

A Study on the Practical Means to Prevent Collision at Sea

- Through risk management theory -

† Ok-Yong Lee* · Devinder Grewal** · Stephen Cahoon***

* Professor, Korea Institute of Maritime and Fisheries Technology, Busan 608-080, Korea

*** Associate Professor, Department of Maritime and Logistics Management, Australian Maritime College

** Lecturer, Department of Maritime and Logistics Management, Australian Maritime College

Abstract : *The statistics of Korean Maritime Safety Tribunal and Japan Marine Accidents Inquiry Agency shows that the major causes of collision at sea are Improper lookout and Non-compliance with marine traffic rules. Those two causes are occupying more than 70% of collision, and it's clear that those causes are undoubtedly closely related to simple human error. In this paper we tried to find out the root causes of this kind of human error of OOWs(officers on watch) through risk identification method, and studied how to tackle them via risk control theory. In conclusion, the measures studied in this paper could be applied to help OOWs avoid their own human error as well as be used in shipping company for their fleets' safety management.*

Key words : *Collision, Cause of collision, Improper lookout, Non-compliance of traffic rule, Risk management*

1. Introduction

1.1 Purpose of the study

In any country, the collision of vessels at sea always takes a great portion of the marine casualties and is a big barrier to achieve safe maritime transportation and to keep the ocean clean. All countries are endeavoring to reduce maritime casualties, particularly the collision at sea. However, in spite of such efforts, vessel's collisions does not appear to have decreased, and it's because, we can assume, most of the accidents are deeply concerned with human error followed by underlying causes. This is why today IMO as well as relevant organizations are addressing to the sector of human error of watch officer.

「Two recent updates to SOLAS clearly demonstrate the IMO's change in direction from a regulatory regime to that of a safety culture with a strong emphasis on the human element. Bridge Resource Management, information processing and decision making, workload, human error, fatigue and distraction, together with clarity of controls, alarms, displays and status indication are all addressed. Indeed in the light of the development of Chapter V-15, there is a feeling that the scope of the Regulations should be widened, to encompass everything that could influence the watchkeeper's function on the bridge.」 [The Nautical Institute, 2003]

「A classification society's view of Human Element issues" ; ABS is now moving beyond simple ergonomic design issues, and is looking into areas such as human fatigue, situation awareness, management and organizational factors, and root cause analysis for incidents. ABS is committed to discovering new means to enhance human and organizational performance - means that will reduce the number of casualties and incidents resulting from human error.」 [The Nautical Institute, 2004]

The purpose of this study is to identify the underlying root causes of human errors causing ship collision and seek practical, helpful means to tackle the root causes.

1.2 Method of the study

This study has been done via following procedure: First, data of maritime accidents was gathered through the statistics of Korea(1995-2004) and Japan(2000-2004), and the features of collision including the major causes are analyzed.

Second, 'Heinrich's Domino Theory' and advanced Domino Theory, the so-called principle of preventing accident was discussed to describe the core action to be done to prevent accidents.

Third, focusing on the fact that the major reasons of collision have close relationship with human error, the nature of human behavior is discussed, including the precedent factors affecting the final behavior (attitude of

† Corresponding Author : Ok-Yong Lee, oylee@seaman.or.kr (051)620-5764

** D.Grewal@amc.edu.au +61 3 6335 4820

*** S.Cahoon@amc.edu.au +61 3 6335 4769

people).

Fourth, through the Fault Tree Analysis method - the hazard identification method of risk management, found out the underlying causes (root causes) of collision based on the literature survey and reports on the maritime accidents, mainly in relation to collision.

Fifth, the practical measures to be taken by the relevant organization which would be helpful for the prevention of collision at sea were sought.

Finally, the study concludes by focusing on the key concepts outlines throughout this study.

2. The Status of Marine Accidents

2.1 Statistics of marine accidents in major countries

1) Korea (Republic of)

Table 1 Classification of marine accidents

Unit : Case

	Collision	Contact	Grounding	Fire or Explosion	Sinking	Machinery Damage	Distress	Damage to facilities	Death or Injury	Safe Operation Hindrance	Others	Total
1995	183	10	69	49	75	189	49	1	8	21	55	709
1996	170	15	67	41	56	159	18	1	15	60	59	661
1997	181	9	85	68	99	236	47	2	6	56	51	840
1998	147	5	77	60	84	242	48	4	8	43	54	772
1999	173	2	68	67	90	269	24	2	13	73	68	849
2000	130	11	58	48	63	196	23	0	19	51	35	634
2001	141	15	60	62	72	135	25	1	17	44	38	610
2002	184	13	58	42	55	110	18	3	20	13	41	557
2003	182	9	65	53	50	57	21	0	43	12	39	531
2004	210	12	75	57	69	147	45	1	80	42	66	804
Total	1,701	101	682	547	713	1,740	318	15	229	415	506	6,967
Ratio (%)	24.4	1.4	9.8	7.9	10.2	25.0	4.6	0.2	3.3	6.0	7.0	100

* Taken from The statistics of marine accidents, 1995-2004, Korean Maritime Safety Tribunal

Table 2 Classification of Marine Accidents by Category of Causes

Unit: Case

Causes	Type of Accident	Collision	Contact	Grounding	Fire or Explosion	Sinking	Machinery Damage	Distress	Death or Injury	Others	Total
Inappropriate preparation for sailing		2	-	5	-	8	-	-	-	2	17

