Arab Academy
for Science Technology & Maritime Transport

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"Marlog 11"

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Investigating maritime accidents using hierarchical clustering

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Towards a SUSTAINABLE BLUE ECONOMY

20 - 22 March, 2022
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NEW DIAMOND
PANAMA

This research was developed in the framework of the **OMD project**

OMD – Observatoire des Marchandises Dangereuses
Management of risks in the port environment
and improvement of maritime safety

CONTEXT OF THE STUDY

- The international shipping industry
  - **90% of world trade**
  - **60,000 merchant ships**
  - **> 1M seafarers**

- Highly **dynamic and high-risk environment** characterized by a **high rate of accidents** and maritime disasters

- When the cargo involves **dangerous goods**, maritime transport becomes **even more complex** and delicate

UNDERSTANDING THE MARITIME ACCIDENTS PHENOMENON IS EXPEDIENT TO GIVING SHIPPING PRACTITIONERS A FOCUS FOR TAILORED INTERVENTIONS AIMED AT ENHANCING MARITIME SAFETY

CONTEXT OF THE STUDY

- The marine accidents can be caused by a **variety of factors**:
  - related to the ship
  - related to the equipment
  - linked to environmental issues
  - navigational factors
  - operational factors
  - related to the traffic
  - related to human factors (**recognized as the main cause contributing to 75%-96% of marine accidents** [Galieriková, 2019]

OFTEN, ACCIDENTS ARE CAUSED BY A COMBINATION OF FACTORS [Fadda et al., 2021]

RELATED LITERATURE

- The attention of the scientific literature towards the topic is significant and growing
- The focus of the research has shifted from naval architecture to human error **[Luo and Shin's, 2019]**
- Several studies investigated the role of human errors in marine accidents and provided recommendations to decrease the risk associated to specific causes **[Antão and Guedes Soares, 2019]**
- Research in maritime safety and accident domain deal with underreporting of maritime accidents **[Hassel et al., 2011]** and fractioned data collection **[Luo and Shin, 2016]** that may have prevented a larger application of quantitative methods for investigating the role of human factors in maritime accidents

GOALS OF THE STUDY

Application of **hierarchical clustering methods** to an **IMO dataset** including 1,079 sea accidents occurred worldwide between 2009 and 2019, in order to:

- identify the main factors contributing to accidents at sea and compare them by homogeneous groups
- investigate the role of human factors on maritime accidents

DATA

- **Source**: IMO Marine Casualties and Incidents Database
- **Period**: 2009-2019

3710
INCIDENTS*

4347
INVOLVED VESSELS

1310
LOST SHIPS

780
INJURIES

7234
DEATH AND MISSING

2129
SERIOUS INCIDENTS

*THEY INCLUDE: VERY SERIOUS, SERIOUS AND LESS SERIOUS MARINE CASUALTIES (NOT MARINE INCIDENTS)

WE CONSIDER ONLY THE ACCIDENTS THAT REPORT COMPLETE INFORMATION: **1,079 ACCIDENTS**

DATA

EACH ACCIDENT IS CHARACTERIZED THROUGH **70 VARIABLES**:

17 variables relate to the vessel

- IMO number
- Flag
- Length
- Tonnage
- Type of ship
- Type of service
- …

53 variables relate to the accident

- Date and Time
- Position
- Crew on board
- Initial event
- …

The analysis was carried out on a subset of the 70 variables (criteria: suitability of the variable for the purpose of the analysis, % of completeness, etc.)

DATA

- **17 variables selected**:

