prevent a re-occurrence of the same or a similar accident based on lessons learned, in the event that such an accident should occur.

"Safety" is management's top priority. In order to realize this, it is important to correctly identify "the bud of a potentially new accident" and to prevent a re-occurrence based on the lessons learned. Most accidents at this bud forming stage can be referred to as events that require attention or risky events and are often due to human error. Thus, it would be vitally necessary to analyse such phenomenon thoroughly from a human factor perspective.

This method is derived from an accident investigation method adopted by the US National Transportation Safety Board (NTSB) and has been used in various fields including the industrial arena. With this method, we can not only look at error factors from multiple perspectives but also examine preventive measures from a wide range of viewpoints.

2－1 Errors Made by an Involved Party and Organizational Errors

Although we have established preventive measures for every time an accident occurs, why then has the 4M4(5)E analysis been the subject of recent interest?

According to The Hudson Model: Types of Safety Culture (See Figure 14), Safety Culture has been developed as follows:

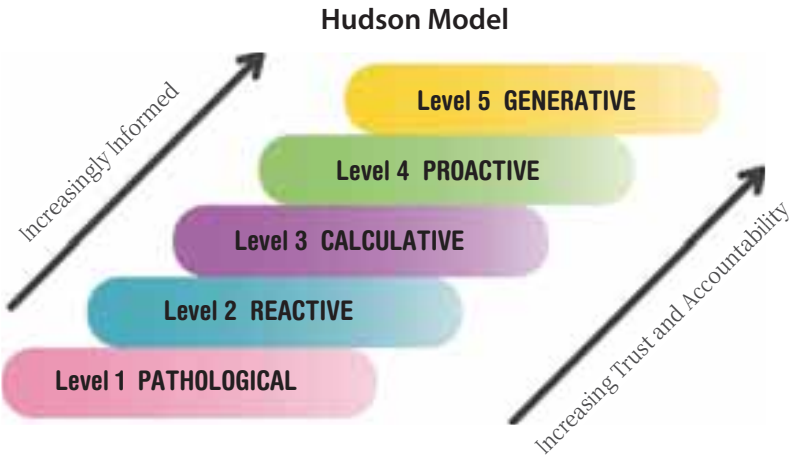


Fig. 14

Level 1 Pathological	Safety problems are caused by the workers. Safety concerns only the Safety department.
Level 2 Reactive	Safety is important, but we activate it only after an incident. Mistakes are punished.
Level 3 Calculative	Safety driven by SMS and safety is improved through PDCA. Emphasis on continuous monitoring using safety measures.
Level 4 Proactive	All staff understand the importance of safety. The organization tries to prevent accidents with proactive measures (manpower, equipment and cost to be included).
Level 5 Generative	Safety is an inherent aspect of a sustainable organization. All staff unconsciously give priority to safety.

In other words, in the past, when an accident occurred, because almost all accident causes were due to human error, the person who caused the accident was identified and the mistakes that led to the accident investigated. Then, the case would have been closed after having reprimanded the individual by saying something like, “Be careful in future”

or holding the individual to account by punishing him/her (“grave-post type”). The above Level 1 (Pathological) and Level 2 (Reactive) are applicable to this.

But, we have learned that this kind of preventive measure lacks in efficacy. Therefore, it is a must that we examine the factors behind human error and explore further as to why an individual causes a human error. Then we can take effective countermeasures (“preventive type”) to prevent future re-occurrence.

Figure 15 illustrates this.（Why are accidents repeated - the analysis of the human factor written by Akira Ishibashi; from Japan Industrial Safety and Health Association (JISHA)）(Provisional translation)

Fig. 15 Why are accidents repeated - the analysis of the human factor written by Akira Ishibashi

Source: Seminar on Analysis and Countermeasures of Accidents Learned from Case Studies, by Japan Industrial Safety and Health Association (JISHA) (Provisional translation)

In the event that an accident is considered to have been caused by human error, it is easy to take remedial measures for visible and technical errors. Moreover, it seems clear at first glance that the parties involved should be punished and that the technology should be improved.

