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TPK5160 Risk Analysis

Titanic Viewed from Different Perspectives on Major Accidents

24 January 2014
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Contents

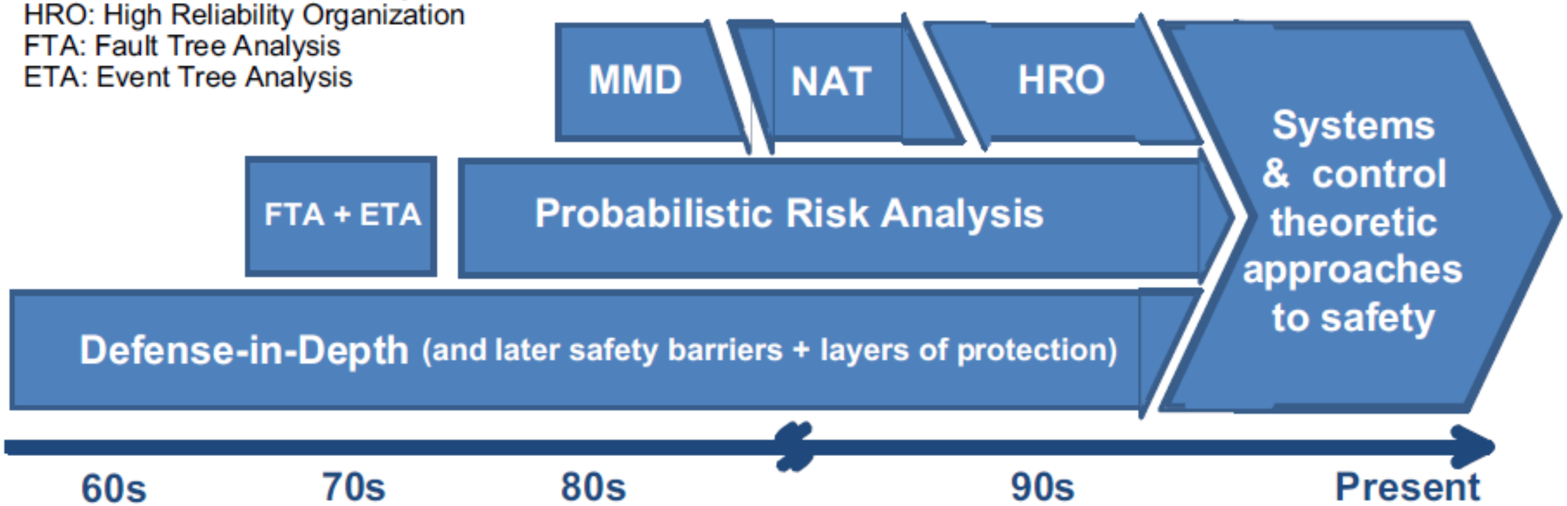
1. Background & Objectives

1. Background & Objectives

1.1 Background

- Several accident perspectives have evolved over decades

Nomenclature
MMD: Man-Made Disasters
NAT : Normal Accident Theory
HRO: High Reliability Organization
FTA: Fault Tree Analysis
ETA: Event Tree Analysis



Ref: (Saleh et al. 2010)

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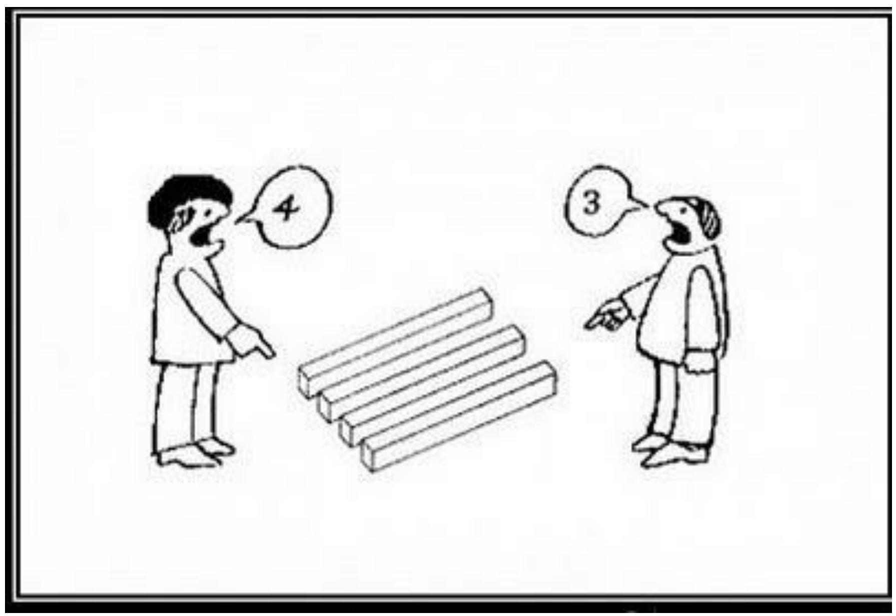
1. Background & Objectives

1.1 Background

- Each perspective looks at the causes of an accident in its own particular way
- Even for a same accident, some perspectives focus on different causes



1. Background & Objectives

1.2 Objectives

- Study how each perspective can be applied to an actual accident of the Titanic

- Lecture Questions

  1) What is main idea of each accident perspective?

  2) What are the causes of Titanic accident, and how can we structure them?

  3) How can we apply each accident perspective to the causes of the Titanic accident?

  4) What happens if we focus on only one perspective for an accident?

2. Six Perspectives on Major Accidents

Solving equation by

$$\frac{1}{n}\sin x = ?$$

$$\frac{1}{\cancel{n}}\operatorname{si}\cancel{n}\,x =$$

$$six = 6$$

2. Six Perspectives on Major Accidents

- Energy-Barrier Model
- Man Made Disasters (MMD) Theory
- Normal Accident Theory (NAT)
- High Reliability Organisations (HRO) Theory
- Conflicting Objectives Perspectives
- Resilience Engineering

2. Six Perspectives on Major Accidents

2.1 Energy-Barrier Model

- Accidents occur when objectives are effected by harmful energy in the absence of effective barriers

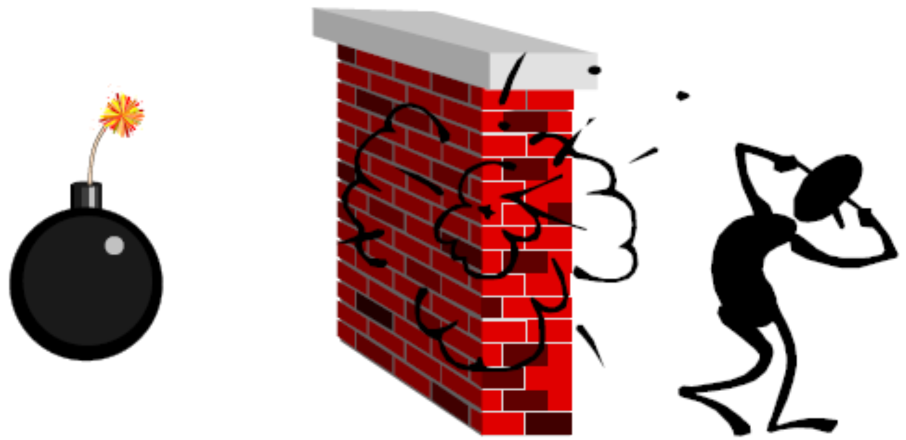


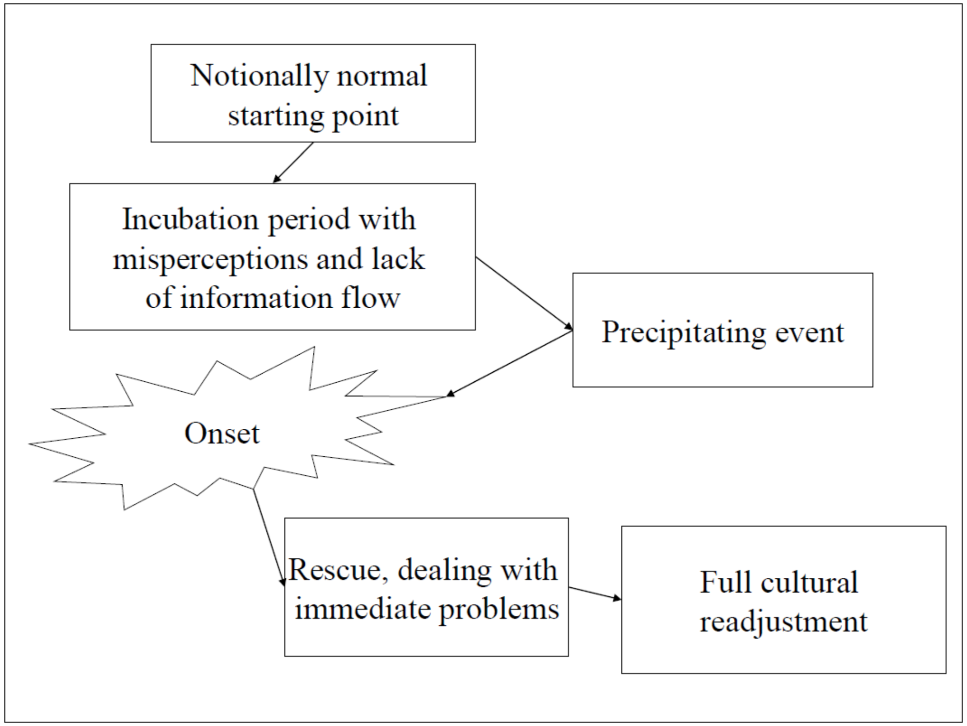
Figure 3. The energy and barrier model of accidents (adapted from Haddon, 1980)

Ref: (Rosness et al. 2010)

2. Six Perspectives on Major Accidents

2.2 Man Made Disasters (MMD) Theory

- Accidents develop through a long chain of events, leading back to root causes such as lack of information flow and misperception among individuals and groups
- Someone, somewhere do actually know something



Ref: (Rosness et al. 2010)

2. Six Perspectives on Major Accidents

2.3 Normal Accident Theory (NAT)

- Tightly coupled systems can only be effectively controlled by a centralised organisation
- Systems with high interactive complexity by a decentralised organisation
- An organisation cannot be both centralised and decentralised at the same time
- Systems with high interactive complexity and tight couplings are conducive to system accidents

Table 1. Organising for coupling and complexity.

Interactions / Coupling	Linear	Complex
Tight	*Centralise to handle tight coupling!*	*Centralise to handle tight coupling AND decentralise to handle unexpected interactions!*
Loose	*Centralise or decentralise! (Both will work.)*	*Decentralise to handle unexpected interactions!*

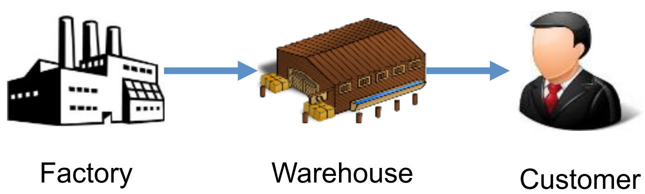
Impossible

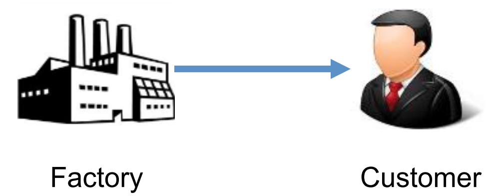
Ref: (Rosness et al. 2010)

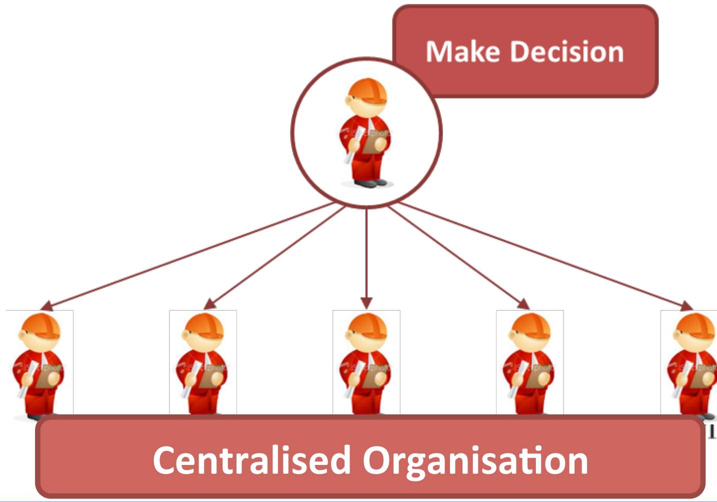
2. Six Perspectives on Major Accidents

2.3 Normal Accident Theory (NAT)

Loose Coupling	Tight Coupling
Presence of buffers	Absence of buffers (a change in one component lead to a rapid and strong change in related components)



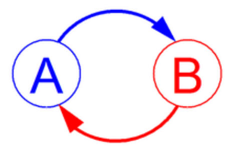


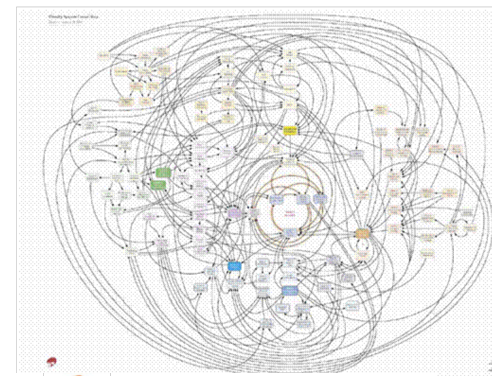


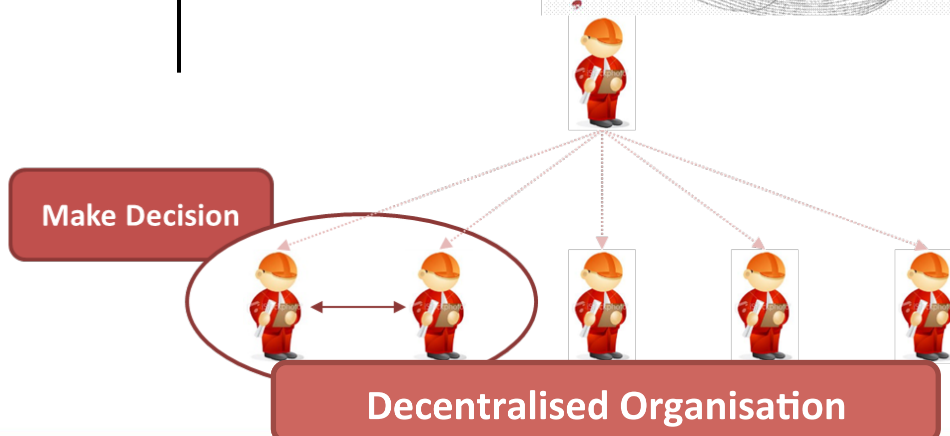
2. Six Perspectives on Major Accidents

2.3 Normal Accident Theory (NAT)

Linear Interaction	Complex Interaction
Predictable and comprehensible sequence	Unpredictable sequence Often related to feedback loops

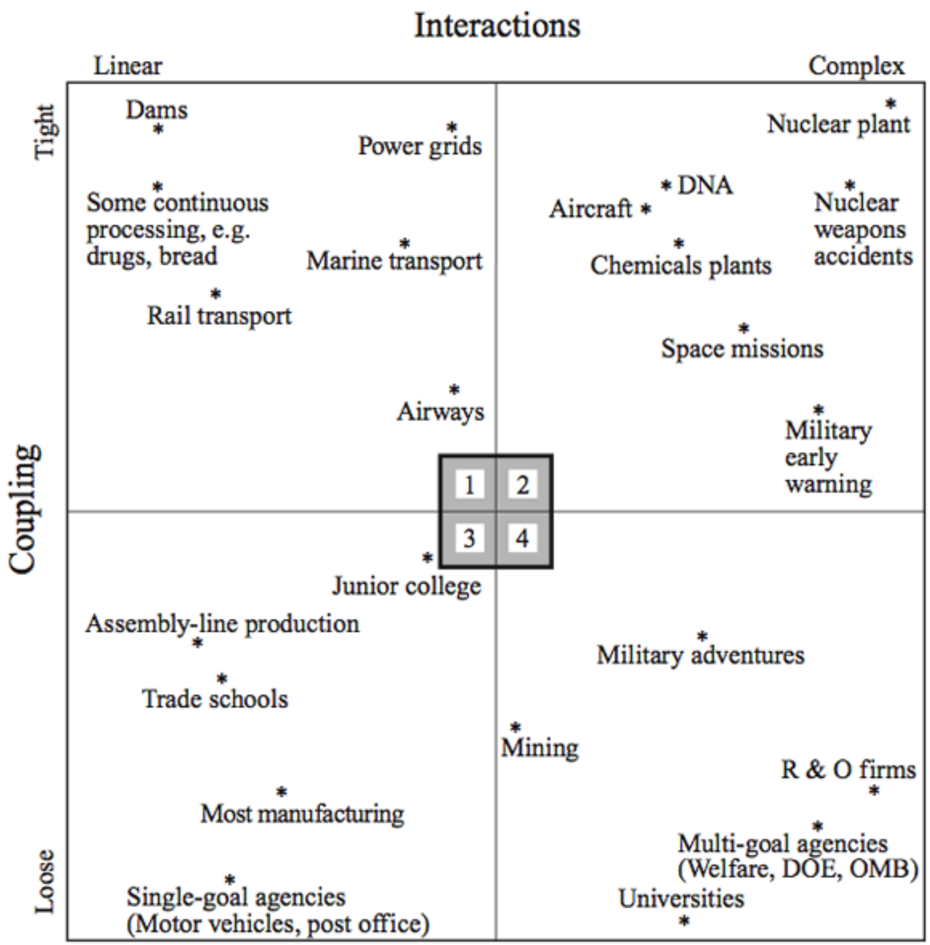






2. Six Perspectives on Major Accidents

2.3 Normal Accident Theory (NAT)



Ref: (Perrow 1984)

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2. Six Perspectives on Major Accidents

2.4 High Reliability Organisations (HRO) Theory

- There are not so many disasters, Why?