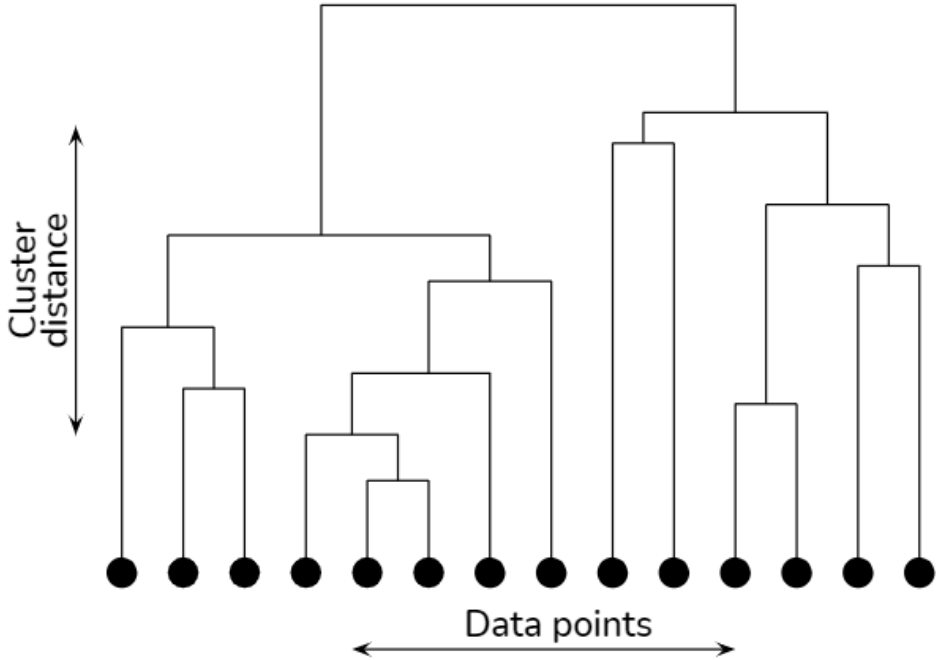
1. Ship type
2. Type of casualty
3. Loss of life
4. Location of the casualty
5. Consequences to the ship
6. Pilot on board
7. Human errors
8. Human violations
9. Technical failure
10. Problem with ship's cargo
11. Adverse weather conditions
12. Navigational tools problem
13. Communication
14. Standards of personal competence or lack of training
15. Fatigue, stress, or excessive workload
16. Hardware issues
17. Software issues

METHODOLOGY

- **Used Method**: Hierarchical clustering

- **Scope**: grouping the incidents in such a way that those belonging to the same cluster have similar characteristics to each other and different from those of the other clusters

- It creates a **hierarchical decomposition of the data represented by the dendrogram** which is cut at a certain height to define the number of clusters of interest



APPLICATION

HIERARCHICAL CLUSTERING

STEP 1:
WHOLE DATASET

1,079 accidents

STEP 2:
DANGEROUS GOODS DATASET

153 accidents

RESULTS – WHOLE DATASET

Hierarchical tree

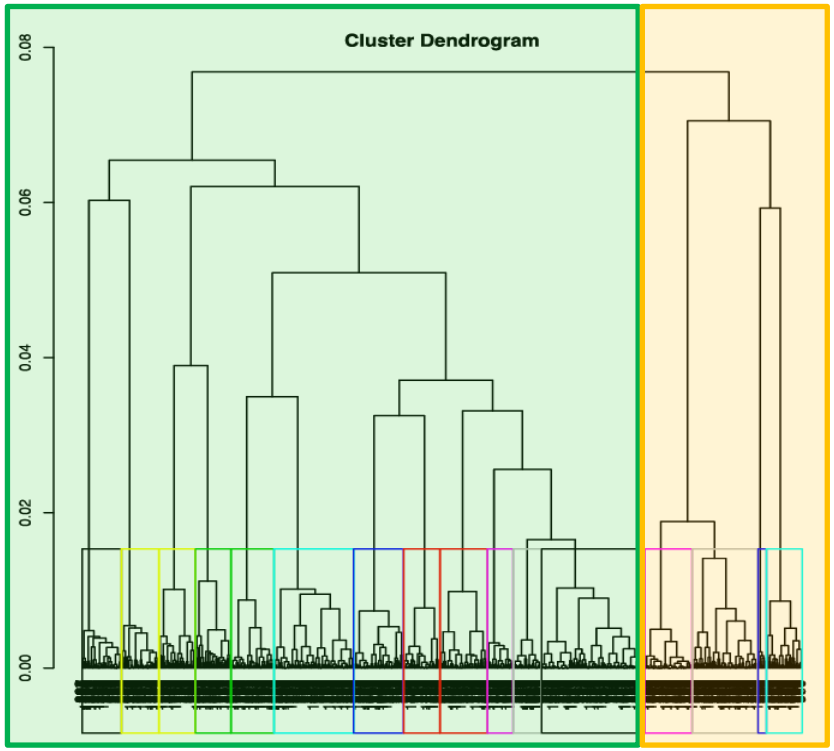


Figure 1: Dendogram – whole dataset (1,079 accidents)