For example, as for collision accidents, most of their direct causes are related to human error such as insufficient lookout and non-compliance with the navigation act. As a result, compliance with Article 5 of the Act on Preventing Collision at Sea (Lookout) and its 2nd Chapter (Navigation act) are followed, and the party involved is punished, then the case is closed.

However, each Master and Navigation Officer who has a seaman's competency certificate fully understands the importance of lookout and compliance with the Navigation act. True preventive measures cannot be established unless we analyse in depth as to why professional qualified mariners "neglected appropriate lookout and could not comply with the navigation act". For example, as organizational errors that are not readily apparent manifest themselves, shown in Figure 15, we must construct recurrence preventive measures by analysing the "Underlying causes", to establish if there are errors in the organization or team, such as an inappropriate manual, insufficient training, poor working conditions and excessive paperwork.

2－2　4M4(5)E Analysis

As mentioned above, the 4M4(5)E analysis considers the cause of the accident to be a result of organizational error. A matrix table of specific causes behind the accident and countermeasures is formulated. The specific causes behind the accident are described (4M)、and then countermeasures (5E) in terms of training, technology, reinforcement/enforcement, examples, and environment (organization both within the company and onboard), are added.

4M

Shows specific factors behind an accident

- Man
- Machine
- Media (Environment)
- Management

4(5)E

Reveals countermeasures

- Education
- Engineering
- Enforcement
- Example
- (5) Environment (within company and on-board ship etc.)

When considering the conditions that cause occupational accidents, it can be said that 85.6% occur as a result of a combination of "unsafe behaviour" and "unsafe conditions". (See Figure 16)

Fig. 16

Source: Seminar on Analysis and Countermeasures of Accidents Learned from Case Studies, by Japan Industrial Safety and Health Association (JISHA) (Provisional translation)

On considering the reasons behind “unsafe behaviour” or “unsafe conditions”, the root cause is often found in an “organization’s safety management deficiencies”. (See Figure 17) for 4M4(5)E analysis, whereby these “root causes” and “direct causes” are organized into a table, analysed, and preventive measures formulated.

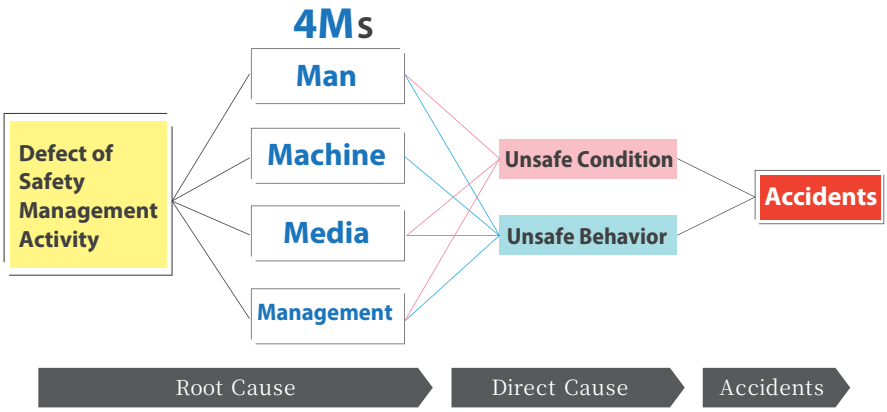
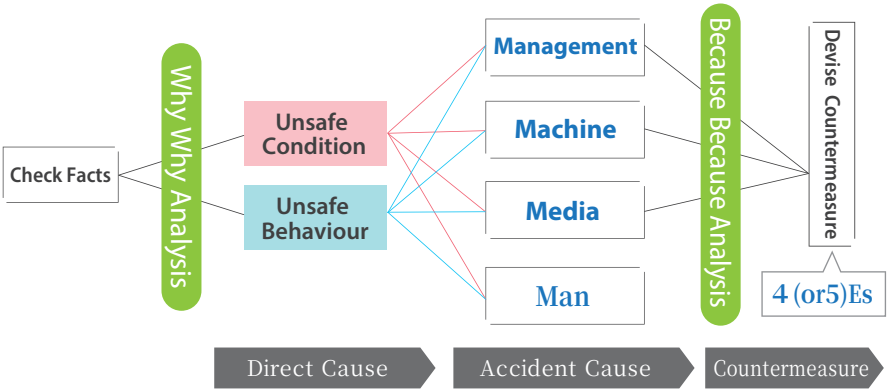


Fig. 17

2－3　4M4(5)E Analysis Plus Why Why Analysis: Investigation, Analysis and Countermeasures

The 4M4(5)E analysis and countermeasure planning workflow is shown in Figure 18.