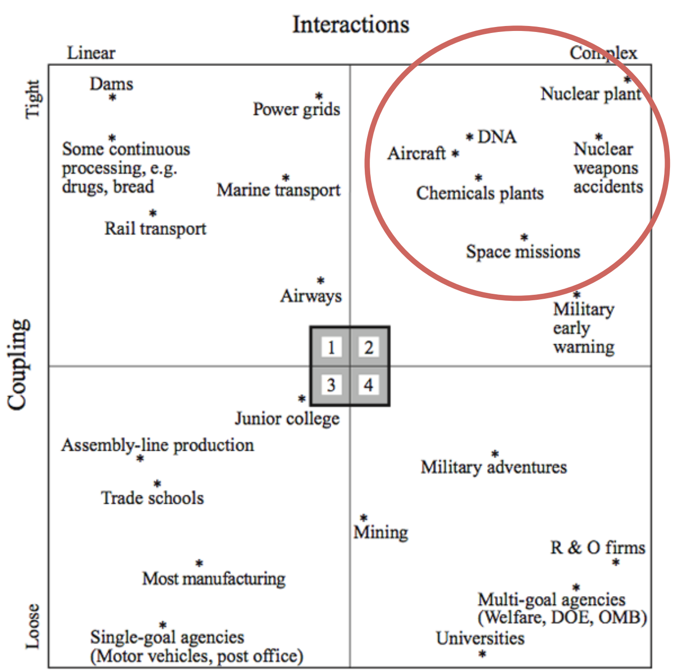

Table 1. Organising for coupling and complexity.

Possible

Interactions Coupling	Linear	Comp
Tight	*Centralise to handle tight coupling!*	*Centralise to handle tight couplings AND decentralise to handle unexpected interactions!*
Loose	*Centralise or decentralise! (Both will work.)*	*Decentralise to handle unexpected interactions!*

- Because HROs have
  - Organisational Redundancy
  - Spontaneous Reconfiguration of Organisation
  - Mindfulness

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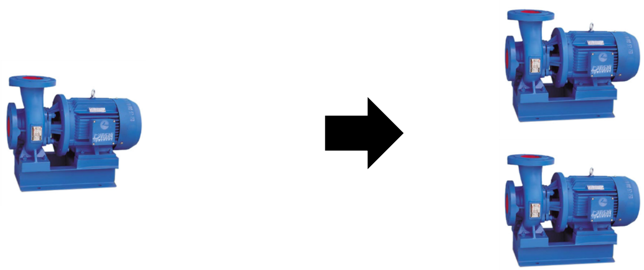
2. Six Perspectives on Major Accidents

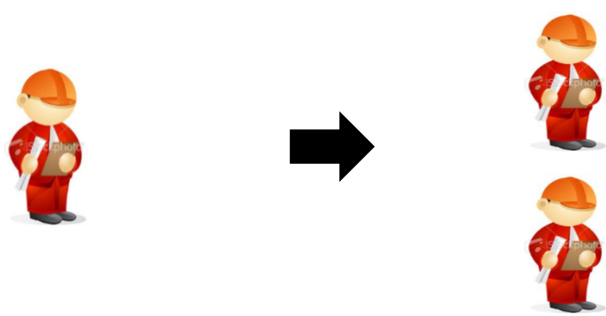
2.4 High Reliability Organisations (HRO) Theory

- Organisational Redundancy

  - Build reliable system from less reliable components



  - Derive highly reliable performance from less than perfect human beings

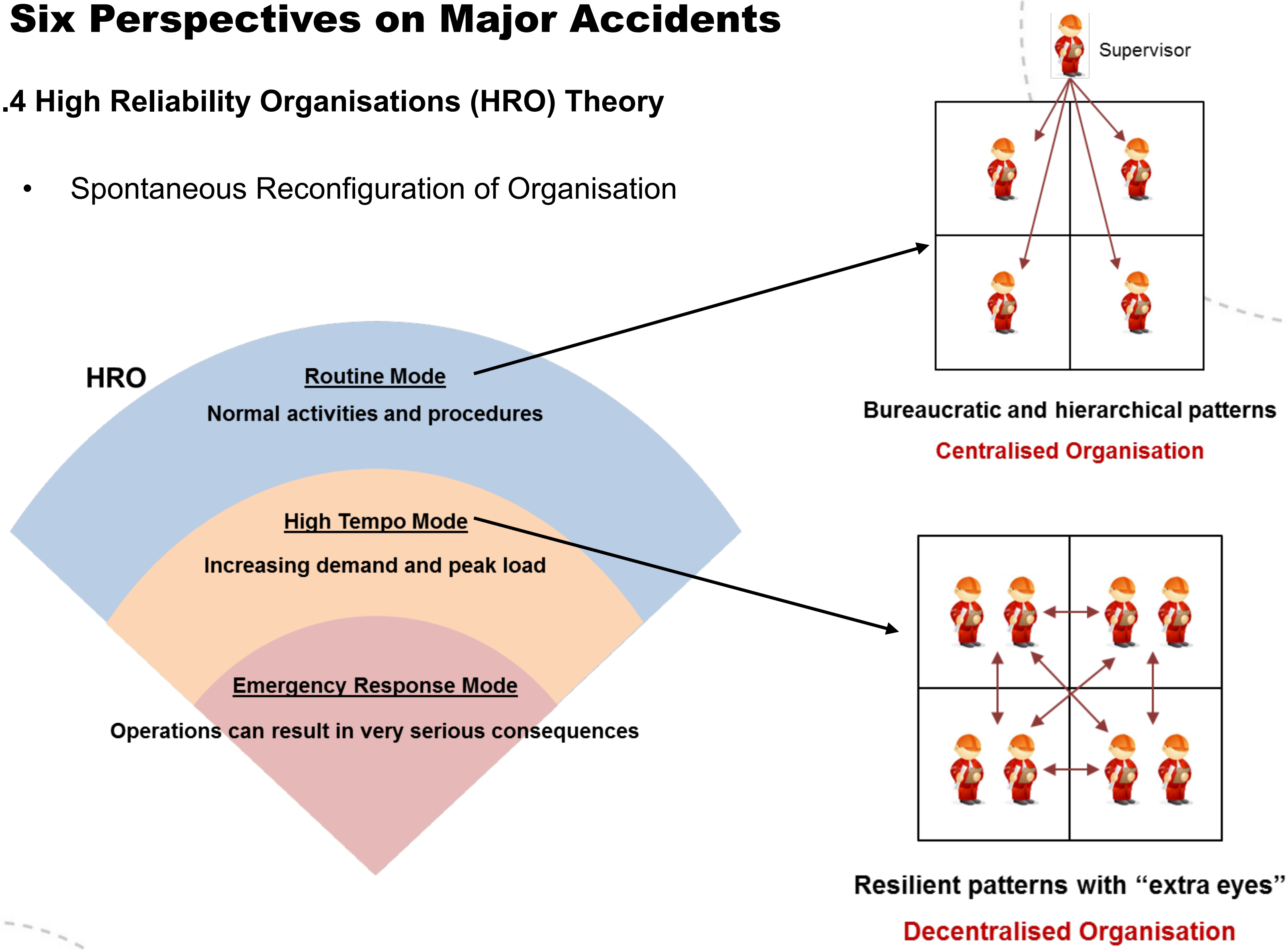


Organisational Redundancy

2. Six Perspectives on Major Accidents

2.4 High Reliability Organisations (HRO) Theory

- Spontaneous Reconfiguration of Organisation



2. Six Perspectives on Major Accidents

2.4 High Reliability Organisations (HRO) Theory

- Mindfulness

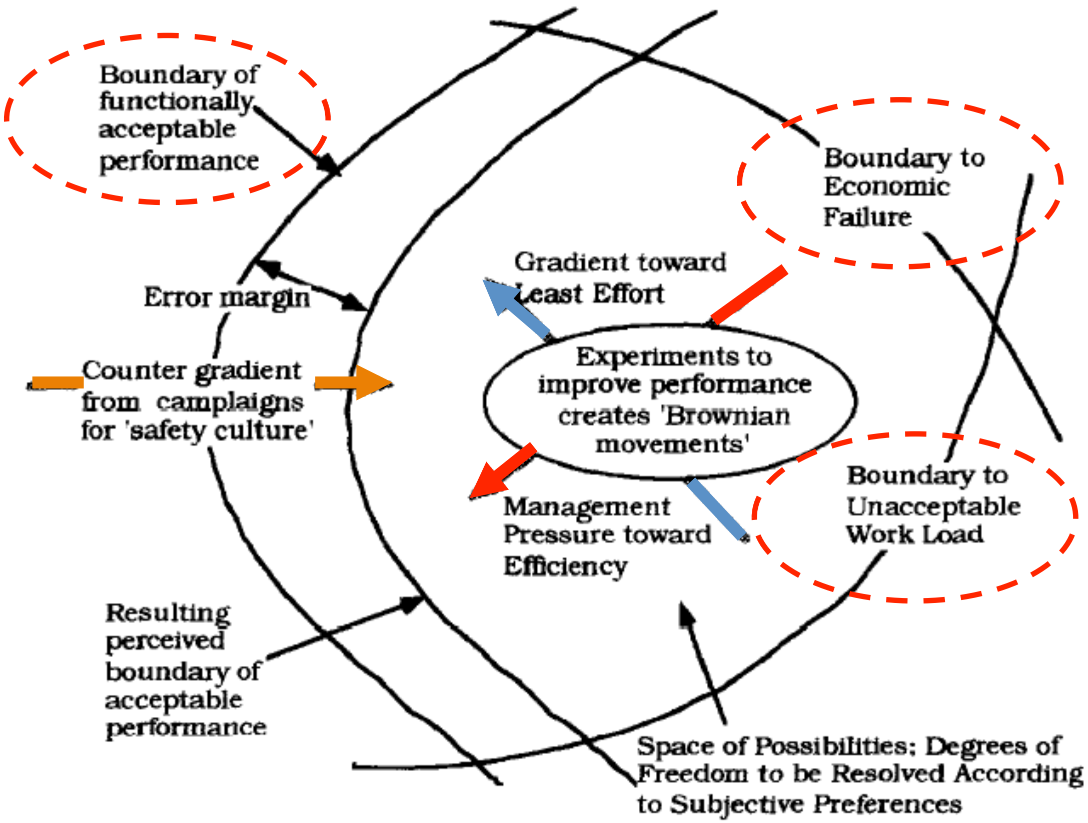
Table 2. Elements of "Mindfulness". Summarised from Weick and Sutcliffe (2001)

Anticipation and awareness of the unexpected	**Description**
Preoccupation with failure	People in HROs know that all potential failures modes have not been experienced or exhaustively deduced. Because the cost of the failure is so high, people in HROs look for symptoms and encourage reporting of errors.
Reluctance to simplify interpretations	Simplify less and see more. Simplifications could produce blind spots, HROs use people that represent different functional background to expand the organisation's sensing mechanisms.
Sensitivity to operations	Normal operations can reveal deficiencies – free lessons could be learned. This allows early problem detection before problems become too substantial.
Contain the unexpected	**Description**
Commitment to resilience	HROs are not error free, but errors do not disable the system. People in HROs with varied experience come together as the situation demands, it increases the knowledge and actions can be brought to solve the problem
Defence to expertise	Decisions are made in the front line. Decisions migrate to the persons with experience and expertise to solve the problem.

2. Six Perspectives on Major Accidents

2.5 Conflicting Objectives Perspective

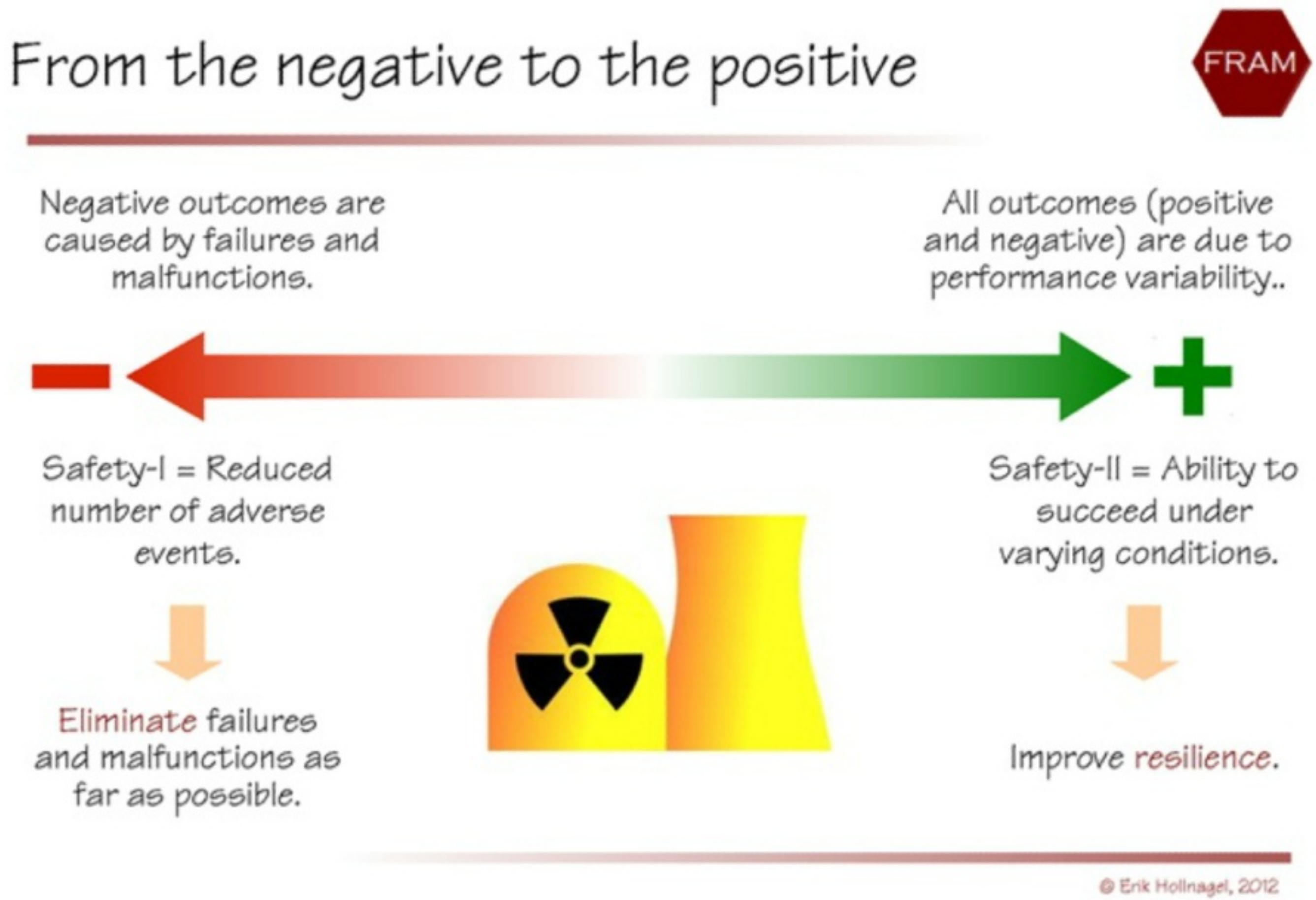
- Organisational Pressure



2. Six Perspectives on Major Accidents

2.6 Resilience Engineering

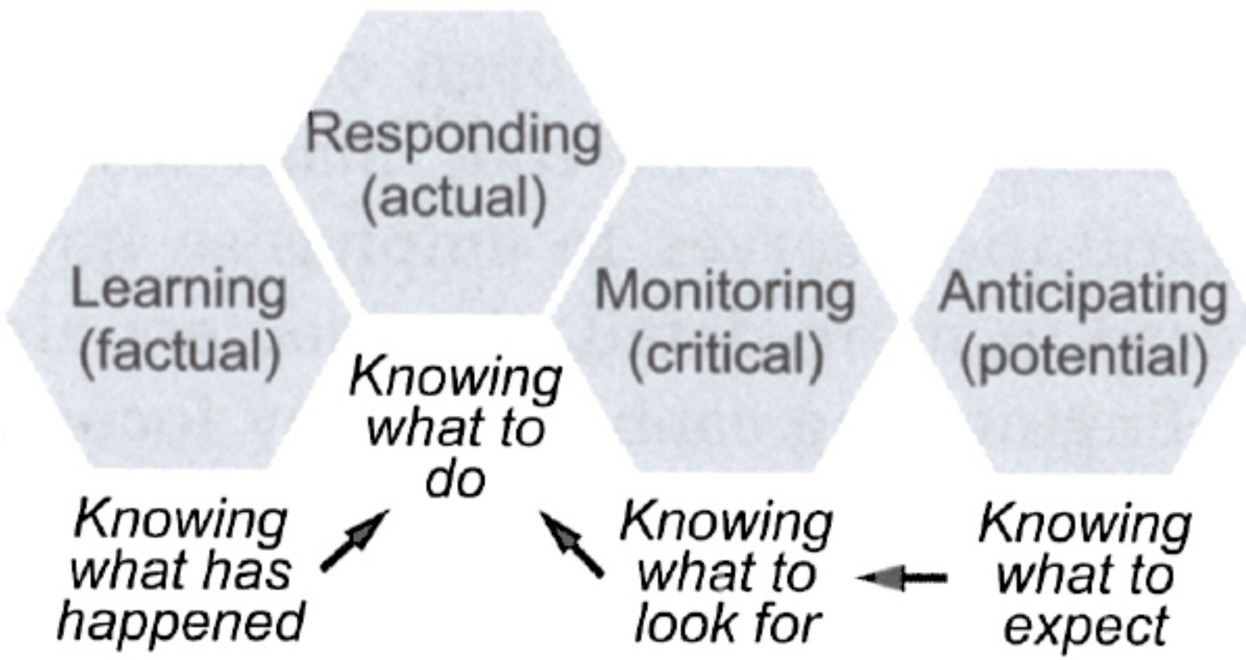
- Why only look at what goes wrong? – Ability to Succeed



