An Approach to Human Error Analysis for Marine Systems Maintenance

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Maintenance error Analysis - Motivation

- Maintenance error is responsible for about 3% of shipping accidents (ABS, EMSA)
- New fuels are planned for ship- propulsion
  - Ammonia as a fuel is hazardous, requires increased safety management and training
  - Nuclear ship propulsion requires MUCH increased attention to safety engineering, maintenance and operation
- Current safety case protocols and design guides do not consider maintenance
  - IMO Code of safety for nuclear merchant ships does not mention maintenance
  - MCS Formal safety assessment for container vessels:
    - "Risks associated to construction, docking, repair, inspection, maintenance, decommissioning or scrapping are considered out of scope"

NEED FOR GUIDANCE IN MAINTENANCE SAFETY DESIGN

Human Error Analysis - Problems

There are over 200 published methods for HRA

There are only 8 published studies which give evidence based human error probability data, 4 of them are from the 1960’s.

No methods which focus on design error

Only a few studies of maintenance error probability, not evidence based

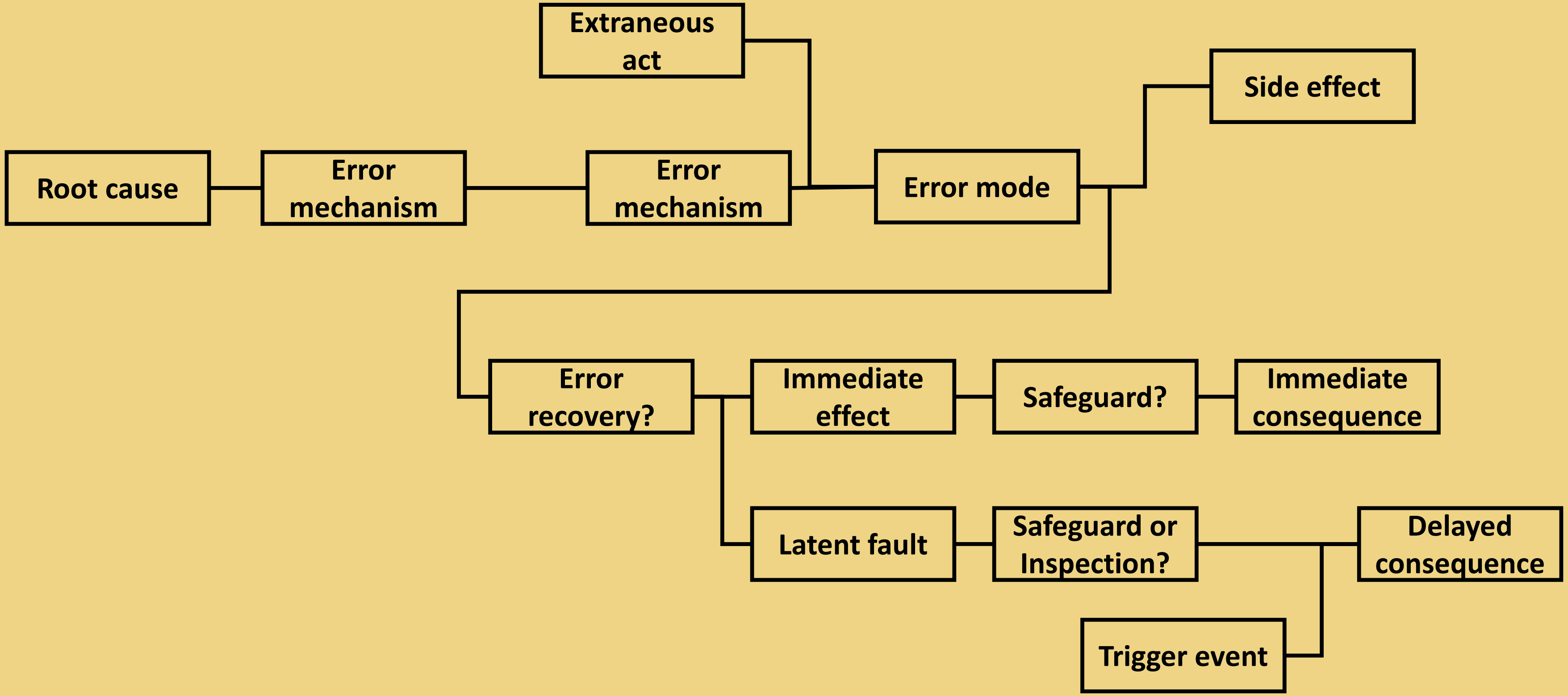
Most methods consider only a few error modes, This limits their usefulness in design.