Negligence in vessel operation	Insufficient study of waterway	2	2	15	-	2	-	-	-	1	22	
	Poor selection and maintenance of course	9	2	6	-	-	-	-	-	-	17	
	Non-confirmation of vessel's position	1	1	51	-	-	-	-	-	-	53	
	Inappropriate maneuvering	63	10	12	-	8	-	-	1	9	103	
	Improper lookout	558	2	5	-	1	1	-	1	-	568	
	Insufficient attention to weather of sea condition	4	-	11	-	36	-	-	4	25	80	
	Improper anchoring or mooring	1	1	1	-	-	-	-	-	1	4	
	Non-compliance with marine traffic rules	262	-	-	-	1	-	-	1	1	265	
	Inappropriate supervision	-	-	1	-	-	-	-	-	1	2	
	Negligence in watch-keeping	14	3	9	2	8	-	1	1	1	39	
Mis-handling and deficiency	Non-observation of safety working regulation	1	-	2	7	1	-	-	40	4	55	
	Others	152	8	19	1	15	3	-	11	19	228	
	Sub total	1,069	29	137	10	80	4	1	59	64	1,453	
	Improper handling of main engine	9	2	3	36	10	103	-	3	2	168	
	Poor maintenance, inspection and handling of electric equipment	-	-	-	94	-	1	-	1	-	96	
	Defect of hull and engine	3	-	2	3	48	5	3	4	8	76	
	Sub total	12	2	5	133	58	109	3	8	10	340	
	Others	Bad stowage of cargo	-	-	1	-	7	-	-	2	19	29
		Improper vessel operation	3	-	3	2	13	1	-	1	3	26
		Inappropriate manning	4	-	2	-	2	-	-	1	-	9
Bad condition of navigation assistance equipment		3	2	-	-	2	-	-	-	-	7	
Act of God		4	2	3	-	12	-	-	1	9	31	
Others		23	-	-	2	3	-	-	2	3	33	
Sub total		37	4	9	4	39	1	0	7	34	135	
Total	1,118	35	151	147	177	114	4	74	108	1,928		

* Taken from The statistics of marine accidents, 2000-2004, Korean Maritime Safety Tribunal

2) Japan

Table 3 Category of Marine Accidents

Unit : Case

	Collision	Contact	Grounding	Fire and Explosion	Capsizing	Machinery Failure	Death and Injury	Others	Total
2002	364	59	177	-	29	99	46	60	834
2003	300	52	153	14	22	77	45	52	715
2004	303	57	137	16	28	91	48	80	760
Total	967	168	467	30	79	267	139	192	2,309
Ratio (%)	41.3	7.6	20.1	1.5	3.6	11.3	6.2	8.5	100

* Taken from Reports on Marine Accidents, 2002-2004, Japan Marine Accidents Inquiry Agency

Table 4 Category of Marine Accidents by Causes

Unit: Case

Causes	Collision	Contact	Grounding	Fire or Explosion	Capsizing	Machinery Failure	Damage or Injury	Death	Others	Total
Inappropriate preparation for sailing	1	-	1	-	-	-	-	-	3	5
Insufficient study of waterway	1	4	27	-	-	-	1	-	2	35
Poor maintenance of course	-	4	29	-	-	-	2	2	-	37
Non-confirmation of vessel's position	-	9	52	-	-	-	3	1	-	65
Improper Maneuvering	7	14	6	-	3	-	1	3	2	36
Improper lookout	494	8	1	-	-	-	1	5	-	509
Inappropriate measure for bad weather	-	-	1	-	20	-	-	-	-	21
Improper anchoring or mooring	1	2	3	-	3	-	-	3	6	18
Non-compliance with marine traffic rules	180	-	-	-	-	-	-	-	-	180
Improper supervision	39	6	22	5	4	-	1	14	-	91
Dozing	29	11	53	-	-	-	1	-	-	94
Improper management	3	1	1	1	2	2	-	7	1	18
Improper repair of hull, engine or equipment	1	-	-	-	-	5	-	3	-	9
Light or shapes off	18	-	-	-	-	-	-	-	-	18
Failure to sound signal	86	-	-	-	-	-	-	1	-	87
Inappropriate speed	18	5	-	-	-	-	-	3	-	26
Inappropriate taking-over	16	1	6	-	1	-	1	-	-	25
Inappropriate deck work, cargo work	-	-	-	1	1	-	-	23	-	25
Insufficient maintenance, of main engine	1	-	-	1	-	65	-	-	6	73
Insufficient maintenance, of auxiliary engine	-	2	-	1	-	10	-	-	10	23
Insufficient handling of LO or fuel oil	-	-	1	4	-	31	-	-	3	39
Insufficient maintenance, electric equipment	-	-	-	6	-	-	1	1	6	14
Bad handling of fire	-	-	-	7	-	-	-	-	-	7
Others	3	-	8	4	5	2	2	15	2	41
Total	898	67	211	30	39	115	14	81	41	1,496

* Taken from Reports on Marine Accidents, 2002-2004, Japan Marine Accidents Inquiry Agency

2.2 The major causes of collision

1) Korea (Republic of)

Table 5 The causes of collision

Unit: Case

	2000	2001	2002	2003	2004	Total	Ratio (%)
Improper lookout	117	104	124	125	88	558	49.9
Non-compliance with traffic rules	57	64	49	51	41	262	23.4
Inappropriate maneuvering	10	5	24	20	4	63	5.6
Poor maintenance of course	1	-	3	-	5	9	0.8
Negligence in watch-keeping	6	1	5	1	1	14	1.3
Improper anchoring or mooring	-	-	-	-	1s	1	0.1
Insufficient attention to weather condition	-	-	2	-	2	4	0.4
Others	35	63	41	34	34	207	18.5
Total	226	237	248	231	176	1,118	100

* Taken from The statistics of marine accidents, 2000-2004, Korean Maritime Safety Tribunal