2. Six Perspectives on Major Accidents

2.6 Resilience Engineering

- Four Cornerstones of Resilience



2. Six Perspectives on Major Accidents

2.7 Summary

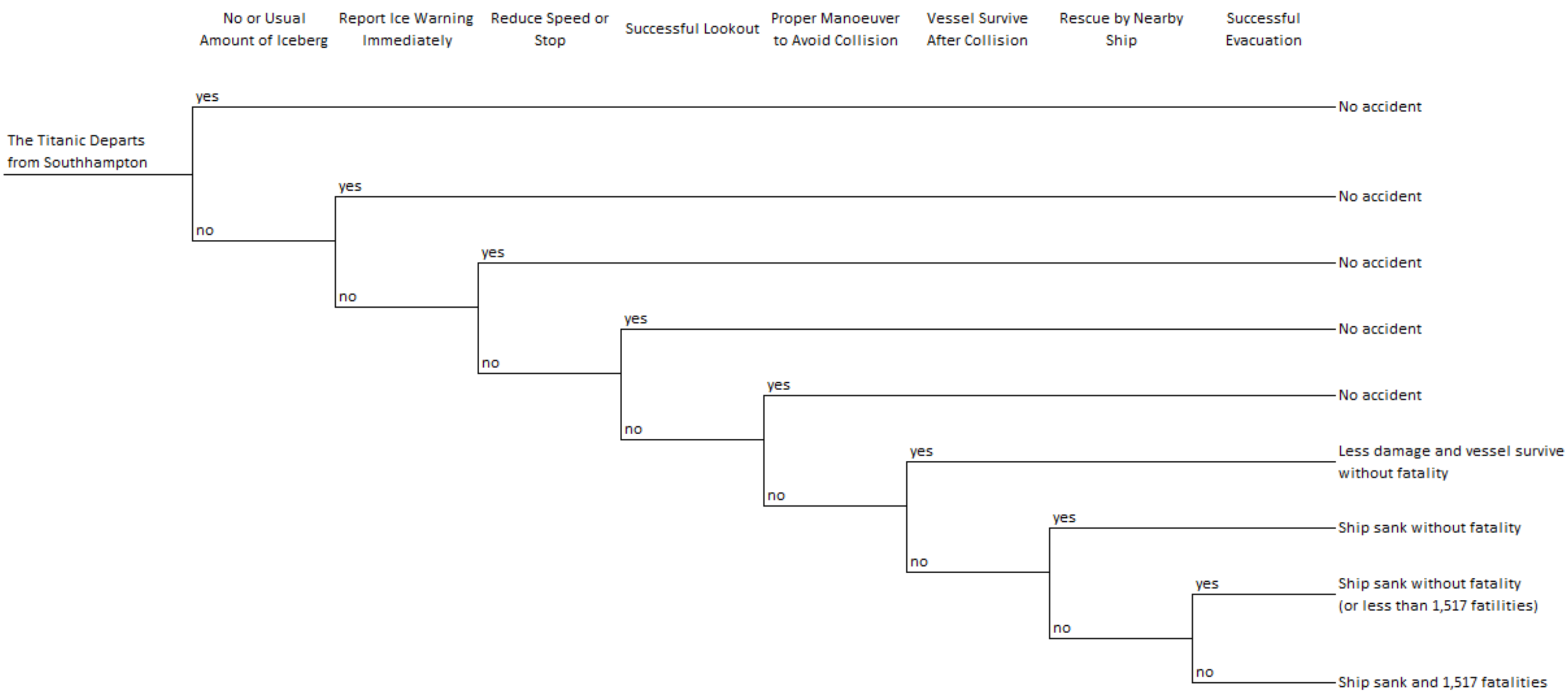
Accident Perspective	Why Accident Occur?	How to Prevent Accident?
Energy-Barrier Model	Failure to establish and maintain adequate barrier functions	Include barrier functions in the design of the system and maintain barrier functions throughout system life
MMD Theory	Lack of information flow and misperceptions with incubation period	Make systematic efforts to collect information about hazards and build culture for active search for signals of danger
NAT	Mismatch between complexity and coupling	Reduce complexity or loose couplings and discard high-risk systems that are both complex and tightly coupled
HRO Theory	Not discussed explicitly but there seems to be an implicit understanding that accidents are caused by un-recovered errors	Build organisational redundancy and cultures that combines requirement for fault-free performance with openness to the fact that errors do occur (mindfulness)
Conflicting Objectives Perspective	Distributed decision making in dynamic and opaque systems with invisible and untouchable boundaries (organisational pressure)	Establish counter-pressures that favour safe performance and make boundaries to unacceptable performance visible and touchable
Resilience Engineering	A mismatch between the coping capacity of the organisation and the emerging dangerous interactive patterns	Build and maintain the abilities to anticipate, monitor, respond, and learn

Ref: (Rosness et al. 2010)

3. Titanic Accident Investigation

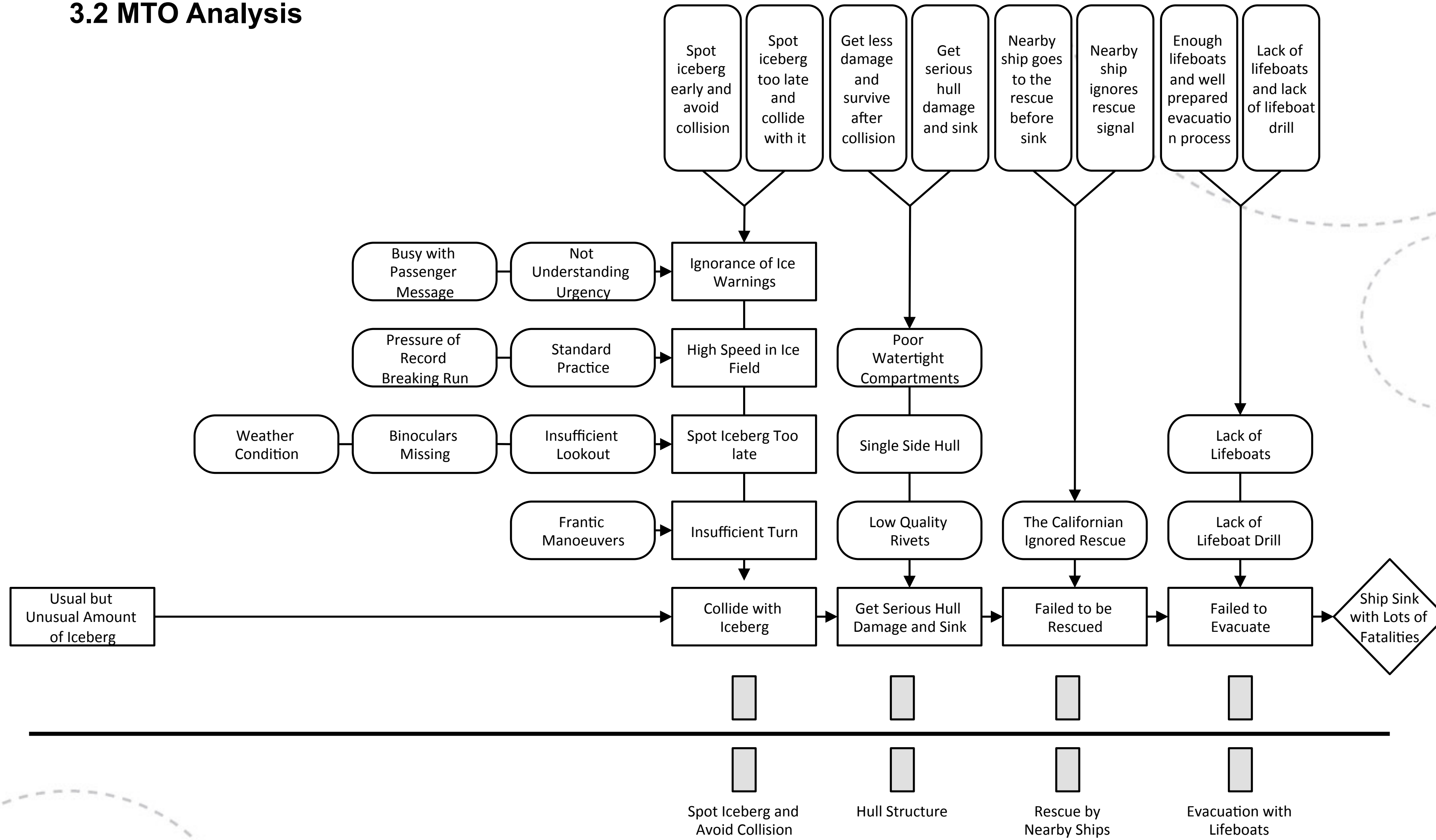
3. Titanic Accident Investigation

3.1 Even Tree Analysis



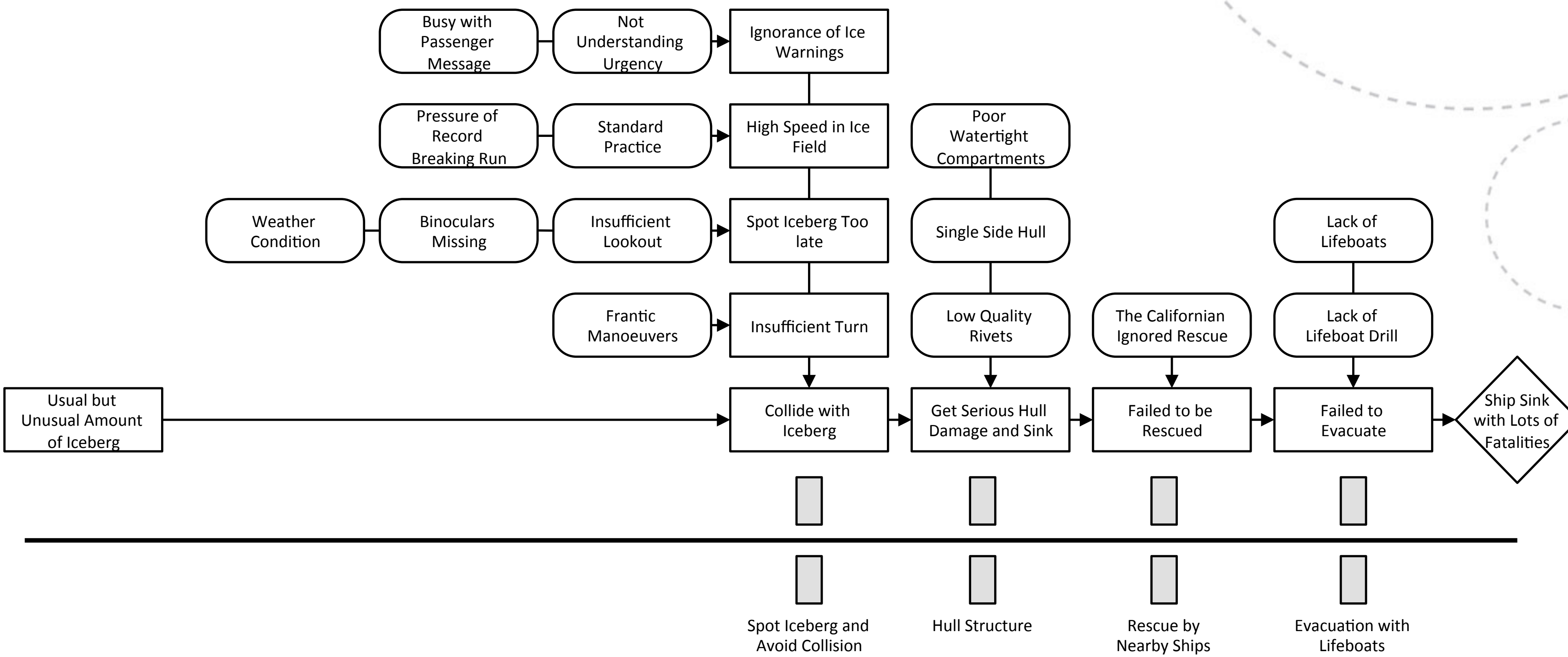
3. Titanic Accident Investigation

3.2 MTO Analysis

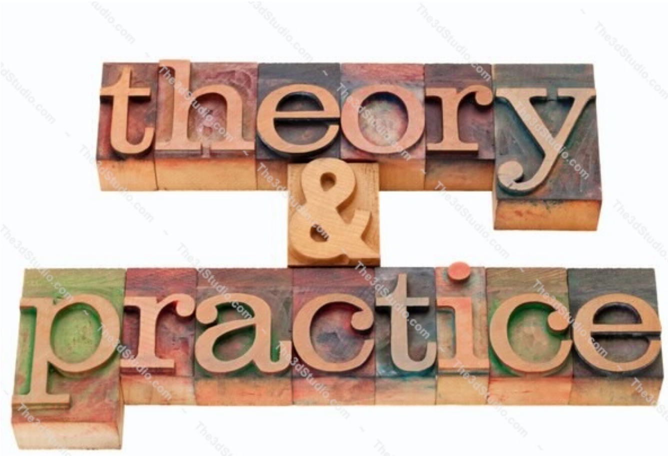


3. Titanic Accident Investigation

3.2 MTO Analysis

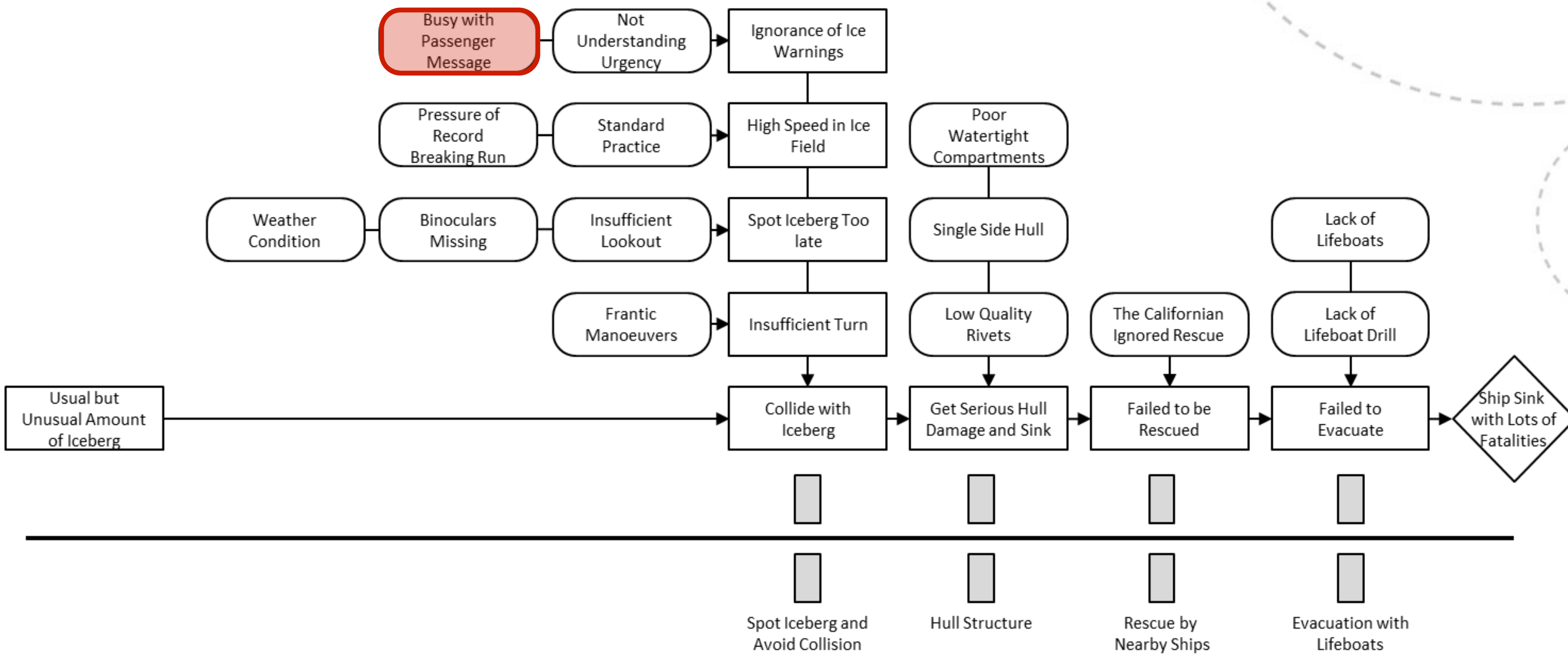


4. Accident Perspectives and the Titanic Accident



4. Accident Perspectives and the Titanic Accident

4.1 Wireless Operator Busy with Passenger Messages



4. Accident Perspectives and the Titanic Accident

4.1 Wireless Operator Busy with Passenger Messages

- Main role was to send passenger message
- The transmitter broke down and took seven hours to repair (one day before the accident)
- Faced with a backlog of messages
- Wireless operator was busy and exhausted

4. Accident Perspectives and the Titanic Accident

4.2 Wireless Operator Busy with Passenger Messages

- Main role was luxury message service for passenger

  → Conflicting Objectives perspective
- The wireless operator was exhausted and busy with passenger messages
- Titanic was entering iceberg warned area
- Increasing demand and peak load (high-tempo mode)

  → HRO theory
- The wireless operators were not prepared for this high demand situation (ability to respond)
- Captain failed to monitor the stress and overload of the wireless operator (ability to monitor)