＊Because it is important to check the facts, countermeasures are not to be made based on own speculation. Conduct a further investigation, if necessary.

Fig. 18

An outline of the analytic procedure will be explained below. (See Attachment 1 P.93)

1. Site investigation

Carry out investigation in as much detail as possible, ideally by a third party (such as a surveyor or marine consultant etc.)

2. Analysis of site investigation report

- Clarify accident cause/s (4M), using a classification table and so on.
  (See Attachments 2-1, 2-2 and example in Figure 19.)
- Organize these into a matrix to examine the facts (See Attachment 3).

1. Facts extracted from the accident investigation report that caused the accident have been identified and listed under each factor in the table to the right.
2. Classify into Unsafe Behaviour or Unsafe Conditions by factor.
3. After clarifying the accident cause/s, in order to analyse this, assess accident cause by prioritizing according to the scale of the cause.
4. Furthermore, clarify which items need to be inspected/investigated again.

＊ Accident Reports

Ship reports, ship management company reports, survey reports, attorney (maritime auxiliary) reports, transportation security reports, and as much information as possible, such as accident investigation reports of all committees and decisions of the Japan Marine Accident Tribunal, are to be collected.

Example

Vessel superintendent was aware of the low visibility weather forecast, but, as he assumed that the Master also knew, he did not report it.

2 radars were equipped on board, but the magnetron of No.1 radar was to be replaced by the manufacturer at the next port. The Master was requested to navigate using only No. 2 by the vessel superintendent, and agreed despite feeling uneasy about it.

Attachment 3

Maritime Accident Summary of Related Facts

Reference No.	Identified problems from survey findings				Direct cause		Accident cause evaluation	Re-examination necessity
	Date	Time	Caused by	Check facts and problem areas	Unsafe behaviour	Unsafe conditions		
1	Unspecified date	Approx. 3 p.m.	Vessel superintendent	Did not report a forecast of low visibility to the Master	○		4	
2	Unspecified date	Approx. 4 p.m.	Vessel radar	No. 1 radar was out of order	△	○	3	○
3	Unspecified date	Approx. 5 p.m.	Vessel superintendent	Requested the Master to navigate using only No. 2 radar until next port, because arrangement to fix No. 1 radar at the port had been made	○		5	○
4	Unspecified date	Approx. 5 p.m.	Master	Approved navigation to the next port using only one radar.	○		6	
5	Unspecified date	Unspecified time	2/O	Did not report to the Master, although there was the low visibility (less than 2 nautical miles) (According to the Safety Management Code, low visibility is defined as less than 3 nautical miles.)	○		2	
6	Unspecified date	Unspecified time	2/O	Searched for the other vessel at 6.6 nautical miles via radar, but did not notice the image captured on ARPA, because he believed he could pass starboard to starboard	○		1	

Example

Accident cause assessment: Prioritized according to the scale of the cause

At XX:XX (unspecified time), the 2/O knew that there was low visibility of less than 2 nautical miles, but he did not report it to the Master.

At XX:XX (unspecified time), Although the 2/O searched for Vessel △△ at approximately 6.0 degrees on their starboard bow in the vicinity of <015> 6.5 nautical miles via radar, he believed he could pass starboard to starboard, but did not notice the image captured on ARPA.

Fig. 19 (P.98 Attachment 3)

3. Once the above have been established, compile this information into an accident cause/s matrix (unsafe behaviour and unsafe conditions).

(See Attachments 4 and 5)

Pick out the relevant facts, and compare “unsafe behaviour” and “unsafe conditions” using the 4M classification table and carry out a “Why Why Analysis”. Circle the corresponding items.