- **16 CLUSTERS**

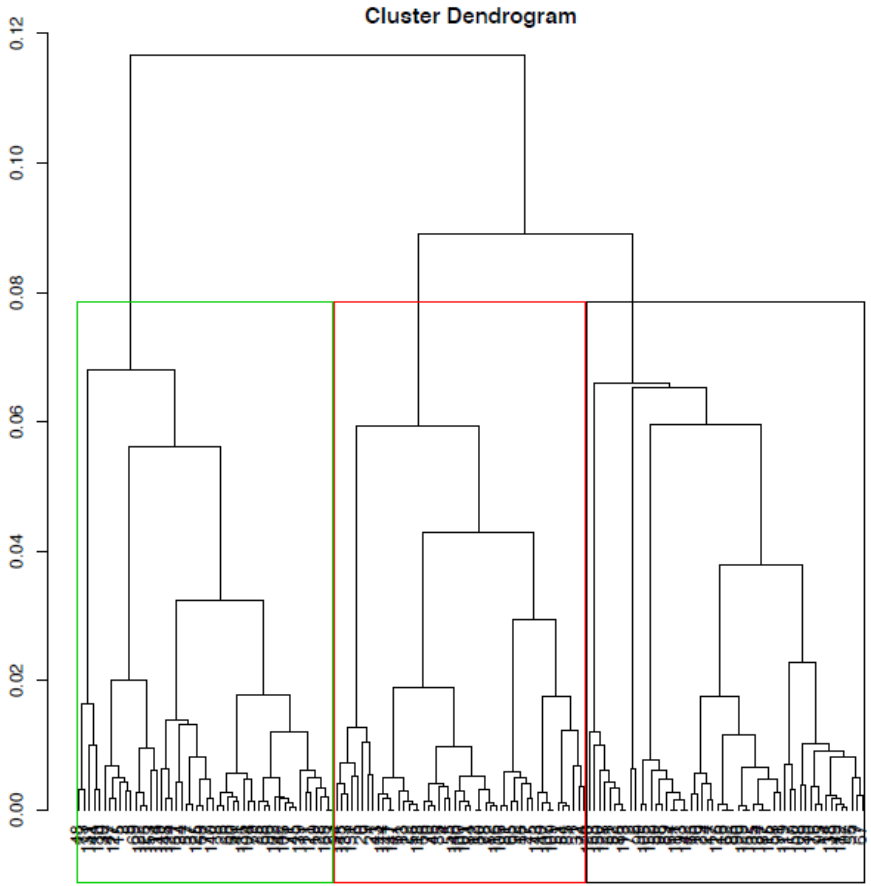
Two main groups

1. accidents due to technical causes
2. accidents where the human factor plays a predominant role

The probability of human errors and/or violations causing an incident increases when problems related to "Software issues" (problems with protocols, standards, and company policy) and "Personnel factors" (inadequate staff training, excessive workloads and communication problems) are reported.