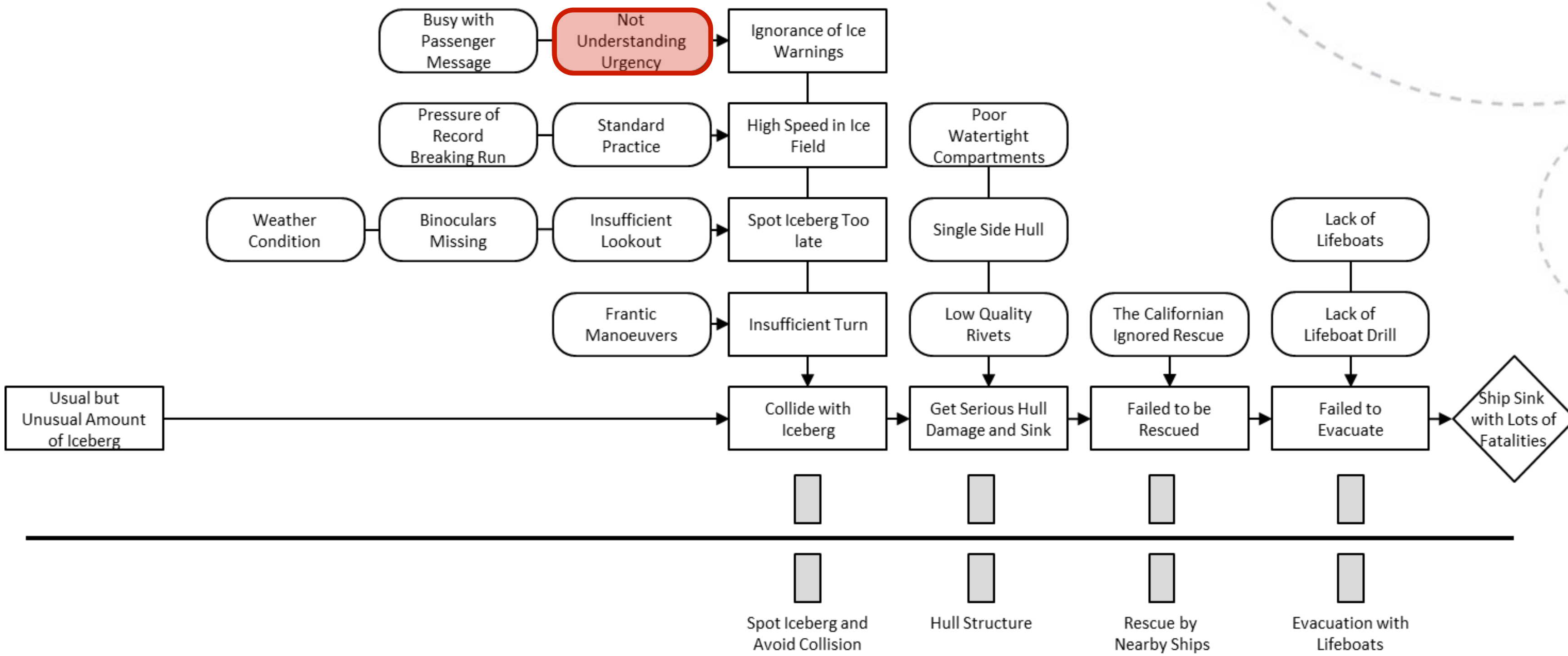
  → Resilience Engineering
- Weakened the barrier of "Spot Iceberg and Avoid Collision"

  → Energy-Barrier model

Energy - Barrier	MMD	NAT	HRO	Conflicting Objectives	Resilience Engineering
X			X	X	X

4. Accident Perspectives and the Titanic Accident

4.3 Wireless Operator did not Understand Urgency of Warnings



4. Accident Perspectives and the Titanic Accident

4.3 Wireless Operator did not Understand Urgency of Warnings

- There were several critical ice warnings from nearby ships
  – ”Icebergs at Latitude 42˚N to 41˚25’N, Longitude 40˚W to 50˚30’W”
- Wireless operators were not trained in navigation
- Latitude and longitude meant nothing to them
- They did not understand the extreme urgency
- “shut up, shut up, I am busy; I am working Cape Race”

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4. Accident Perspectives and the Titanic Accident

4.3 Wireless Operator did not Understand Urgency of Warnings

- Somebody knew there was a hazard
- Failure of information flow

  → MMD theory
- Mindfulness (failure of continuous surveillance of existing situation)

  → HRO theory
- Ability to monitor

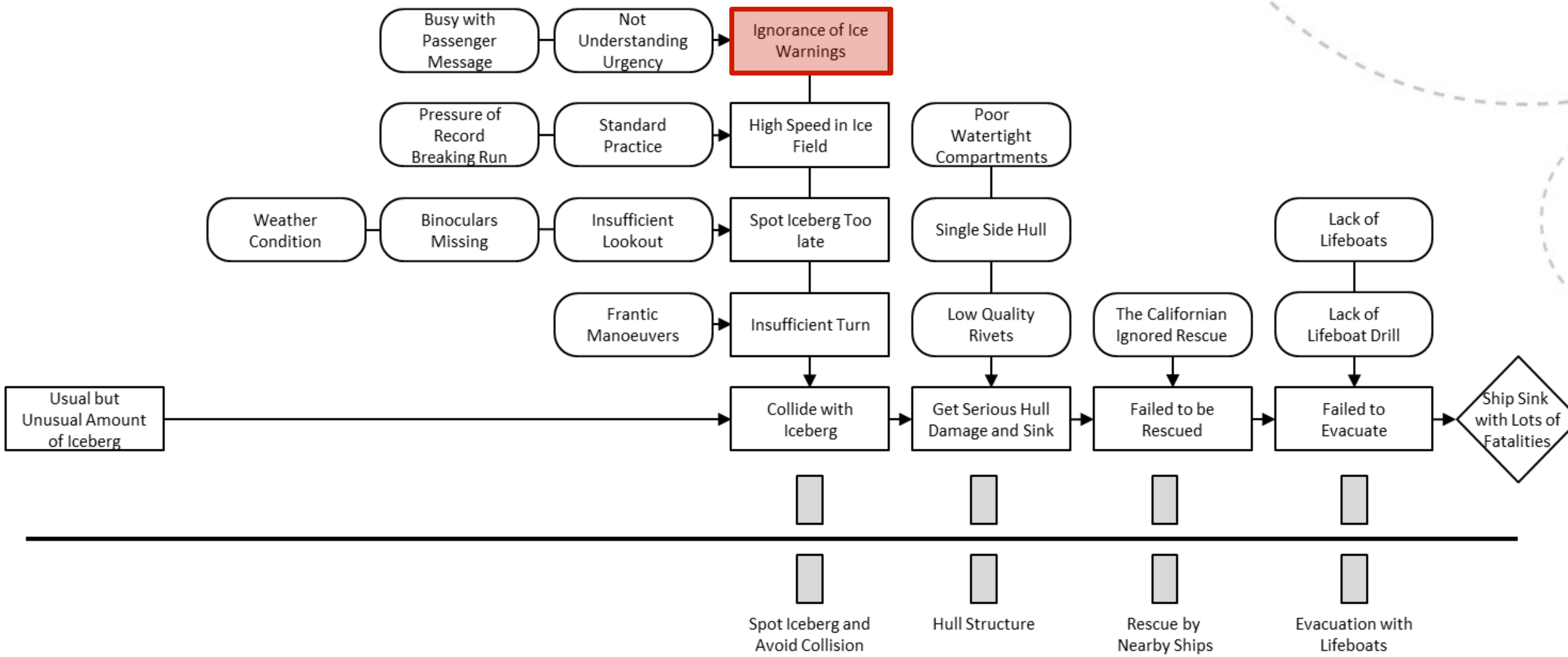
  → Resilience Engineering
- Weakened the barrier of "Spot Iceberg and Avoid Collision"

  → Energy-Barrier model

Energy - Barrier	MMD	NAT	HRO	Conflicting Objectives	Resilience Engineering
X	X		X		X

4. Accident Perspectives and the Titanic Accident

4.4 Ignorance of Ice Warnings



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4. Accident Perspectives and the Titanic Accident

4.4 Ignorance of Ice Warnings

- Ice warnings were usual at that time of the year on the route of the Titanic
- Wireless operators were busy
- Did not understand the urgency

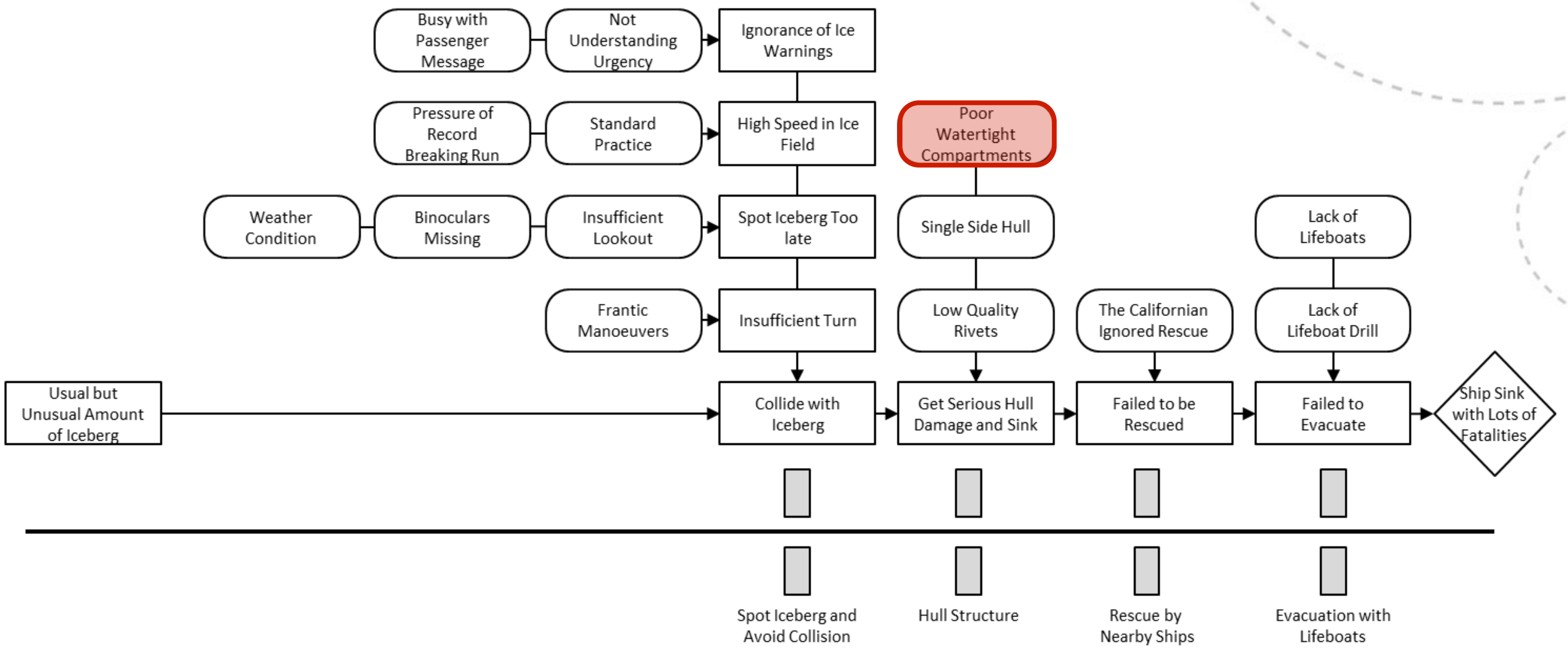
- Result of previous two conditions

→ Energy-Barrier model, MMD theory, HRO theory, Conflicting Objectives perspective, and Resilience Engineering

Energy-Barrier	MMD	NAT	HRO	Conflicting Objectives	Resilience Engineering
X	X		X	X	X

4. Accident Perspectives and the Titanic Accident

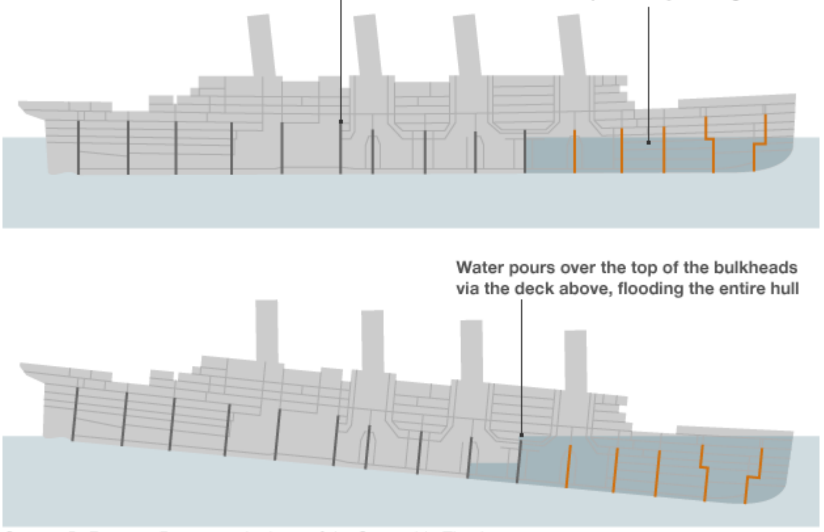
4.5 Poor Watertight Compartments



4. Accident Perspectives and the Titanic Accident

4.5 Poor Watertight Compartments

- The Titanic was fitted with 15 transvers water-tight bulkheads
- To increase passenger space, only 1 bulkhead extended to deck C
- Flooding over deck E contributed largely to the sinking of the vessel



Source: D. Foerster, Report on the Loss of the Steamship Titanic

4. Accident Perspectives and the Titanic Accident

4.5 Poor Watertight Compartments

- The owner wanted to increase passenger convenience

  → Conflicting Objectives perspective

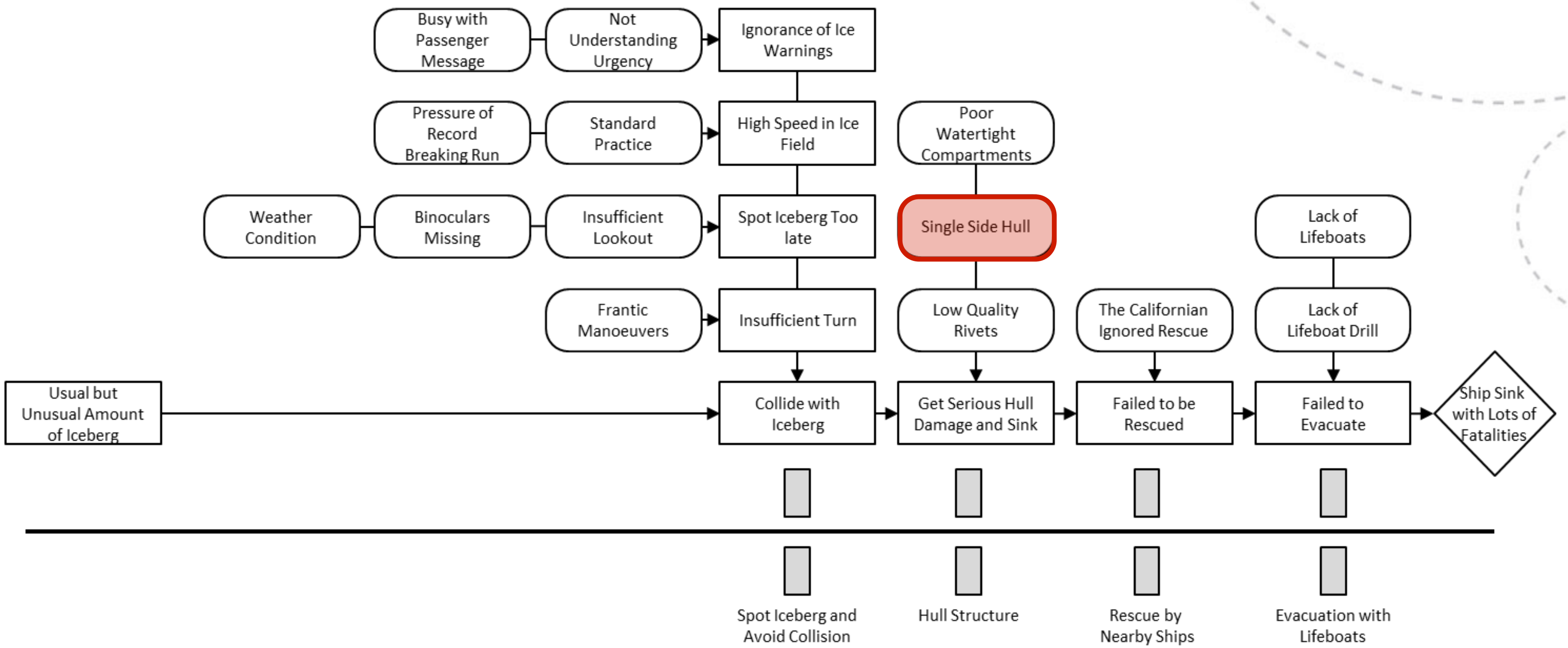
- Weakened the barrier of “Hull Structure”

  → Energy-Barrier model

Energy-Barrier	MMD	NAT	HRO	Conflicting Objectives	Resilience Engineering
X				X	

4. Accident Perspectives and the Titanic Accident

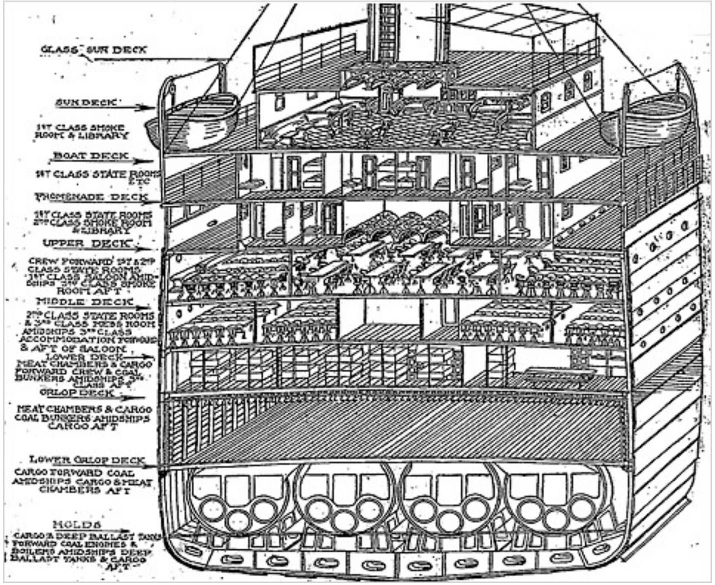
4.6 Single Side Hull



4. Accident Perspectives and the Titanic Accident

4.6 Single Side Hull

- The sides of the Titanic were just a single shell under the waterline
- There was no side protection
- The weight and cost of double side hull was so great