2) Japan

Table 6 The Causes of Collision

Unit: Case

	2002	2003	2004	Total	Ratio (%)
Improper lookout	494	405	391	1,290	52.7
Non-compliance with marine traffic rules	180	140	150	470	19.2
Inappropriate direction or supervision on work	39	39	45	123	5.0
Dozing	29	19	25	73	3.0
Light or shapes off	18	15	13	46	1.9
Failure to sound signal	86	76	99	261	10.7
Inappropriate speed	18	24	40	82	3.3
Inappropriate reporting or taking-over	16	18	24	58	2.4
Others	18	12	16	46	1.9
Total	898	748	803	2,449	100

* Taken from Reports on Marine Accidents, 2002-2004, Japan Marine Accidents Inquiry Agency

3) The major causes of collision consolidated (Korea and Japan)

Table 7 The consolidated major causes of collision

	Period of Survey	Cases Included	Major Causes Identified		Total
			Improper lookout	Non-compliance with marine traffic rules	
Korea	2000-2004	1,118	49.9%	23.4%	73.3%
Japan	2002-2004	2,449	52.7%	19.2%	71.9%
Average			51.3%	21.3%	72.6%

As shown in the above tables for marine accidents in Korea and Japan, collision takes a great proportion of marine casualties (Korea: 24.4%, Japan: 41.3%). In case of Korea, if sinking resulted from collision, the accident is finally classified as sinking. Therefore, actually the proportion of collision is supposed to be more than 30% of the whole cases. Through the above statistical data we can see that collision is the major accident at sea. That means, if we could prevent the collisions at sea, about one third of the marine casualties could be diminished.

Also these data are showing that the major causes of collision are 'improper lookout(51.3%)' and 'non-compliance with marine traffic rules(21.3)'. It's very clear that the causes affecting collisions are simple human errors of the officers on watch(OOWs). Regarding this UK P&I Club analyzed as follows.

「In the past ten years more attention has been paid to the human factor in shipping, in particular the need for better training of officers and crew in order to minimize the incidence of avoidable errors. It has long been a truism that most marine accidents/casualties and claims are caused by "human error". We know that approximately three out of every five major claims are directly related to an error on the part of one or more individuals engaged in the operation of the Member's ships.」 [UK P&I Club, 1997]

3. How to prevent the collision

3.1 The principle of preventing accidents

1) Heinrich's Domino Theory

According to Heinrich's 'Domino Theory' accidents result from a chain of sequential events, metaphorically like a line of dominoes falling over as shown in Fig. 1. When one of the dominoes falls, it triggers the next one, and the next...(Heinrich et al., 1980)

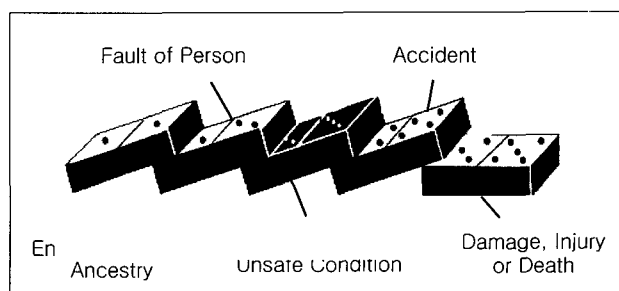


Fig. 1 Heinrich's Domino Theory

By removing one of the dominoes which is a key factor out of the line, the processing of the chain reaction can be stopped as shown in Fig. 2. Heinrich explained that unsafe acts and unsafe conditions were the key factor in occurring accidents.

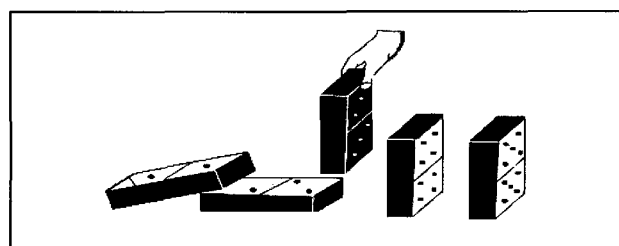


Fig. 2 The Theory of Accident Prevention

according to the above theory, the only means to prevent collision is that the OOWs always pay strict attention not to commit any unsafe acts during their watch.

2) Updated 'Domino Theory'

The original 'Domino Theory' developed by Heinrich was a classic in safety thinking and teaching for over 30 years in many countries around the world. Frank E. Bird Jr. updated the domino sequence to reflect the direct management relationship involved with the causes. This means while Heinrich put stress on removing the unsafe acts of the people at workplace for the prevention of accidents, Bird saw the precedent factor of unsafe acts as the 'lack of control' by management. The result is the updated 'Domino Theory' focuses on the 'importance of safety management' to help people at the workplace not to make any unsafe acts or unsafe conditions. The improved Domino Sequence represents the modern loss control thinking since it has been used widely in the past to convey the principles of accident prevention and loss control. (Bird et al., 1976)

3.2 The features of unsafe acts

According to 'Domino Theory', the key factors to prevent

accidents is avoiding or removing the unsafe acts of people and unsafe conditions at workplace. Practically, however, it's not so simple to get rid of such human errors because the human error is a matter of human behavior or habit.

Probably there would be no one else in bridge who doesn't know they should pay strict attention not to make any unsafe acts - human errors during the watch. Nonetheless, these kind of human errors always take a great portion of the causes of collision every year.

Here, it comes to the necessity to think about the features of human behavior to understand the reason why it's so difficult to quit inappropriate behavior.

3.3 The feature of human behavior

Committing human error at the workplace seems a very common situation across the nations. That means human beings are apt to make mistakes.

The one thing we need to pay attention, however, is the fact that not all people easily make mistakes. While there are some people who easily make mistakes, there are other people who barely make mistakes at the same workplace or in the same circumstances.

What would make the differences?

For example, some people (say 'Group A') never drive when they are drunk. On the contrary, some people (say 'Group B') don't mind driving even though they drank quite a lot of alcohol. This may be a very simple example of different human behavior that individual people are showing.