No.	Size	Type of casualty	Ship type	Location	Loss of life	Consequences to the ship	Pilot on Board	Hardware factors	Software factors	Personnel factors	Human error	Human violations	Other causes
Overall	1151	Capsizing (5%), Collision (34%), Damage to the ship (5%), Fire (15%), Flooding (1%), Grounding (14%), Machinery Failure (6%), Work Accident (20%)	Cargo (57%), Fishing (12%), Passenger (10%), Special Craft (8%), Tanker (13%)	Coastal waters (25%), Inland waters (8%), Open Sea (27%), Port (40%)	Yes (32%) No (68%)	Ship remains fit to proceed (49%) Ship rendered unfit to proceed (28%) Total loss of the ship (23%)	Yes (19%) No (81%)	Yes (19%) No (81%)	Yes (40%) No (60%)	Communication (11%), Standards of personal competence (18%), Fatigue (8%), Other (11%), No (66%)	Error in judgement (29%), Failure to respond appropriately (12%), Incorrect operations of control (11%), Inappropriate choice of route (5%), Forgetting to report information (2%), Failure to advise officer on the watch (2%), Deciding not to pass on information (4%), Failure to report due to distraction (2%), Other Errors (24%), No (46%)	Necessary (6%), Routine (12%), Other (9%), No (75%)	Problem with cargo (10%), Technical failure (33%), Structural failure (8%), Adverse weather (29%), Navigational tool problems (6%), No (40%)
1	63	Machinery failure (98%, 100%)			No (7%, 91%)	Ship rendered unfit to proceed (9%, 44%)				No (8%, 91%)	No (10%, 79%)	No (7%, 89%)	Technical failure (13%, 78%), Structural failure (21%, 30%)
2	58	Collision (9%, 64%), Grounding (11%, 29%)	Cargo (8%, 89%)	Inland waters (60%, 100%)	No (7%, 93%)	Ship rendered unfit to proceed (7%, 40%)	Yes (19%, 71%)	No (6%, 93%)	No (7%, 80%)				
3	69	Fire (15%, 38%)	Passenger (62%, 100%)	Coastal waters (9%, 36%)	No (8%, 94%)	Ship rendered unfit to proceed (11%, 52%)					No (8%, 61%)		
4	80	Grounding (50%, 100%)	Cargo (9%, 75%)	Coastal waters (13%, 45%)	No (10%, 98%)	Ship rendered unfit to proceed (10%, 39%)				Other (14%, 21%)	Inappropriate choice of route (25%, 19%)		Adverse weather (12%, 51%)
5	127	Fire (63%, 87%)	Fishing (24%, 25%)	Open sea (21%, 50%)	No (13%, 76%)	Total loss of the ship (18%, 39%)	No (12%, 91%)	Yes (17%, 30%)	No (13%, 72%)	No (15%, 87%)	No (18%, 75%)	No (13%, 91%)	Technical failure (21%, 63%), Problem with cargo (21%, 19%)
6	41	Collision (7%, 68%)	Special Craft (43%, 100%)	Coastal waters (6%, 44%)	No (5%, 90%)	Ship rendered unfit to proceed (6%, 46%)	No (4%, 93%)		No (5%, 80%)				No (6%, 61%)
7	60	Damage to ship (100%, 100%)				Ship remains fit to proceed (8%, 77%)					No (8%, 73%)	No (6%, 90%)	Technical failure (10%, 67%)
8	45	Collision (11%, 98%)	Fishing (27%, 80%)	Open sea (8%, 53%)	Yes (8%, 62%)	Total loss of the ship (11%, 67%)	No (5%, 96%)	No (5%, 96%)		No (6%, 93%)			No (8%, 78%)
9	165	Collision (40%, 95%)	Cargo (24%, 96%)	Port (18%, 49%)	No (18%, 85%)	Ship remains fit to proceed (17%, 58%)	Yes (19%, 25%)	No (17%, 96%)	No (18%, 75%)	No (17%, 78%)	Failure to respond appropriately (27%, 23%), Error in judgement (19%, 39%), Deciding not to pass on information (26%, 7%)		Adverse weather (20%, 40%)
10	76	Work accident (12%, 37%)	Tanker (50%, 100%)			Ship remains fit to proceed (9%, 70%)	Yes (12%, 33%)	No (7%, 90%)		Communication (12%, 21%)			No (12%, 74%)
11	57	Grounding (15%, 40%)		Inland waters (10%, 18%)	No (7%, 91%)				Yes (9%, 70%)		Inappropriate choice of route (25%, 26%), Error in judgement (9%, 51%), Incorrect operations of control (11%, 25%), Failure to respond appropriately (9%, 23%)	Necessary (11%, 14%)	Navigational tool problems (87%, 97%)
12	14	Flooding (100%, 100%)	Fishing (4%, 43%)	Coastal waters (3%, 64%)		Total loss of the ship (5%, 86%)			Yes (2%, 72%)	Standards of personal competence (3%, 43%)			
13	57	Capsizing (98%, 100%)	Special Craft (18%, 30%)	Coastal waters (9%, 44%)	Yes (9%, 56%)	Total loss of the ship (19%, 90%)	No (6%, 97%)	Yes (9%, 33%)		Standards of personal competence (8%, 28%)			Problem with cargo (20%, 40%)
14	76	Work accident (33%, 99%)	Cargo (11%, 92%)	Open sea (10%, 41%)	Yes (19%, 93%)	Ship remains fit to proceed (13%, 93%)		No (8%, 100%)	No (8%, 72%)	Other (13%, 21%)			No (13%, 75%)
15	58	Work accident (9%, 34%)		Coastal waters (9%, 43%)					Yes (9%, 72%)	Communication (12%, 28%), Fatigue (67%,	Failure to report due to distraction (33%, 14%), Other (10%, 47%), Error in judgement (8%, 48%), Deciding not to pass on information	Necessary (14%, 17%)	

RESULTS – DANGEROUS GOODS DATASET



- **3 CLUSTERS**

Cluster 1 (54): the main cause is a **fire or mechanical failure or damage to the ship**, often (65% of cases) caused by technical problems. HF is not a major factor

Cluster 2 (49): the cause is a **collision or grounding** that occurs frequently in inland waters and with the pilot on board.

Cluster 3 (50): the causes are accidents at work mostly caused by **human errors or violations** (inadequate supervision, communication problems and/or inadequate training of the workers).

CONCLUSIONS

- A notable distinction emerged between the accidents due to technical causes and those where the human factor plays a predominant role. The latter, in the sense of error and violation, occurs most frequently when there is a lack in company protocols, standards and policies, or a problem with on-board equipment.

- The accidents involving dangerous goods do not show any noticeable peculiarity compared to the overall dataset. The only distinguishing feature is a higher percentage of fire and explosion cases

- Results confirm the importance of human factor-oriented measures that are being applied in maritime transport and contribute to giving shipping practitioners a focus for maritime safety interventions which can potentially enhance maritime safety.

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Thank YOU

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