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4. Accident Perspectives and the Titanic Accident

4.6 Single Side Hull

- The weight and cost of double side hull

  → Conflicting Objectives perspective

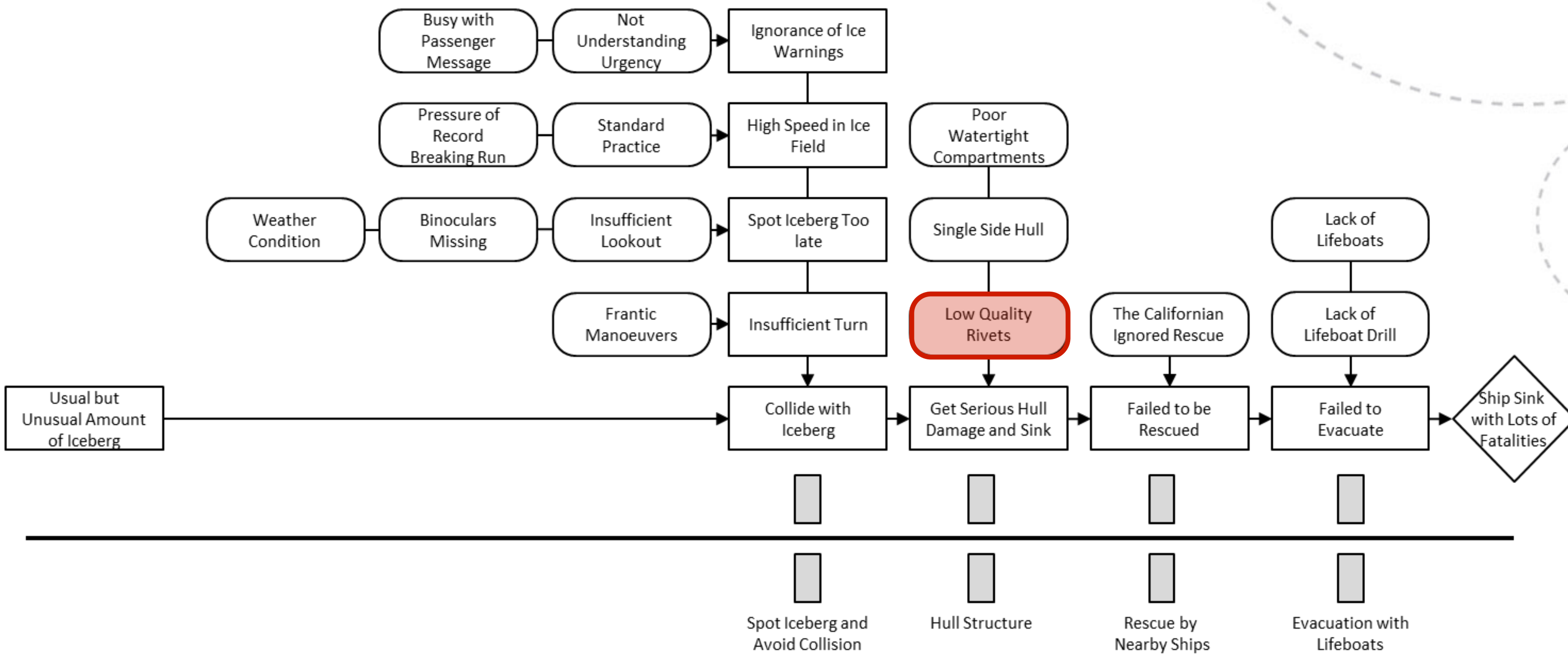
- Weakened the barrier of “Hull Structure”

  → Energy-Barrier model

Energy-Barrier	MMD	NAT	HRO	Conflicting Objectives	Resilience Engineering
X				X	

4. Accident Perspectives and the Titanic Accident

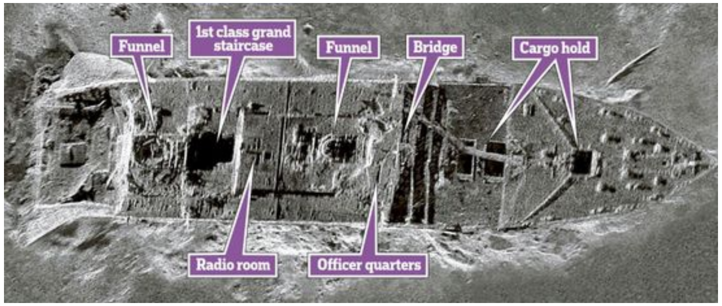
4.7 Low Quality Rivets



4. Accident Perspectives and the Titanic Accident

4.7 Low Quality Rivets

- Using sub-surface sonar, the iceberg damage has been mapped
- Hull was not severely deformed
- There was a failure of the riveted seams



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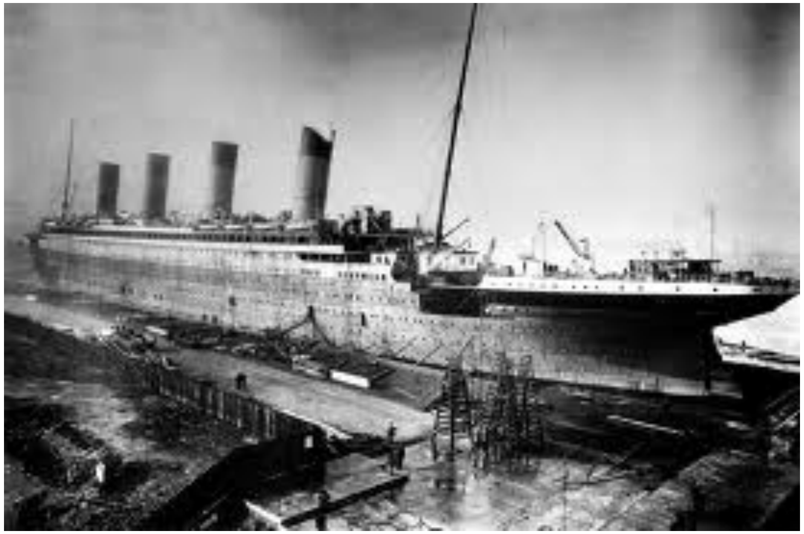
4. Accident Perspectives and the Titanic Accident

4.7 Low Quality Rivets

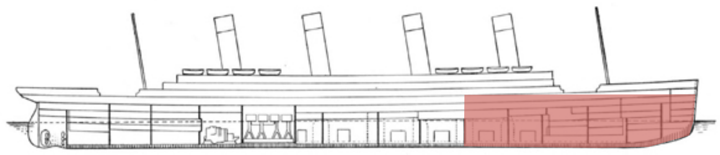
- Used low quality rivets because of the pressure to finish the Titanic



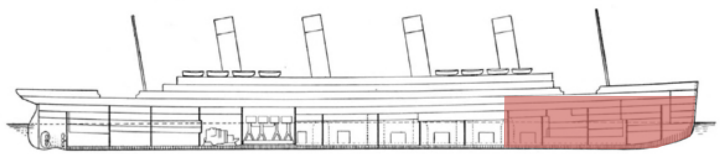

Titanic hand riveting

4. Accident Perspectives and the Titanic Accident

4.7 Low Quality Rivets



- With low quality rivets
- Six watertight compartments flooded



- With average quality rivets
- Fewer compartments flooded
- If five, the Titanic would have sunk slowly, enough to wait for the Carpathia

4. Accident Perspectives and the Titanic Accident

4.7 Low Quality Rivets

- Pressure of schedule caused to use low quality of rivets

  → Conflicting Objectives perspective

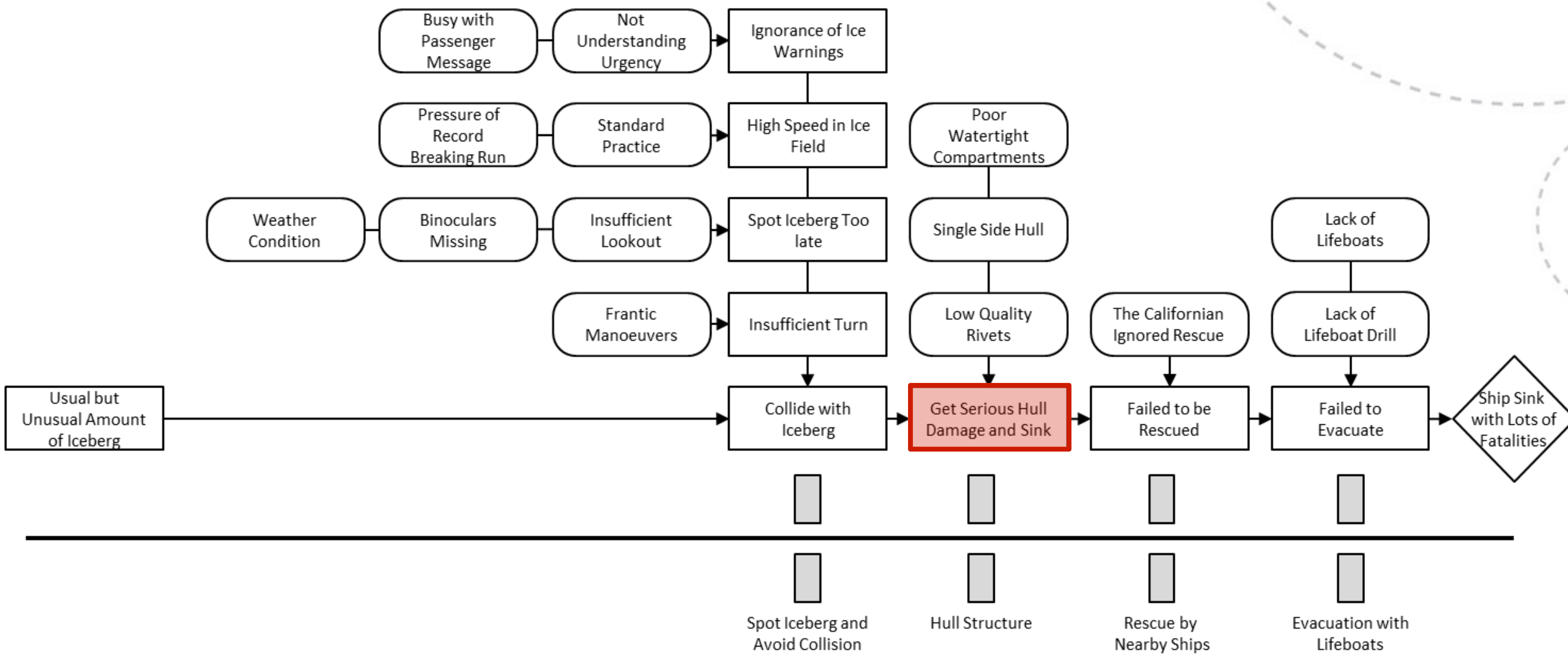
- Weakened the barrier of "Hull Structure"

  → Energy-Barrier model

Energy - Barrier	MMD	NAT	HRO	Conflicting Objectives	Resilience Engineering
X				X	

4. Accident Perspectives and the Titanic Accident

4.8 Get Serious Hull Damage and Sink



4. Accident Perspectives and the Titanic Accident

4.8 Get Serious Hull Damage and Sink

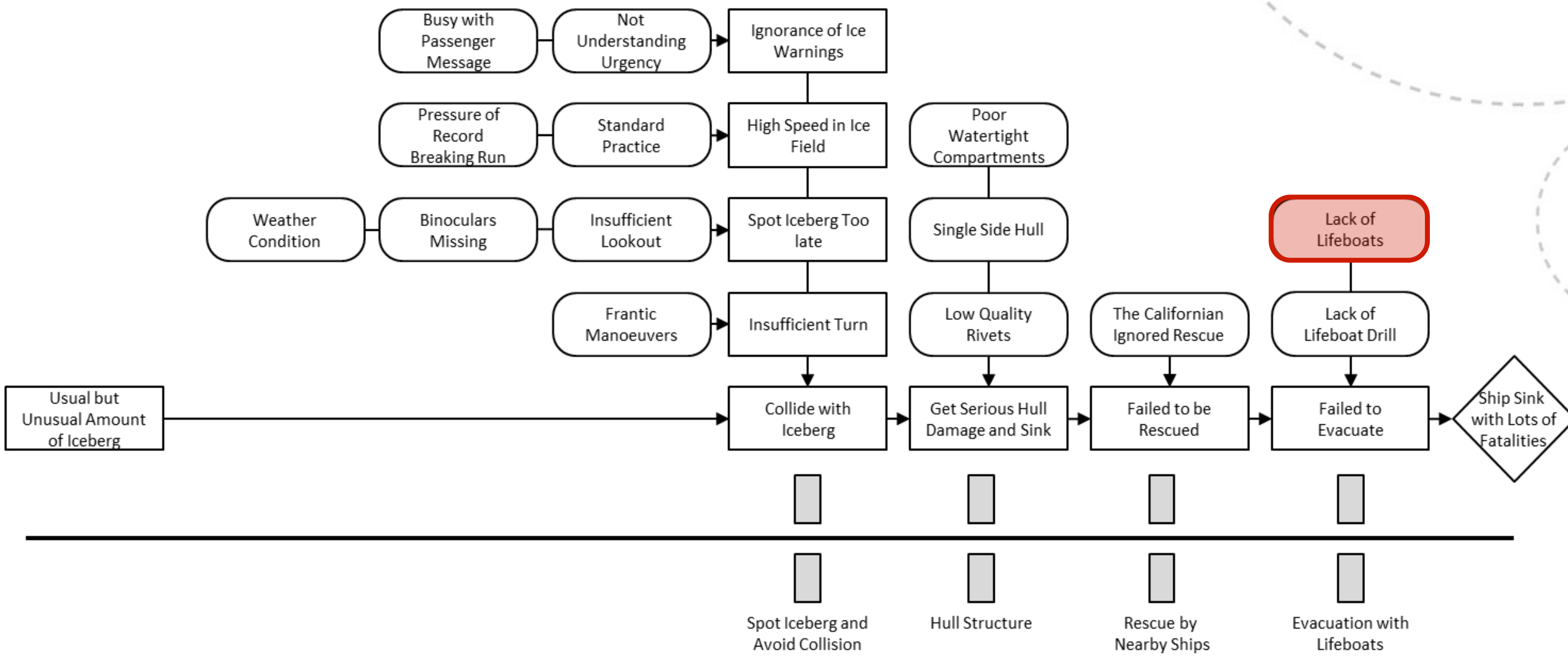
- Result of previous three conditions

→ Energy-Barrier model, Conflicting Objectives perspective

Energy-Barrier	MMD	NAT	HRO	Conflicting Objectives	Resilience Engineering
X				X	

4. Accident Perspectives and the Titanic Accident

4.9 Lack of Lifeboats



4. Accident Perspectives and the Titanic Accident

4.9 Lack of Lifeboats

- The Titanic carried 20 lifeboats
- Total capacity of lifeboats was 1,176P (Total persons aboard was 2,223P)
- Still more than required by law

Regulation (16 Lifeboats)

The Titanic (20 Lifeboats)

4. Accident Perspectives and the Titanic Accident

4.9 Lack of Lifeboats

- Number of passengers was not considered relevant in the regulation at that time

- The Board of Trade committee considered changing their regulations for lifeboats, one year before the Titanic accident
- Alexander Carlisle, an expert witness, argued that the vessels should carry far more lifeboats
- However the committee actually recommended fewer lifeboats than before

4. Accident Perspectives and the Titanic Accident

4.9 Lack of Lifeboats

- The Titanic was capable of carrying sixty four lifeboats for any change in the regulations
- White Star Line equipped only 20 lifeboats for more deck space

Capacity (64 Lifeboats)

Equipped (20 Lifeboats)

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4. Accident Perspectives and the Titanic Accident