How could the people in 'Group B' change their behavior?

To find the solution, we'll need to think about the question 'from where does the personal behavior (attitude) derive?'. The sequence in which people take some kind of behavior can be illustrated as the following figure.

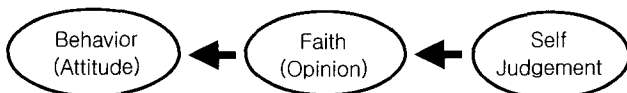


Fig. 3 Behavioral Sequence

As Fig. 3 shows, the personal behavior comes from one's own faith, and the faith is derived from his own judgement. Therefore, nobody else can easily help them change their inappropriate behavior or attitude. It means, unless their own faith is changed, their undesirable behavior won't be easily changed.

Coming back to the example, we can assume that the

people in 'Group 'B' surely have some kind of wrong faith in terms of drunk-driving such as "there will be no risk" or "there might be some risks, but if I drive carefully there wouldn't be any accident". Another interesting point is that people always hope any bad thing not to happen to them, so they assume that the accident will never happen to them, in that they are somehow immune. As long as they stick on this kind of wrong faith, they will keep on drunk-driving. Therefore, to change their inappropriate behavior - unsafe act, they have to change their wrong faith regarding drunk-driving. To change their wrong faith as a driver, they have to think about the potential danger of drunk-driving and to recognize the absolute necessity of changing their driving habit. If they had success in this kind of endeavor they will be able to change their inappropriate behavior.

Here we can understand that, as the 'advanced Domino Theory' emphasizes, safety management to help the OOWs not to commit any unsafe acts is vital important. UK P&I Club analyzed that some form of human error, those which derive principally from human temperament and mood, cannot, by their every nature, be completely eliminated. However, while human error cannot be eradicated, there is not doubt that thoughtful and well designed working environments, sound procedures, proper training and enforcement of good practices help to make such errors less likely.」 (UK P&I Club, 1997)

4. Identifying the underlying (root) causes of collision

4.1 Classification of the case of committing human errors

It might be possible to classify the following cases as the reasons why the officers on watch(OOWs) commit human errors.

Case A:

When the OOWs are unable to do their duty properly due to insufficient knowledge or skill relating navigational watch on bridge.

- Insufficient knowledge or skill for proper lookout
 - Insufficient knowledge about COLREG
 - Insufficient knowledge or skill for using radar/ARPA
- In these cases, even though they are quite diligent and

positive in their duty, they can't execute their duty properly and efficiently.

Case B:
When the OOWs can't use their ability even though they have sufficient relevant knowledge or skill due to the following reasons.

- When they are distracted from watchkeeping because of some other jobs.
- When they left bridge due to some reasons.
- When they are sleepy

In these cases, no matter how skilled they are, they can't use their ability and are likely to make mistakes.

Case C:
When the OOWs don't use their ability because of various reasons listed below, even though they have sufficient relevant knowledge or skill,

- When they misjudge that 'there's no immediate risk of collision' or 'the measures they have taken are sufficient to prevent collision', or 'the other vessel will take preventive measure'.
 - When they are negligent in watchkeeping due to lack of safety awareness etc.
- this case, the OOWs won't do their duty properly, diligently or positively, and which would lead to unsafe acts.

4.2 Identifying the underlying causes of unsafe acts committed by OOWs

The unsafe act (human error) normally has several underlying causes, so-called root causes, so it would be very important to identify them to seek the practical measures to avoid collision. The factors of such unsafe acts (human errors) classified above will be discussed respectively below.

1) Insufficient knowledge or skill

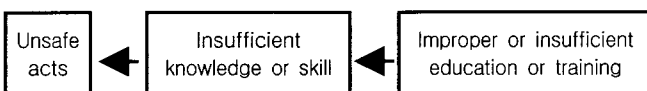


Fig. 4 Fault Tree of Insufficient Knowledge or Skill

Insufficient or improper knowledge or skill of the OOWs regarding lookout, international regulation for collision prevention and using the radar or other navigational

equipments can be a direct cause of unsafe acts of watch officers. (UK P&I Club, 1997)

(1) The issue of 'improper lookout'.

COLREG 1972 Rule 5 stipulates as follows regarding proper lookout.

「Every vessel shall at all times maintain a proper lookout by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and risk of collision.」

Also, STCW Convention amended in 1995 requires the followings.

「A proper look-out shall be maintained at all times in compliance of Rule 5 of the International Regulations for the Prevention of Collisions at Sea, 1972, and shall serve the purpose of detecting ships or aircraft in distress, shipwrecked persons, wrecks, debris, and other hazards to safe navigation.」

But unfortunately, as analyzed in accident inspection reports, improper lookout took more than half of the causes of collision.

(2) The issue of 'non-compliance with marine traffic rules'.

In the nature of navigation at sea such as "there are no policemen at sea", "there are no traffic lights on the fairway", "there are no marked tracts on the sea" or even "there are wide room between vessels", it's very easy for the OOWs to ignore traffic regulations, or even there are possibility of their poor knowledge about traffic regulations.(Lee, 2000)

(3) The issue of 'improper radar observation'.

MAIB report analyzed that the most common contributory factors in all of the collisions were poor lookout and poor use of radar, and the OOWs on 73% of the vessels involved in collision potentially contravened Rules 7(b) regarding the proper use of radar. (MAIB, 2004)

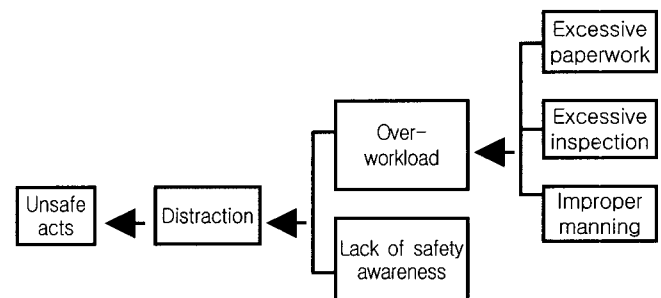


Fig. 5 Fault Tree of Distraction

However, the OOWs often think 'lookout by eye' is enough because the sea apparently looks wide enough. Also they often have over-confidence for the radar because apparently it shows all targets on the screen.