1. Enter relevant factors into Analysis Tables 1 to XX, and enter why these occurred in (2) to (6) below.
2. Then, circle each applicable column.
3. Enter the sub-item number of each item in the 4M Classification List for Machine, Media, and Management.
4. For items requiring re-investigation, circle the corresponding column to the right.

4. Once the above 3 has been completed, analyse and devise countermeasures.

(See Attachments 6 and 7)

- Classify the direct cause and indirect/root cause of the accident referring to the 4M4(5)E table.
- Devise a countermeasure for every 4(5) item.

1. Copy over the risk factors from the analysis chart (including the applicable numbers).
2. Copy over countermeasures to reduce or improve the risk factors into the 4(5)E table.

Why Why Analysis

The Why Why Analysis method is a way of finding and verifying the efficacy of solutions to a certain problem. By repeatedly asking the question “Why?”, the method seeks to identify what caused the problem, what factors led to that cause, and so on and so on. This is a mainstay component of the Toyota Production System.

Method (Figure 20)

- The first stage is to present the problem in question. In order to make a logical progression to the next stage, it is helpful at this point to go through a process of elimination of irrelevant causative factors.
- A list of potential causes can then be created. This is the result of the first "Why?" There may be multiple causes but they must all have a logical connection to the original problem.
- The next stage is to come up with the potential factors which led to those causes. This is the result of the second "Why?" As with the first stage, there may be a number of different factors involved, but each must have a logical connection to the subsequent cause.
- This process is repeated in the same manner with the 3rd and 4th stage of "Why?s".

It is difficult to say at what point it is best to suspend this repeated process, but in practical terms the ultimate goal is to find a logically proven solution whereby removal of the causative factors leads to elimination of the original problem.
During the "Why Why" process, some causative factors, be they a particular phenomena or something of a more systemic nature, may well be deemed unavoidable. In which case, the analytic process should be suspended. Conversely though, through this same process, it is also possible that factors, which were thought to be unavoidable, are actually shown to be no more than a preconception.

The Toyota Motor Corporation first pioneered this methodology and advocated a 5 "Whys" technique. However, this method is now employed in a variety of different fields and is not restricted to a set number of whys. The important thing is to arrive at the root cause of the problem.

〈 Analysis Chart for Incident & Cause Factors（Model）〉

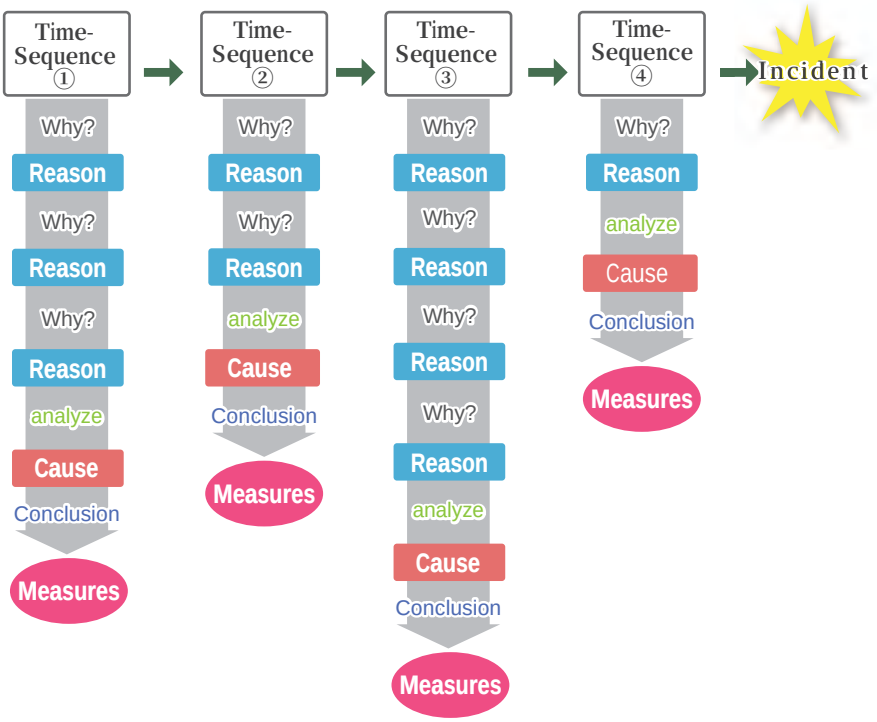


Fig. 20

Devise a countermeasure

Devise a countermeasure for each factor below regarding unsafe behaviour and conditions. The following items from ① to ⑤ are to be extracted from Attachment 4.