4.9 Lack of Lifeboats

- The committee ignored consideration of changing its requirement for lifeboats

  → MMD theory

- Titanic equipped only 20 lifeboats for much more deck space

  → Conflicting Objectives perspective

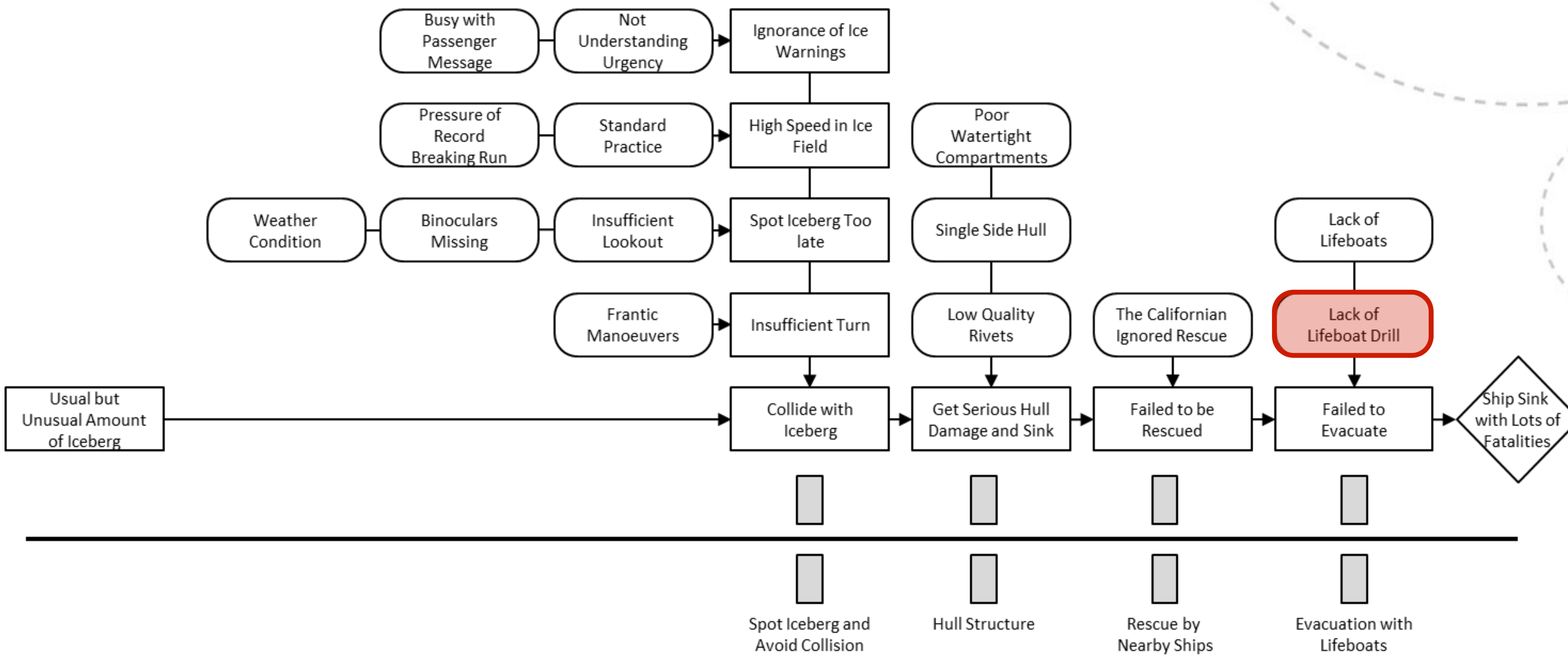
- Weakened barrier of “Evacuation with Lifeboats”

  → Energy-Barrier model

Energy-Barrier	MMD	NAT	HRO	Conflicting Objectives	Resilience Engineering
X	X			X	

4. Accident Perspectives and the Titanic Accident

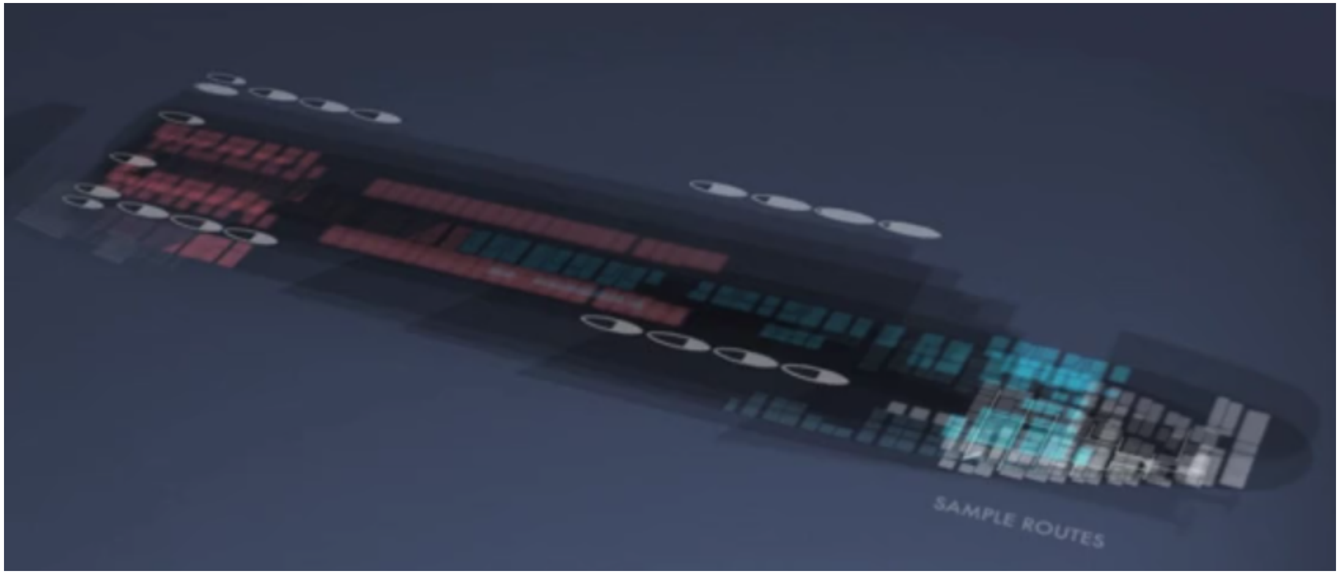
4.10 Lack of Lifeboat Drill



4. Accident Perspectives and the Titanic Accident

4.10 Lack of Lifeboat Drill

- Total capacity of lifeboats was 1,176P
- Saved only 706P (60%)



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4. Accident Perspectives and the Titanic Accident

4.10 Lack of Lifeboat Drill

- Many of the crew did not join the ship until a few hours before sailing
- There had been no proper boat drill nor a muster

- There was wide diversity of opinion as to the number of the crew necessary to man each boat
- There was no direction whatever as to the number of passengers to be carried by each boat
- There was no uniformity in loading them

  (on one side only women and children, other side equal proportion)

- Total capacity of lifeboats was 1,176P
- Saved only 706P (60%)

4. Accident Perspectives and the Titanic Accident

4.10 Lack of Lifeboat Drill

- Crew were not prepared for evacuation with lifeboats (ability to respond)

  → Resilience Engineering

- Mindfulness (anticipation and awareness of the unexpected and contain the unexpected)

  → HRO theory

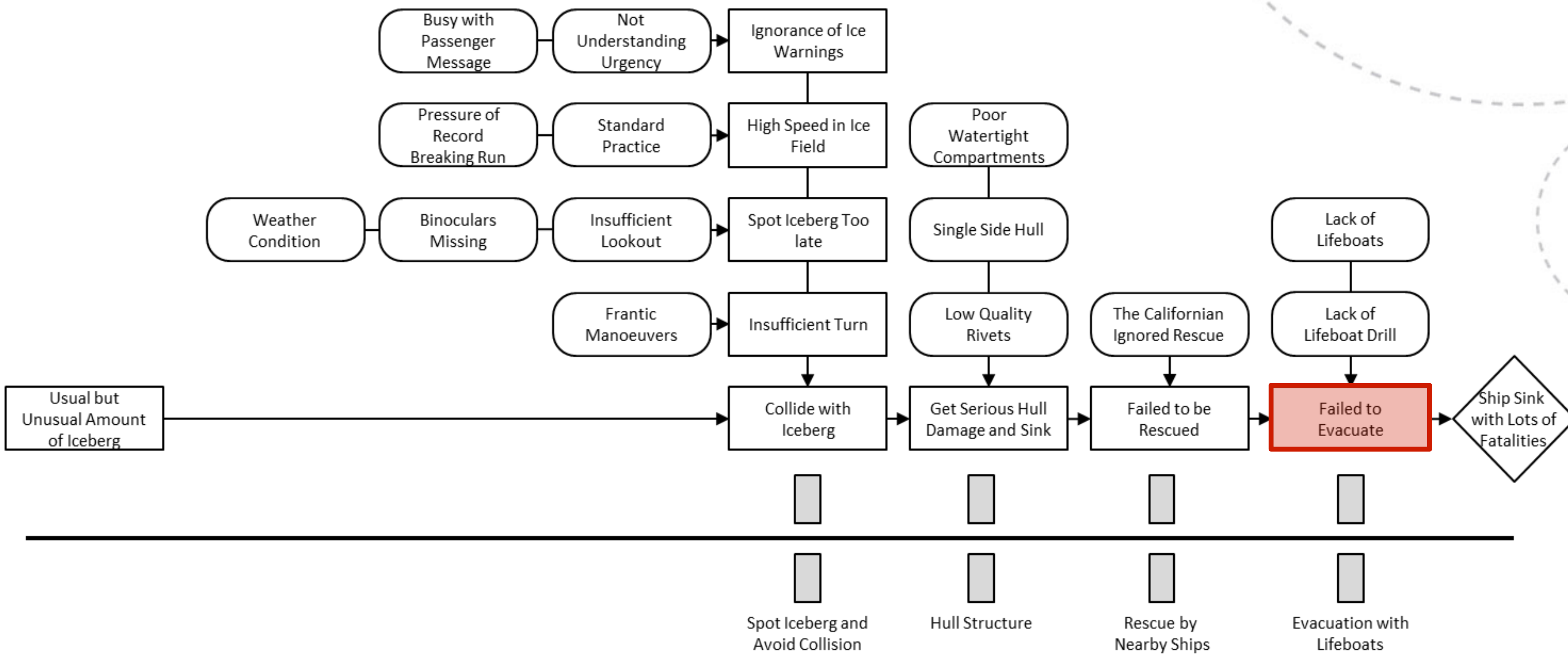
- Weakened barrier of "Evacuation with Lifeboats"

  → Energy-Barrier model

Energy-Barrier	MMD	NAT	HRO	Conflicting Objectives	Resilience Engineering
X			X		X

4. Accident Perspectives and the Titanic Accident

4.11 Fail to Evacuate



4. Accident Perspectives and the Titanic Accident

4.11 Fail to Evacuate

- Result of previous two conditions

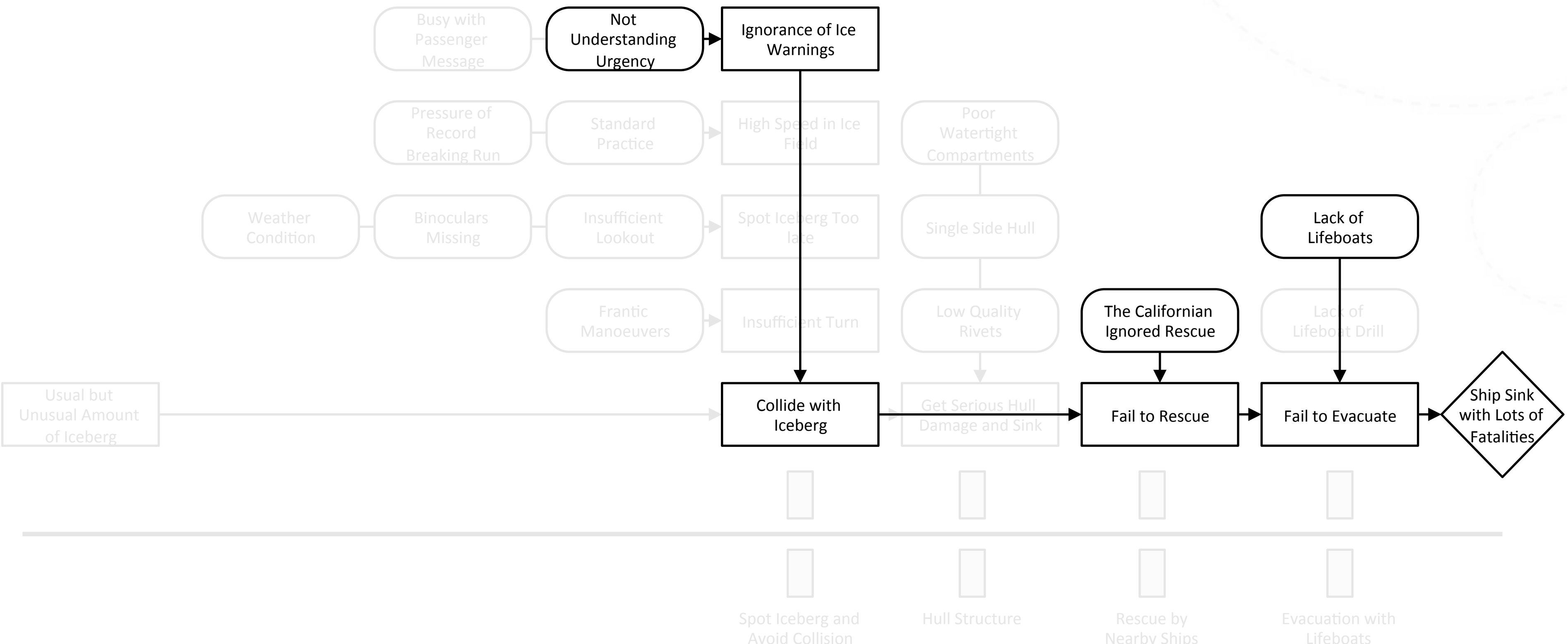
→ Energy-Barrier model, MMD theory, Conflicting Objectives perspective, HRO theory, and Resilience Engineering

Energy and Barrier	MMD	NAT	HRO	Conflicting Objectives	Resilience Engineering
X	X		X	X	X