2) Distraction

If the attention of OOWs is distracted to something other than watchkeeping itself, it will be very hazardous for safe navigation. For this matter STCW 95 requires as follows.

「The lookout must be able to give full attention to the keeping of a proper lookout and no other duties shall be undertaken or assigned which could interfere with that task.」

Today in reality, it's true the officers on watch are under heavy burden of excessive jobs on board because of following reasons.

(1) Excessive paperwork

Nowadays, in addition to the traditional jobs, deck officers have quite a lot more jobs to do because of ISM Code, ISPS Code or port state control.

Especially ISM Code creates huge paper work on board, and which is inevitably giving the deck officers excessive workload. (Lee, 2002)

(2) Excessive inspection

Today, in addition to the original inspections being required by SOLAS Convention, most of the vessels shall get ready for inspection by ISM Code and ISPS Code. And furthermore in the case of oil tanker, deck officers have the burden of several other inspections such as tank inspection, terminal safety inspection and oil major inspection. Because the failure in these inspection can cause the vessel a big problem in operation, deck officers have quite a big stress on it.

(3) Improper manning

IMO 'Guidelines for the application of principles of safe manning' requires as follows regarding hours of work or rest. (IMO, 1999)

「Every company is obliged to ensure that the master, officers and ratings do not work more hours than is safe in relation to the performance of their duties and the safety of the ship.」

But the MAIB study revealed the problem of improper manning as follows.

「The study concludes that the current provisions of STCW 95 in respect of safe manning, hours of work and lookout are not effective.」 (MAIB, 2004)

3) Leaving the bridge



Fig. 6 Fault Tree of Leaving Bridge

STCW requires that OOWs must not leave the bridge until relieved by next duty officer. However, the "Reports on Marine Accidents(2002-2004)" by Japan Marine Accidents Inquiry Agency shows that 68% of 'No lookout' is due to 'No person on the bridge'.

4) Dozing

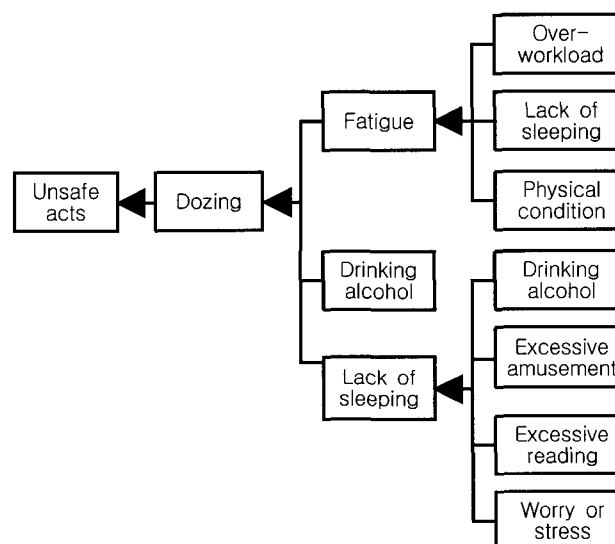


Fig. 7 Fault Tree of Dozing

Dozing during the watch can directly cause improper lookout causing an almost critical situation, particularly in an area of heavy traffic. Nonetheless, there are many causes of dozing as follows.

(1) Fatigue

Most of all, over-workload will be the easiest way to make the officers feel fatigue. Also if they are not in good condition physically they may feel fatigue from long standing during the watch.

(2) Alcohol

Drinking alcohol prior to taking over the watch will be a very effective way to get sleepy during the watch.

(3) Lack of sleeping

Lack of sleeping can be a important underlying cause of fatigue as well as being a direct cause of dozing and misjudgement. A report says as follows.

「Scientific studies have shown that seven to eight hours of continuous sleep are necessary to restore the energy of our bodies. What happens when we don't get enough sleep? The brain, nervous system, and all our body systems cannot function efficiently. Under these conditions, we do not think clearly, become irritable, do not communicate well with each other, become withdrawn and less willing to resolve issues and problems.」 (U.S. Coast Guard, 2003)

In the vessel, the following items may be such factors to affect sound sleep of OOWs.

- i. Drinking alcohol excessively :
- ii. Excessive amusement
- iii. Excessive reading
- iv. Worry or high stress

5) Misjudgement

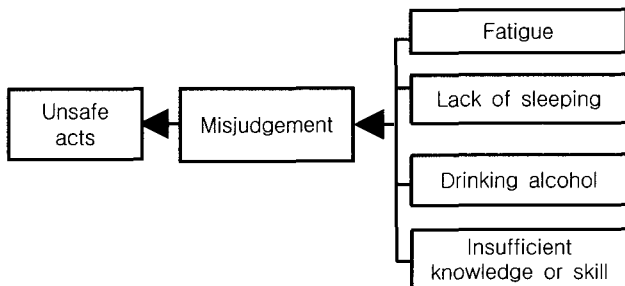


Fig. 8 Fault Tree of Misjudgement

Misjudgement by people often leads to a human error such as incorrect action or omitting necessary action. Japan Marine Accident Inquiry Agency analyzed the causes of 'insufficient observation of the movement of the other vessel' as follows. [Japan Marine Accidents Inquiry Agency 2002-2004]

- Thought there was no risk of collision (49%)
- Thought the other vessel would take action to avoid collision (28%)
- Thought the action taken to avoid collision would be sufficient (7%)
- Thought there was still a margin of safety (12%)

If the OOWs are in a state of fatigue, or lack of sleeping, or in case they drank alcohol prior to taking over the duty, they are very likely to misjudge about the prevailing

circumstances. In case the OOWs have insufficient knowledge or skill for proper lookout, traffic regulations or observing the radar, the situation will be the same.