Action Error Analysis

Action Error Analysis developed by Taylor and Rasmussen 1978

Considers error modes for individual actions

Considers error mechanisms and root causes



Error Modes

Action Error modes	Communication error modes
Omission of action	Wrong object
Missing a cue	Wrong action, procedure, plan
Too early/late	Unwanted action
Too much/little force	Correct action but in the presence of a latent hazard
Too much/too little material	Wrong value, place, substance,
Too slow/fast	Wrong tool, component, material
Too long/ Not long enough	Correct action but in the presence of a latent hazard
Inadequate precision	Correct action but without precondition check
Wrong sequence	Correct action but without considering a side effect
Repetition	Wrong object
Wrong direction	Wrong action, procedure, plan

Sources of data – 107 process plants and ships

5 refineries
6 natural gas processing plants
3 petrochemical complexes
Many platforms
LNG, LPG and ammonia ships

$$\text{HEP} = \frac{\text{No of errors}}{\text{No of opportunities for error}}$$

This means documentation of maintenance activities is needed for all

Error Probability Data

Equipment type	Maintenance action	Error modes	HEP
Subsystem maintenance	Removal and refurbishment	Wrong subsystem taken out of service (if similar)	0.007
		Subsystem not fully isolated prior to maintenance	0.0025
		Isolation removed prematurely	0.0004
		Subsystem or component wrongly placed (where physically possible)	0.0002
		Subsystem or component wrong way up (where physically possible)	0.0002
		Wrong interconnection	0.001
Bearing maintenance	Inspection	Omission of inspection	0.003
		LTA inspection	0.003
		Wrong criteria for inspection	0.0002
		LTA lubrication	0.003
		LTA check of lubrication system	0.02
		No check of lubricant quality or contamination	0.03
	Replacement	Wrong bearing type	0.002
		Failure to remove packing	0.001
		Lubrication supply not restored or LTA	0.006
		Lubricant or bearing contaminated or bearing dirty	0.001
		Misaligned	0.001

What is human error?

Most of the errors studied were forced!

- Lack of access
- Lack of authority
- Distraction by other tasks or job communication
- Design error and design weaknesses
- Management error and poor job organisation
- HMI deficiency
- Time pressure
- Inadequate manning

There is a greater need to study forcing conditions than to study true operator and maintainer error

Example - Ammonia loading

Task step/action	Mechanical failure	Pr_M per transfer	Error mode	HEP per act	Check	Safety measure	Pr_{safety}	Consequence	Overall $Pr_{incident}$
Check weather forecast	Storm coming	2/356	Omission	0.02		Stop, uncouple	0.001	Break due to ship movement	1.1E-6
Check mooring	Mooring LTA	0.001	Omission	0.02		Improve m.	0.001	“”	2.1E-5
Check arm coupling flange	Flange damaged	31E-6 py * 30	Omission	0.02				Leak	1.9E-5
Check ship coupling flange			Omission	0.02				Leak	62E-8
Check hose	Hose leak	4E-3 py	Omission, LTA	0.003		N2 check	0.001	Leak	4E-6 py
Extend and manipulate hose to ship	None		Not significant						
Connect up flange - gasket			Damaged or old gasket	0.01		ESD	0.01	Leak	1.0E-4
Connect up flange – bolt up			Incomplete						
Connect up flange - tighten			Overtighten	0.03	0.001	N2 check	0.001	Possible bolt break	3.0E-7
			Overtighten	0.03		N2 check	0.001	Crushed gasket, leak	3.0E-5
			Under-tighten	0.001		N2 check	0.001	Leak	1.0E-6
Check for leak with N2			Step omission	0.001				Possible latent failure 1	0.001
Open shipboard valve	Latent failure 1					ESD	0.01	Leak	

Risk reduction

Proper protective equipment

Proper procedures and procedure error analysis

Correct tools

Training and correct manning

Replacement parts management and parts certification

Isolation and preparation for maintenance

Work permitting and pre-maintenance inspection

Job safety analysis

New technology – Virtual reality and augmented reality

DESIGN FOR SAFETY IN MAINTENANCE