5. Result

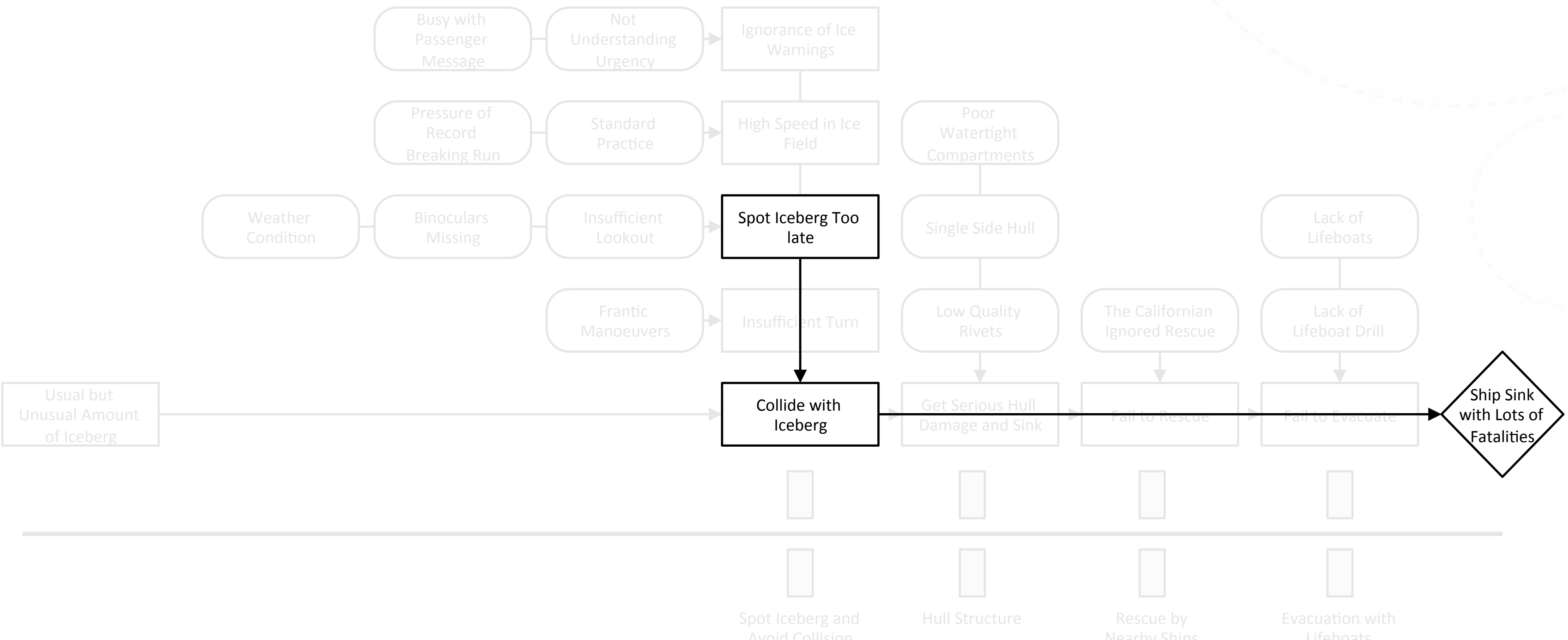
5. Result

5.1 Man-Made Disaster Theory



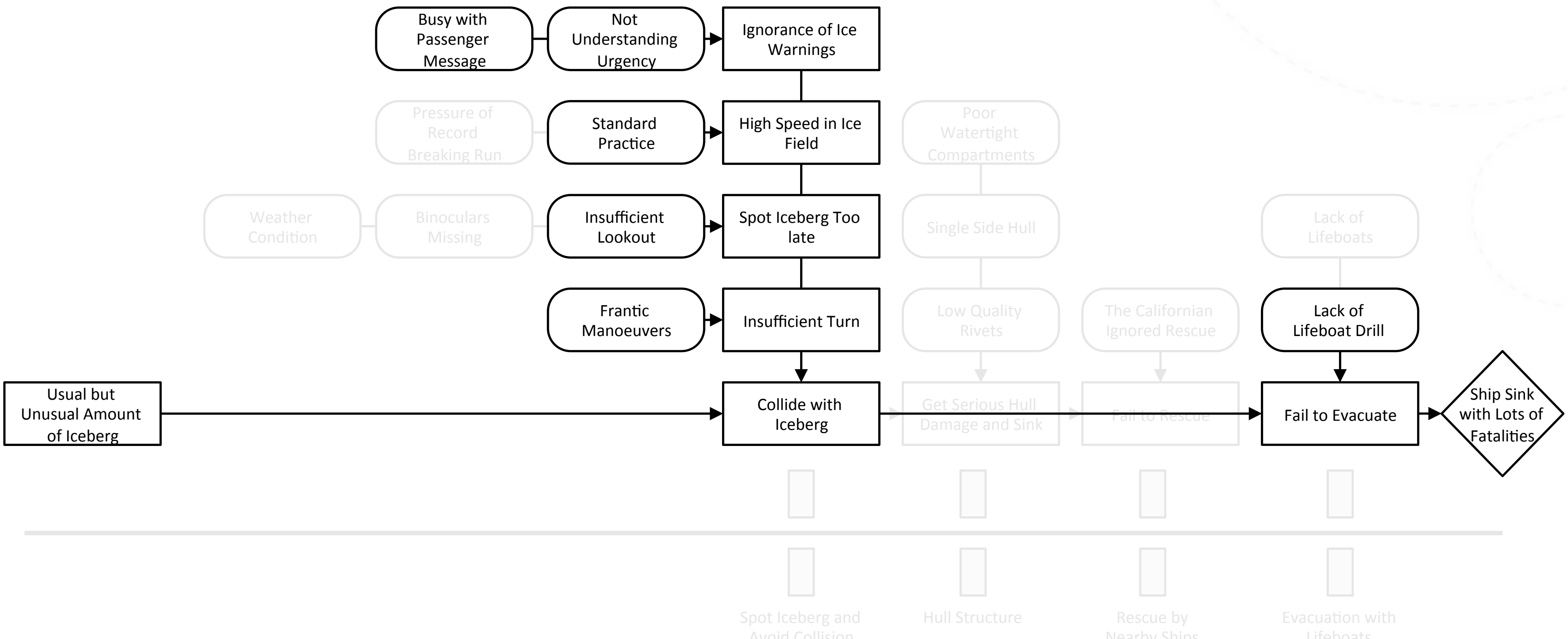
5. Result

5.2 NAT



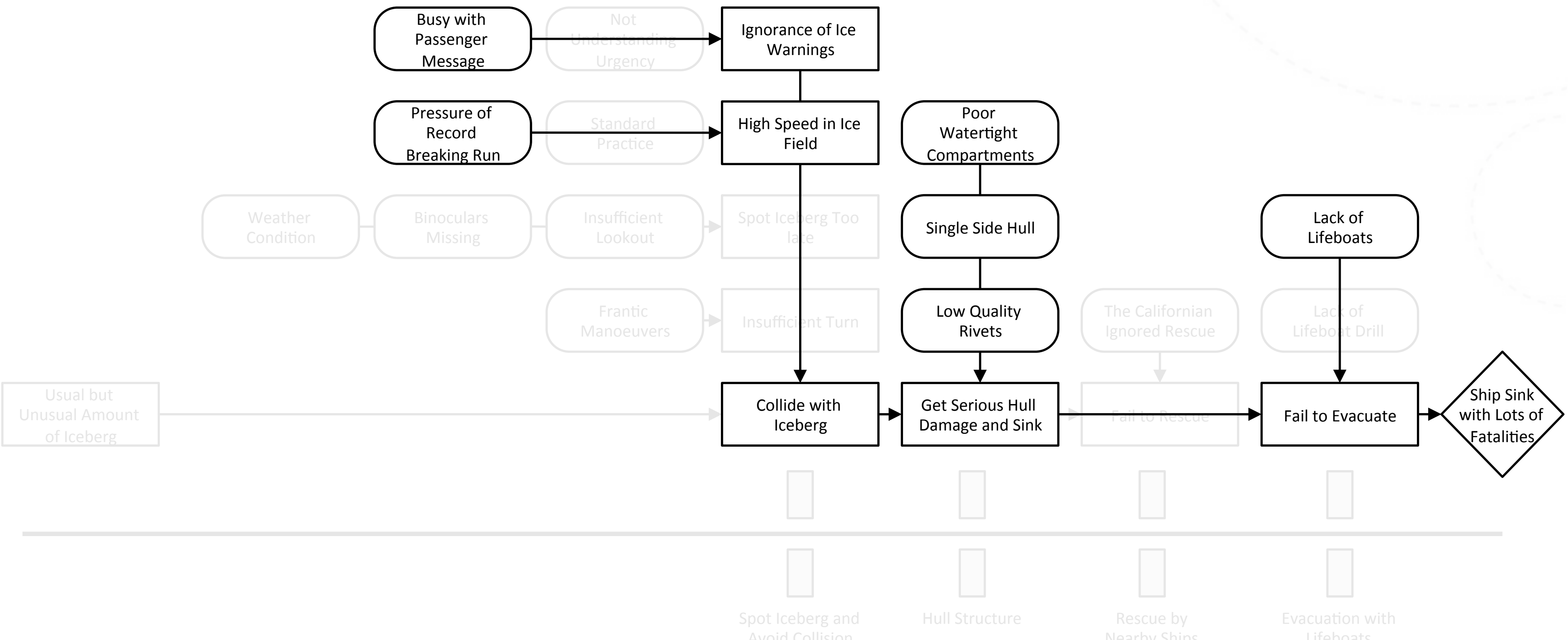
5. Result

5.3 HRO Theory



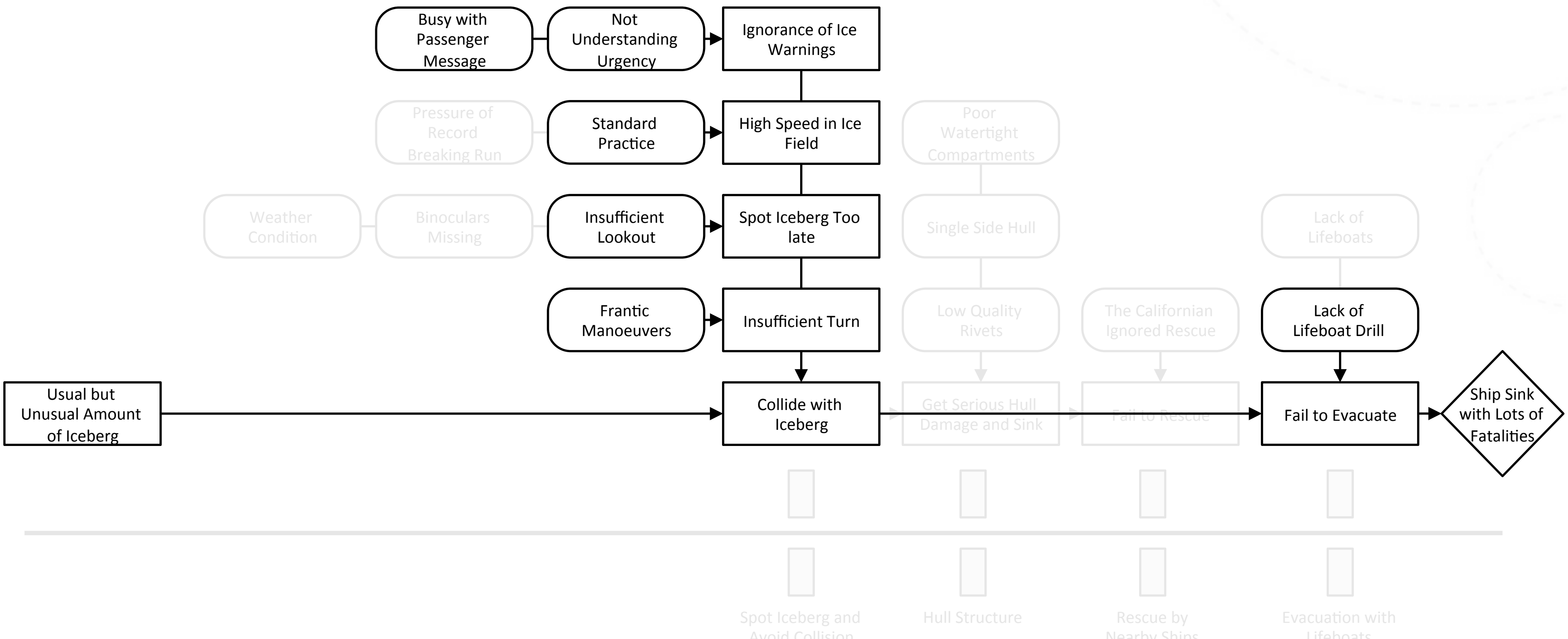
5. Result

5.4 Conflicting Objectives Perspective



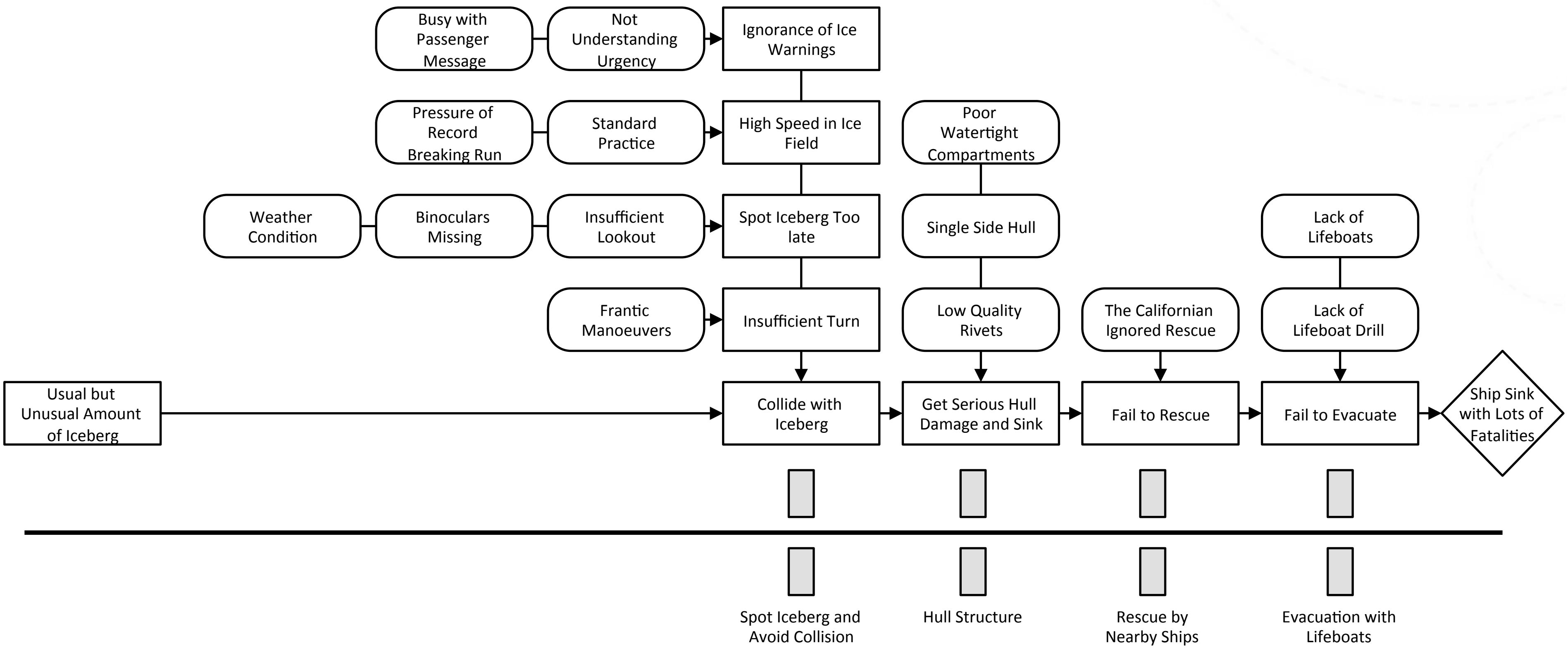
5. Result

5.5 Resilience Engineering



5. Result

5.6 Energy-Barrier Model



5. Result

5.7 Summary

No.	Events and Conditions	Energy-Barrier Model	MMD Theory	NAT	HRO Theory	Conflicting Objectives Perspective	Resilience Engineering
1	Usual but Unusual Amount of Icebergs	X			X		X
2	Wireless operator busy with passenger service	X			X	X	X
3	Not Understanding Urgency	X	X		X		X
4	Ignorance of Ice Warnings	X	X		X	X	X
5	Pressure of Record Breaking Run	X				X	
6	Standard Practice	X			X		X
7	High Speed in Ice Field	X			X	X	X
8	Weather Conditions	X					
9	Missing Binoculars	X					
10	Insufficient Lookout	X			X		X
11	Spot Iceberg Too Late	X		X	X		X
12	Frantic Manoeuver	X			X		X
13	Insufficient Turn	X			X		X
14	Collide with Iceberg	X	X	X	X	X	X
15	Poor Watertight Compartments	X				X	
16	Single Side Hull	X				X	
17	Low Quality Rivets	X				X	
18	Get Serious Hull Damage and Sink	X				X	
19	Californian Ignored Rescue Signal	X	X				
20	Fail to Rescue	X	X				
21	Lack of Lifeboats	X	X			X	
22	Lack of lifeboat drill	X			X		X
23	Fail to Evacuate	X	X		X	X	X

6. Discussion

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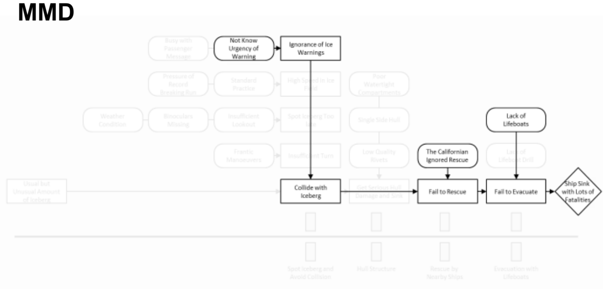
6. Discussion

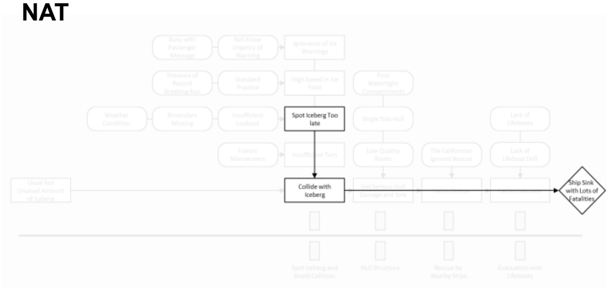
6.1 Can we explain the accident with a single perspective?

- None of the perspectives can alone explain entire sequences, events and conditions

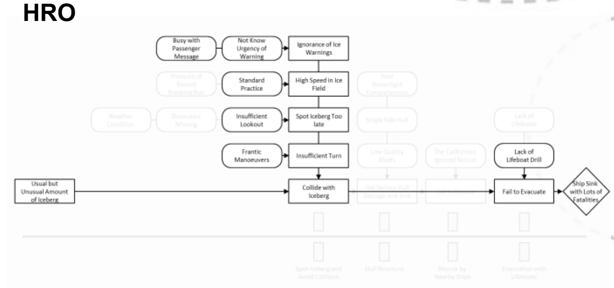
MMD



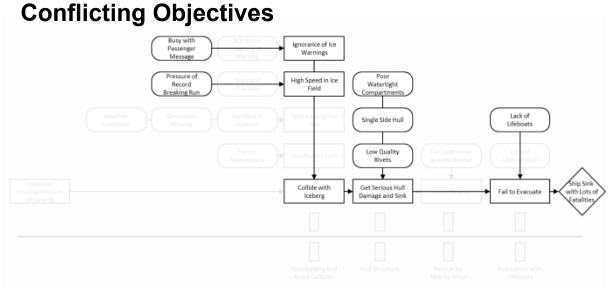
NAT



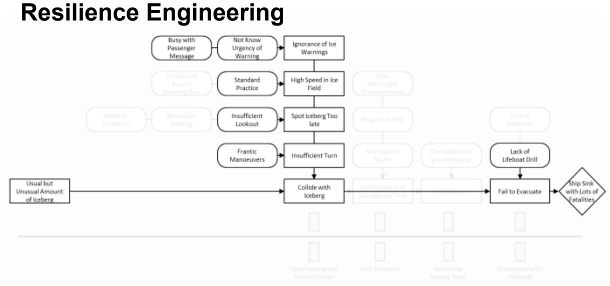
HRO



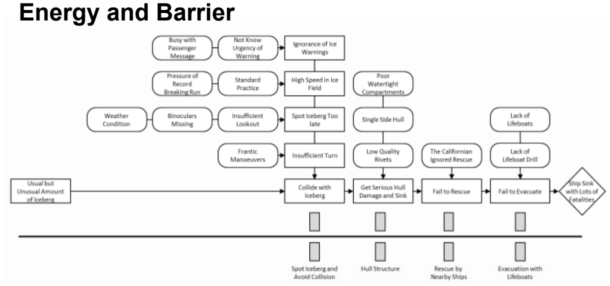
Conflicting Objectives



Resilience Engineering



Energy and Barrier



6. Discussion

6.1 Can we explain the accident with single perspective?

- Integrated accident model is necessary for overall understanding of an accident