6) Lack of experience

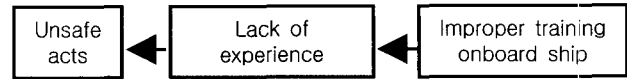


Fig. 9 Fault Tree of Lack of experience

Normally the skill comes from experience. The skills required for the OOWs such as proper lookout, using radar, applying the traffic regulation to perform their duty on watch properly, should be gained through various experience onboard ship in the various situation. This means if the apprentice officers were not trained onboard ship properly during their training period, they would surely become unexperienced watch officer later.

7) Negligence

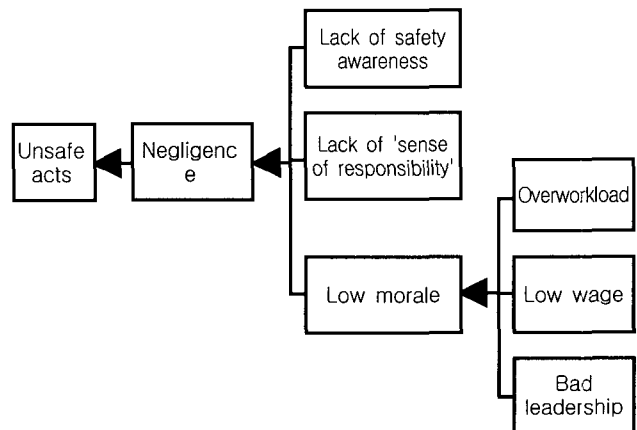


Fig. 10 Fault Tree of Negligence

Probably the negligence of OOWs will be the enemy of successful watchkeeping in any situation, because if they are negligent in performing their duties in the bridge such as lookout, observing the radar, checking ship's position or listening to the VHF, it can lead to an accident at any moment.

The following reasons could be raised as the root causes of negligence during watch.

- i. Lack of safety awareness
- ii. Lack of 'sense of responsibility'
- iii. Low morale

The underlying root causes of collision identified by Fault Tree Analysis so far can be figured as Fig. 11.

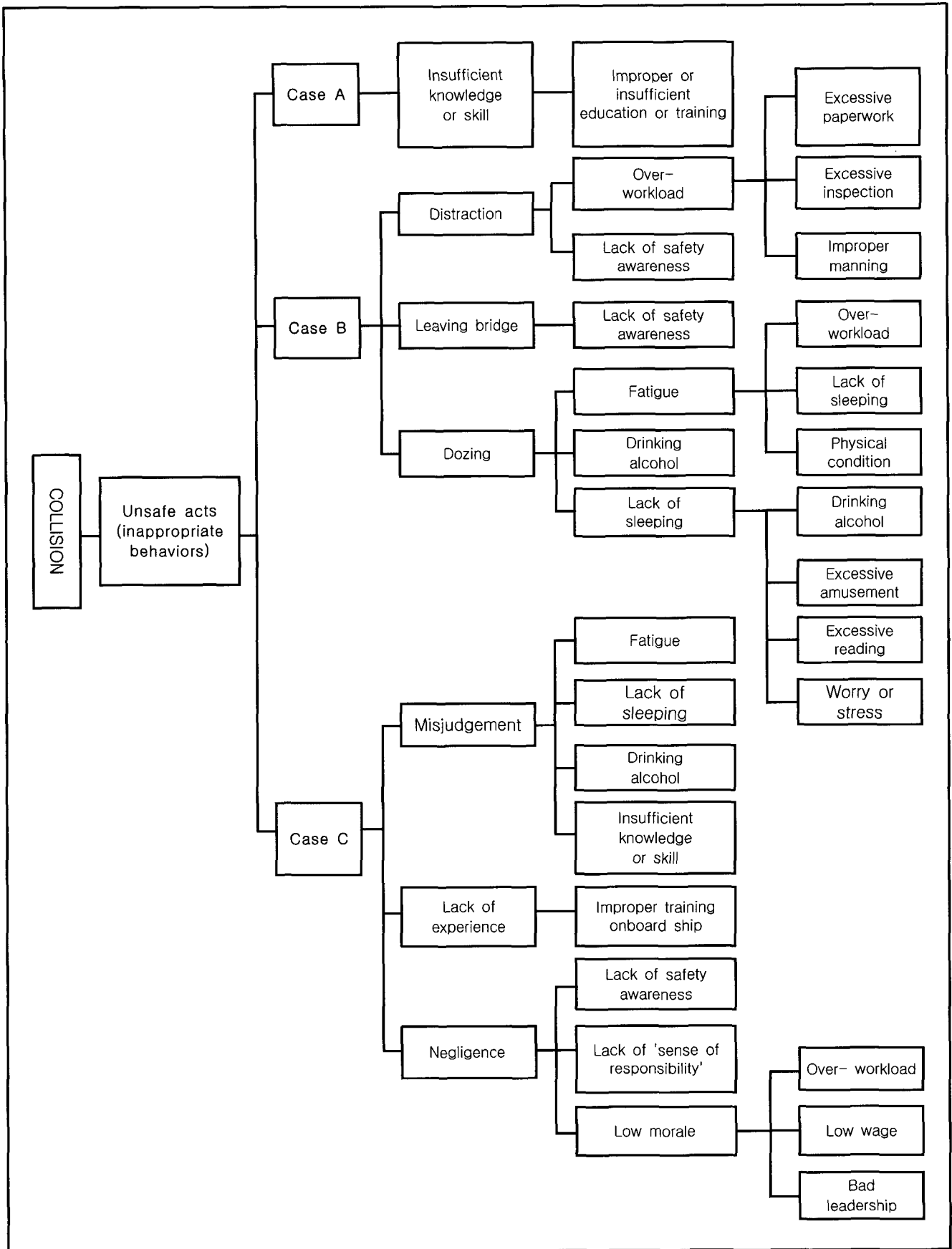


Fig. 11 Fault Tree of Root Causes Affecting Collision

5. Seeking the practical means to tackle the underlying causes of collision

Presently, discussing the reasons why the OOWs commit unsafe acts, and identified the underlying causes of such unsafe acts through Fault Tree Analysis method.