❶ **Education :**
Education and training
Measures to improve the competency, awareness and knowledge required to perform the task.

❷ **Engineering :**
Technology and engineering
Technical measures of handling equipment for safety improvement and improvement of equipment etc.

❸ **Enforcement :**
Thorough guidance and enforcement
Measures related to thoroughly enhanced regulation in order to ensure the work done and revision of the SMS etc.

❹ **Examples :**
Case studies, countermeasures and rules
Measures to show specific cases such as lead by example, experience of success, introducing model cases etc.

❺ **Environment :**
Measures related to working environment, office internal management, on-board organization, etc.

Figure 21 shows an example of recurrence prevention countermeasures.

Example

Risk factors(direct cause and indirect/root cause)

It is considered effective to have them attend training programs such as behavioral psychology to learn awareness.

Risk factors(direct cause and indirect/root cause)

Vessel

1. Why wasn't this captured by ARPA?
(1－③,⑧,⑨,⑩,⑪,4－1－③)
2. Why was the problem of poor visibility not reported to the Master?
(1－②,⑥,⑪,⑫,2－①,3－③)
6. Why did he approve navigating with a single radar?
(1－①,⑤,⑥,⑧,⑨,⑪,4－1－③,4－3－②)

Shipowner and ship management company

5. Why did they request a single radar for navigating?
(1－①,⑥,⑦,⑨,⑪,4－1－①,②,③,④,4－2－①,4－3－②,③)

Education and training Knowledge, skills, consciousness, being given information, etc.	Example Case studies, countermeasures and rules
● Training in behaviour psychology ⇒ Learn to notice things ● Education to reinforce habitually that optical illusions/errors and assumptions can cause a risky behaviour	Lead by example, experience of success, introduce model cases, " Hiyari-Hatto " (near misses), etc. ● Gain a sense of experience using navigation simulations, for example

Fig. 21

5. Carry out and verify countermeasures based on the devised example above, and Brush up using a PDCA cycle.

The key is (1) to ensure that the proposed countermeasures are always implemented, (2) that their effectiveness is evaluated and verified and (3) that any defects are corrected. That is to say, PDCA (Plan・Do・Check・Action（for improvement）shall be performed. If this is not done, the hard-earned measures to prevent recurrence will quickly become a mere formality. In the event of a major accident, it will be of value to have a recurrence prevention campaign annually (so as not to forget).

When considering methods of prevention, for example the PDCA cycle mentioned in Attachment 7, be sure to carry out the following to ensure that the intended preventive measures do not become a mere formality.

Enforcement（thorough guidance and enforcement）
Thoroughly clarify procedures for low visibility in the procedure manual.

Plan

Here, we will examine how to ensure that the existing procedures are reviewed and clarified, as well as how to ensure compliance with the revised procedures at sea. In order to achieve this, 4 root causes (Technicians characteristics, Human behavioural traits, Psychological factors and Human brain capacity）described in 1-2 As a Mechanism behind Maritime Accidents Caused by Human Error, shall be considered. For example, a review of training programmes, internal audit frequency, the launching of an evaluation committee etc. could be considered. The most important is annual scheduling. If the scheduling is vague, these kinds of tasks will be easily put off.

Do

It is important to carry out the planned schedule with certainty.

Check（evaluation）

An assessment committee will be held every 3 to 4 months in order to manage the work plan progress and to assess the implementation report. It is important to identify the problems by providing a general overview of the fiscal year at the end of the year.

Action（improvement）

Analyse the problems identified in the evaluation（including the Why Why Analysis), and formulate measures for improvement.

This outcome will be the Plan for the following fiscal year.