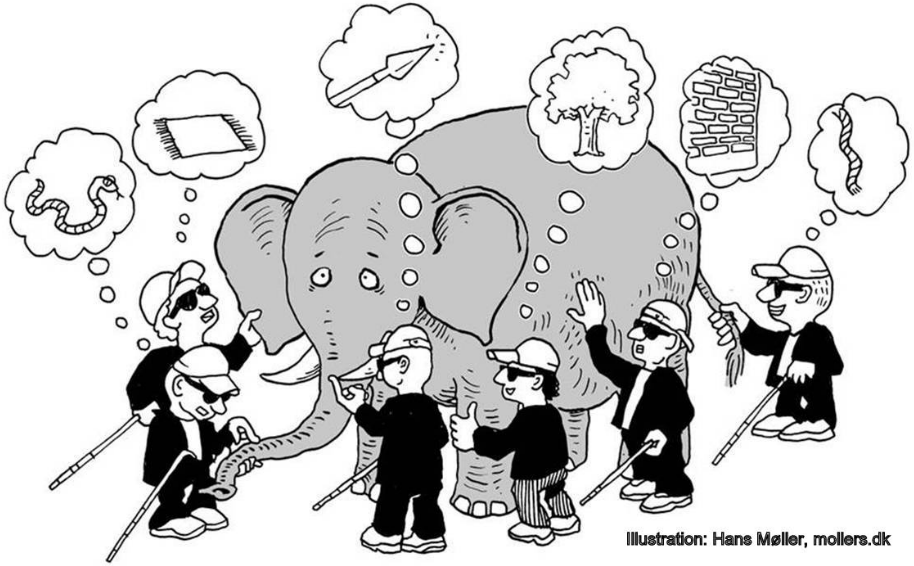


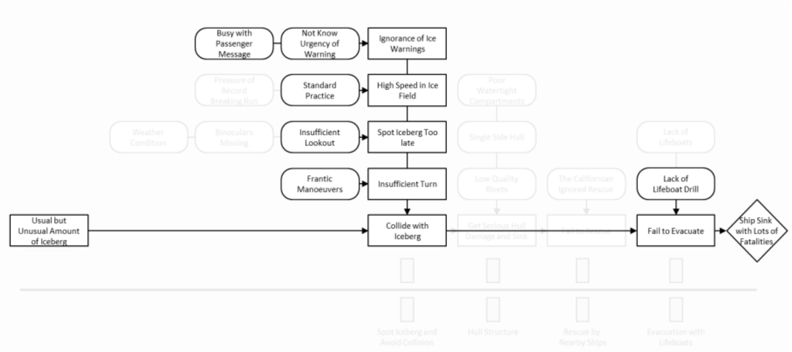
Illustration: Hans Møller, mollers.dk

6. Discussion

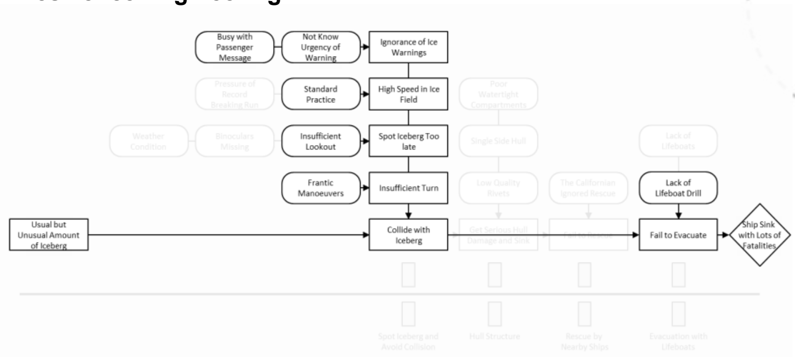
6.2 HRO vs. Resilience Engineering

- Show exactly same result

HRO



Resilience Engineering



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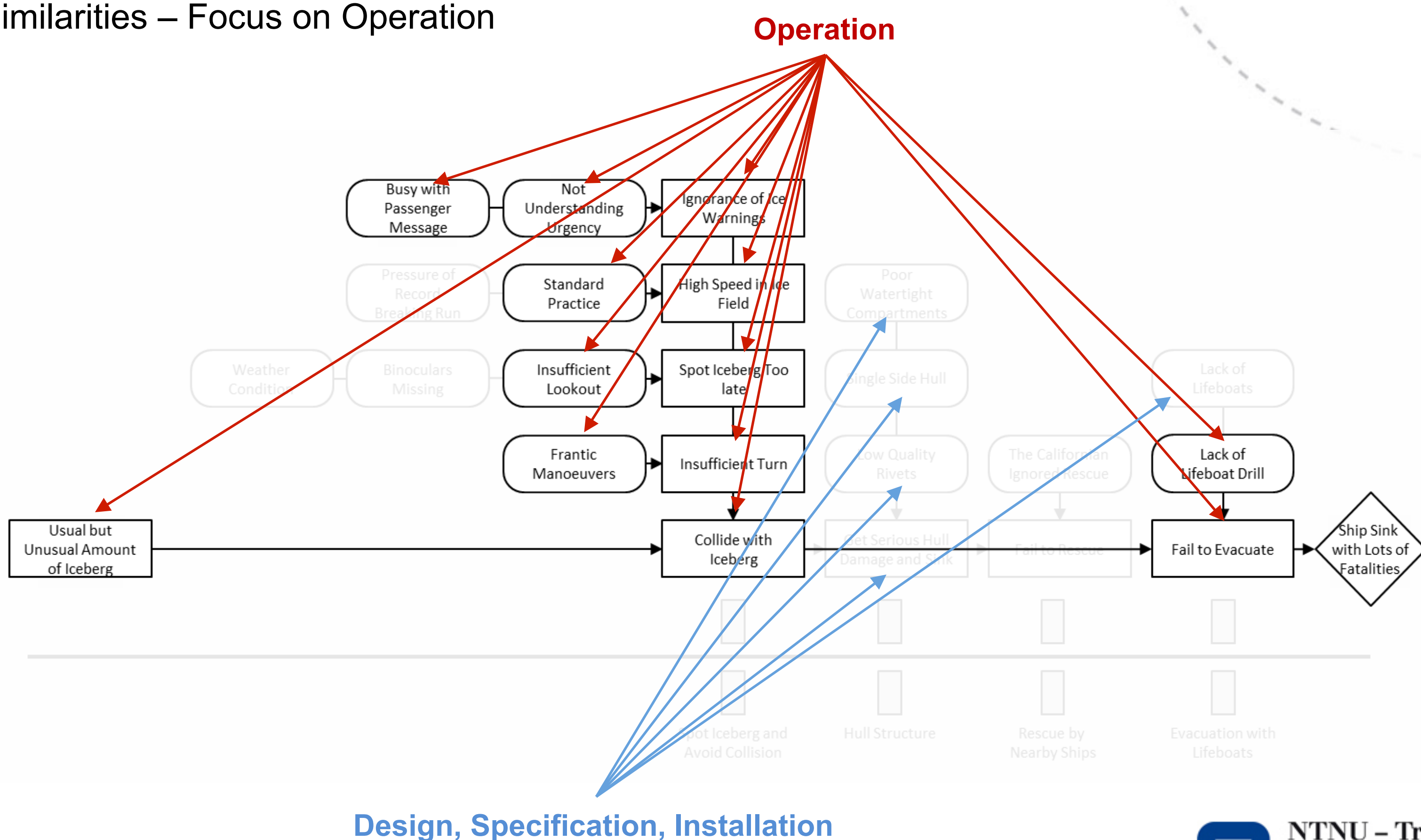
6. Discussion

6.2 HRO vs. Resilience Engineering

- Similarities – Focus on Operation



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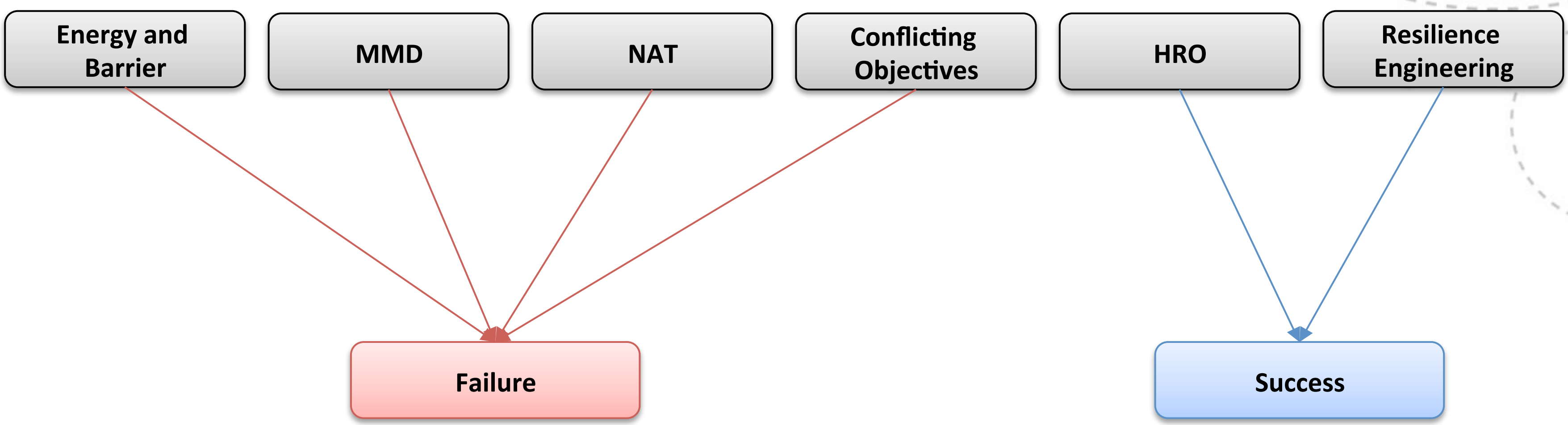
6. Discussion

6.2 HRO vs. Resilience Engineering

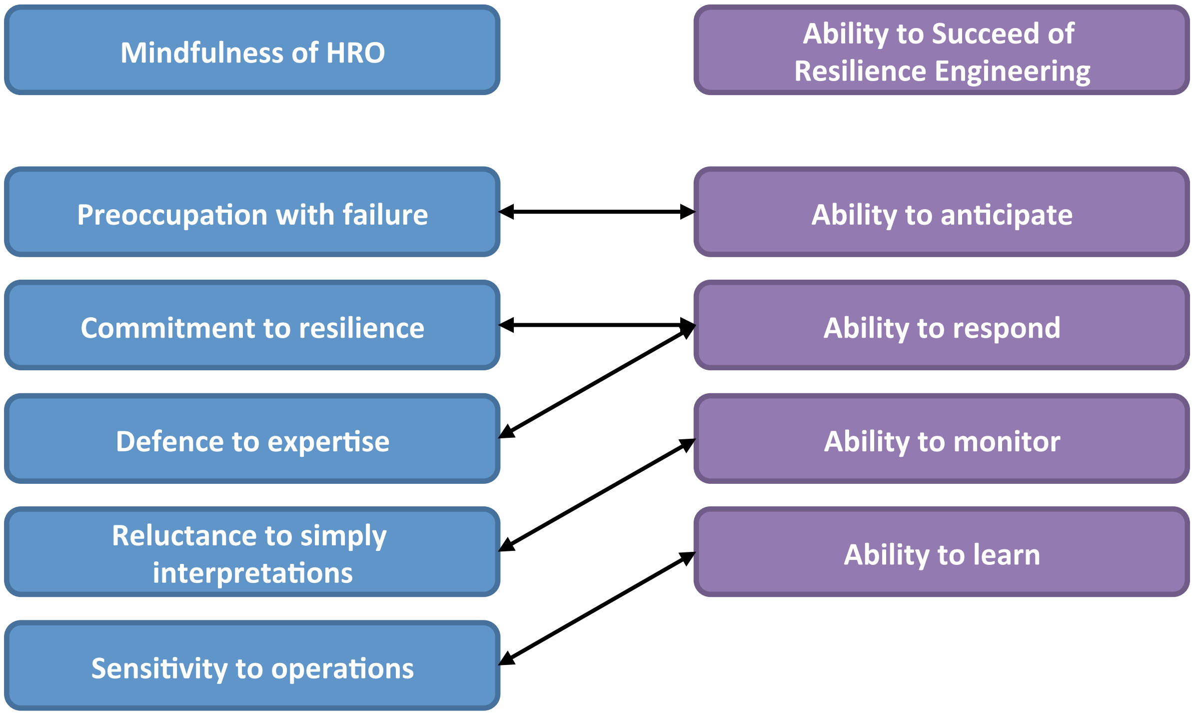
- Similarities – Focus on Success



6. Discussion

6.2 HRO vs. Resilience Engineering

- Similarities – Mindfulness and Four Ability to Succeed



6. Discussion

6.2 HRO vs. Resilience Engineering

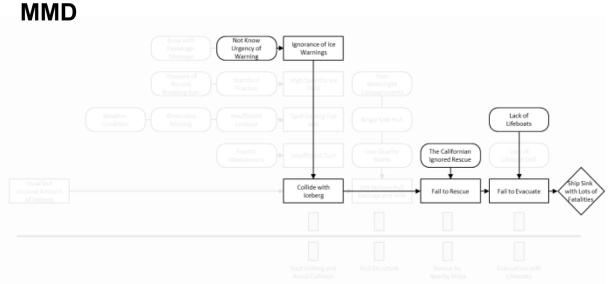
- Are they really same perspectives?
- Is there any practical differences between them?
- How about in actual accident cases?

6. Discussion

6.3 Other Accident Investigation Methods?

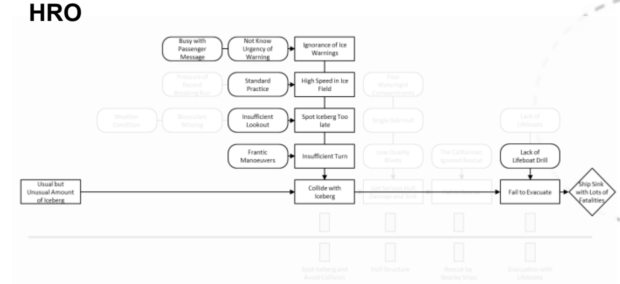
- All conditions and events are relevant to Energy and Barrier Perspective because MTO is based on Barrier Analysis

MMD

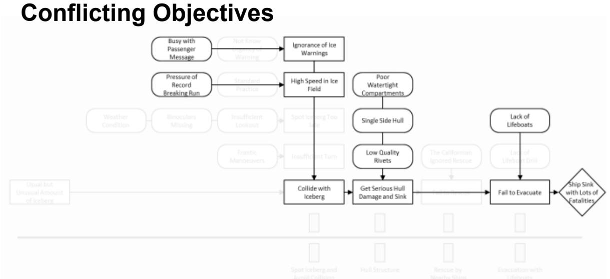


NAT

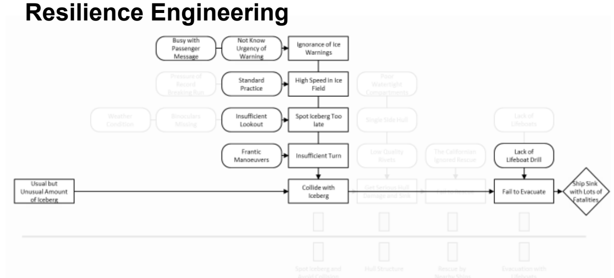
HRO



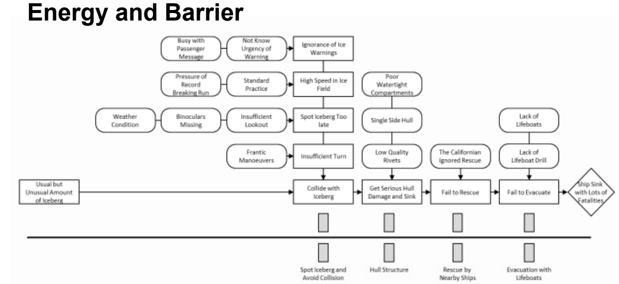
Conflicting Objectives



Resilience Engineering



Energy and Barrier



6. Discussion

6.3 Other Accident Investigation Methods?

- What about other accident investigation methods?

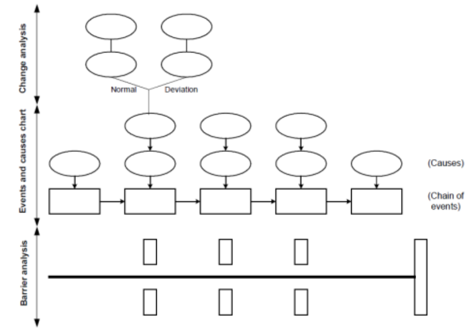


Fig. 4. MTO-analysis worksheet.

STAMP (Systems-Theoretic Accident Modelling and Process)

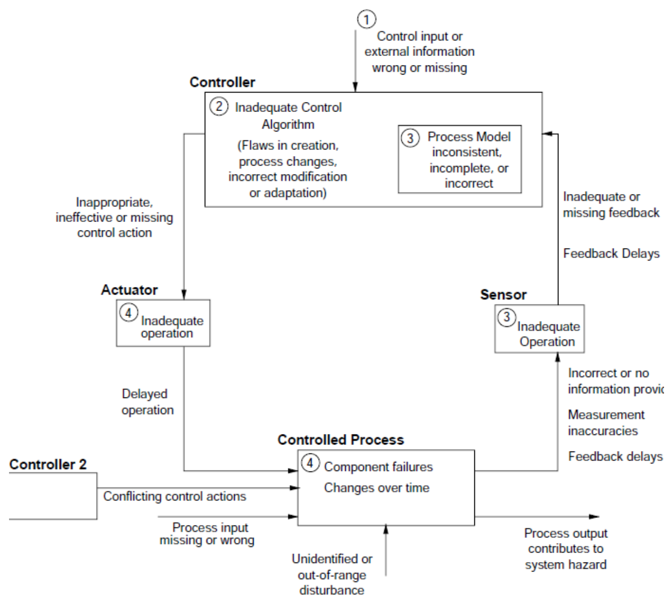


Figure 4.8
A classification of control flaws leading to hazards.

FRAM (Functional Resonance Analysis Method)

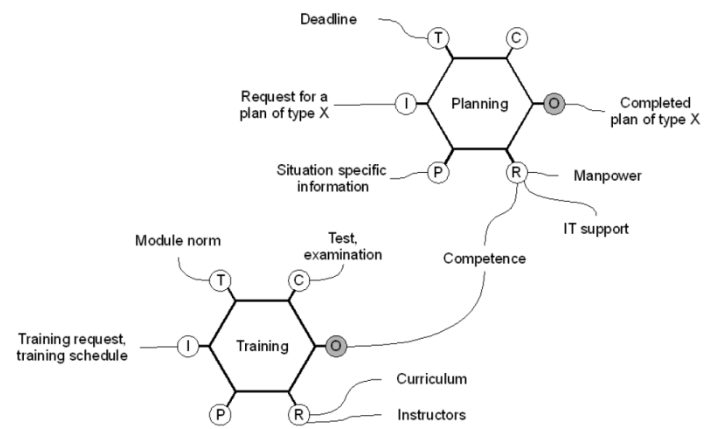


Figure 10: Example of FRAM instantiation

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7. Conclusion

7. Conclusion

- Lecture Questions

1) What is main idea of each accident perspective?

→ Briefly reviewed

2) What are the causes of Titanic accident, and how can we structure them?

→ Total 23 causes have been structured with MTO method

3) How can we apply each accident perspective to the causes of the Titanic accident?

→ 6 perspectives have been applied to 23 causes

4) What happens if we focus on only one perspective for an accident?

→ We cannot understand overall picture of the accident

A single accident perspective cannot explain entire accident causes and sequences

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