As Heinrich said through his 'Domino Theory', removing the risk factors 'unsafe acts or unsafe condition' is the key point for the prevention of any accident. Undoubtedly it's the OOWs themselves who have the direct responsibility of taking proper measure to remove the unsafe acts or unsafe condition. But there are some other aspects which can't be tackled by OOWs themselves, rather which must be handled by external entities such as shipowners, auditing organizations or IMO.

Also there's another thing that can't be overseen. As indicated in the improved 'Domino Theory' amended by Birds, proper management is very necessary to help the OOWs not make any mistake during their watch. Therefore, another important thing, but equally important aspect, is the ability of a master to control, help and supervise the OOWs not to commit any unsafe acts or not to make unsafe condition during their watch.

Of course it won't be easy to find out a complete set of solution to handle this issues but it will be very meaningful to seek the feasible, practical means to help the OOWs tackle the underlying causes of unsafe acts in the bridge. This issue is discussed next.

1) The question of 'insufficient knowledge or skill'

A bulletin had reported about this issue as follow.

「Training is the development of skills or knowledge through instruction or practice. If correctly applied, it is a planned systematic development of the aptitude, knowledge, understanding, skill, attitude and behaviour pattern required by an individual so that he/she can adequately carry out a given task or perform in a particular job. The competence of a mariner will depend not only on good and effective education and training, but also on his aptitude, knowledge and understanding of the subject, on the availability of opportunities to develop his skills and, ultimately, his experience.」 (The Nautical Institute, 2004)

For the cadets in the maritime training/education institution, following steps might be a effective ways to figure out these issues. For the existing deck officers in the refresh courses, these steps could be partially applied.

(1) Step One:

First of all, stress must be put on making deck officers

recognize the reason why they have to maintain a proper lookout continuously, why they have to observe COLREG strictly and properly, and why they should use radar properly. This step could be done as follows.

- i. Help them understand the status and severity of collision at sea using the statistical data of collision of major countries.
- ii. Make them perform case studies with various collision cases so that they recognize the potential risk of unsafe acts of OOWs and recognize the reason why they should maintain a sharp lookout, observe the traffic rules, and need to use radar properly.

(2) Step Two:

Through education and training, let them obtain the relevant knowledge and skill. The education and training should not be done only in classroom but should it be followed by efficient program of practice using training equipment such as radar/ARPA simulator, ship handling simulator or other proper training facilities.

(3) Step Three:

Finally, as STCW requires, efficient actual training program in the training vessel must be followed to help them get practical understanding through applying the knowledges and skills in the real situation. The training on training vessels should be done under a well-organized program so that every relevant knowledge and skill can be applied repeatedly for them to be familiarized.

2) The question of 'distraction'

As identified by Fault Tree Analysis, the main reasons to help the OOWs distracted from their watch are over-workload and lack of safety awareness. To tackle this issue, the following measures might be suggestable.

(1) Enhancing the safety awareness of deck officers

Safety awareness can be explained as a status of one's mind which takes seriously the fact that potential risk factors may exist everywhere, so pay keen attention to any possible accident. Actually, it can be said that high level of safety awareness is the fundamental ground in avoiding any accident. However, the question is how to help the OOWs to get and maintain high level of safety awareness. The following procedure could be suggested.

- i. Educate risk management theory and procedure to deck officers such as risk analysis(risk identification and assessment) and risk control(risk avoidance,

removal or reducing), through which they will recognize the possible existence of latent risk factors around their workplace, how to identify and control the risks.

- ii. Have regular safety meetings on board and execute hazard identification meeting through case studies followed by the practice to find out the risk control measure for the identified risk factors under the supervision of the captain, which will help them get insight for necessity of risk management and capabilities of risk management on board.

(2) Easing the over-workload of OOWs

To ease the workload of deck officers so that they can pay strict attention to their sole watchkeeping duty, the following issues should be considered carefully by the relevant organizations.

i. Regarding adopting a new IMO Convention

It is the actual reality today in the shipping world that the increasing over-workload in the past decade generated by ISM Code, ISPS Code and Port State Control became a critical factor to cause the fatigue of OOWs. Nonetheless, IMO Conventions regulating vessel's operation have been enhanced as the years go by and increasing in its number. Major conventions newly adopted or enhanced in the past decade are as follows.

IMO needs to recognize the fact that creating a new Convention for the purpose of safe operation of vessels creates a new burden for the seafarers at the same time, and which in turn will affect safe operation of the vessel.

Regarding this issue, Julian Parker of The Nautical Institute indicated as follows.

「There is still some considerable divergence between IMO conventions and national laws which have historical, political, technical and social overtones, and can be confusing for the international seafarer. It is one of the ironies of modern rule making in the IMO that the process has been separated from enforcement and so there is only indirect feedback concerning the effectiveness of new measures. Who in the IMO, for example, can say with certainty what effect the implementation of the ISM Code has had on safety standards? The ISPS Code is another initiative without a formal mechanism for evaluation. The lack of coherent enforcement measures has led to a

plethora of inspection, audit and survey practices, which are seen as varied and intrusive to those on board.」

Therefore, when IMO deals with some agenda regarding a new Convention regulating vessel's operation or enhancing the existing conventions, they should consider it carefully before adopting it.

ii. Regarding ISM Code

Theoretically, the Safety Management System on board ships, established on the request of the ISM Code, is a very effective means to create safe working culture as well as providing safe working procedure. In reality, however, nobody can deny the fact that it requires huge paper work and the workload for seafarers. As a result, SMS is causing the OOWs to be distracted from their sole watch, because of paper work created by SMS, particularly in the relatively small vessels or vessels with short running hours. In case the ship's safety manual is ineffective or has quite a volume, the situation is more serious.

Therefore, every shipowner needs to recognize the reality, and endeavor to improve their SMS manual more efficiently and to be as simple as possible.

Also IACS and auditing organizations should play an important role in implementing SMS and should endeavor to help ship owners improve their SMS efficiently and practically. That is, they must not require a high standard of performance equally to every ship. On the contrary, need to set minimum standards to check essential items only, and also it need to set different standards depending on ship's size and navigating area. All of these endeavor will help to reduce unnecessary paper works and consequently it will help to reduce the workload of deck officers as well as improving the implementation of SMS.

3) The question of 'dozing'

As identified previously by Fault Tree Analysis, the factors such as fatigue, drinking alcohol and lack of sleeping could be raised as the major factors that causes dozing during the watch.

(1) Fatigue

As identified, fatigue can be derived mainly from over-workload, lack of sleeping or physical condition including health problem.

i. Over-workload

This issue could be tackled as previously discussed.

ii. Lack of sleeping

This can be caused by over-workload, but mainly it could be derived from the following reasons.

o Drinking alcohol excessively

For this matter, the captain should set a strict rule regarding drinking alcohol on board through a 'alcohol contingency plan' and manage it strictly so that the duty officers and engineers not to drink alcohol 4 hours prior to their duty.

o Excessive amusement

The captain should set a clear rule to regulate the time for amusement such as watching videos, playing go, playing cards or chess, and strictly prohibit gambling on board ship.

o Worry or stress

We understand that mostly these are personal issue, but if the deck officers have excessive worry or stress by some reason, they could not sleep well. Therefore, the captain should pay attention to their mental condition to find the symptom of excessive worry or stress, and take a proper measure at the early moment if necessary.

iii. Physical condition

Different from engine room watch, duty officers in the bridge mostly keep on standing during the four hours of watch, which can cause fatigue, particularly in case they are physically weak or not healthy. Therefore, Deck officers should bear in mind the fact that some kind of exercise should be done regularly with a professional mind as a deck officer, and it's not a matter of personal hobby or aptitude.

(2) Drinking alcohol prior to duty

Excessive drinking habit can be a crucial cause of 'lack of sleeping', and also drinking alcohol prior to duty can be a direct cause of dozing during the watch. Therefore, especially the deck officers should bear in mind this issue and try not to drink excessively at any chance on board ship.

(3) Lack of sleeping

As discussed previously, deck officers should understand this issue clearly and try hard not to get involved in the several causes of 'lack of sleeping' listed previously.

4) The question of 'misjudgement'

If the watch officers are in a state of fatigue, or have a 'lack of sleeping', or are 'drinking alcohol' prior to taking over the duty, even though it's not so serious, they are very likely to misjudge the prevailing circumstance. If the watch officers have 'insufficient knowledge or skill' for proper lookout, traffic regulations or observing the radar, the situation will be the same. Therefore, these kind of issues should be tackled properly as discussed previously.

5) The question of 'negligence'

It would be fair to say that the negligence of watch officers can be derived mainly from 'lack of safety awareness' or 'lack of sense for responsibility' and 'low state of morale'. Therefore, proper measures would be required to help them to get out of this kind of risk factors.

(1) Lack of safety awareness

This issue could be tackled as discussed previously.

(2) Sense of responsibility

If the OOWs recognize the fact that they are in a very important position to protect all of the lives of crew member on board as well as the enormous property of ship and cargo, they will be able to throw away the negligence, and instead they can be more attentive to their duty on bridge. However, in reality, the captain's role to encourage them to get the sense of responsibility would be much more important.

(3) The question of 'morale'

Ship owners should recognize the fact that the people would never be positive in performing their duty if they are not satisfied with their wage or welfare being given to themselves and their families.

There's another factor to affect the morale of seafarers. As the people are very sensitive, if their leader such as captain, chief engineer or chief officer gives them unnecessary stress regarding their duty, they will surely be depressed or frustrated, which will cause the lower morale. Therefore, the leaders in the vessel should understand and recognize this issue and endeavor not to give them unnecessary or improper stress, instead, should always try to encourage them to enjoy their work.

6. CONCLUSION

As discussed previously, collisions are taking a great

portion of maritime accidents in any country and the statistical analysis shows that the major causes of collision are closely related with human error, so-called unsafe acts (inappropriate behavior) of officers on watch. As human behavior or attitude is derived from the precedent factors, the underlying causes (root causes) of inappropriate behavior of OOWs need to be identified to avoid or remove the unsafe acts to prevent the collision.

In this study, the underlying causes of unsafe acts (inappropriate behavior) of OOWs have been identified through Fault Tree Analysis method based on a literature survey on papers about maritime accidents.

To prevent collision at sea, the identified underlying causes of unsafe acts of OOWs should be removed following the principles of 'Domino Theory'. There are some causes which need to be tackled by the OOWs themselves and the leader of the vessel such as chief officer or captain. However, there are some other causes which must be handled by external organizations such as ship owners, IMO, IACS, auditing organizations.

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