Analysis and management of risks related to TDG in Morocco using the FMEAC approach

Imane Moussaoui1*, Younes Fakhradine El Bahi2, Amine Lachheb1, Rachid Saadani1, Miloud Rahmoune1

1Laboratory of Advanced Materials Studies and Applications, department of Physics EST-Faculty of Sciences University Moulay Ismail B.P.11201 Zitoune, Meknes-Morocco.
2 Mechanics & Integrated Engineering, ENSAM School, Meknes, 50000, Morocco.

Abstract. Road transport of dangerous goods is the most accidental mode of transport, which can have an impact on the environment, including air pollution, global climate issues of concern, noise pollution, water pollution, accidents, land use and habitat fragmentation. The objective of this study is to manage the risks associated with Moroccan road transport from an environmental point of view while taking into account the collaborative aspect at the level of a logistics chain. In this regard, the use of a problem-solving approach such as FMECA to identify anomalies and malfunctions that may lead to failure. It consists in analysing the failure modes, their effects and their criticality. This approach is based on four main criteria: severity, frequency, non-detection and criticality.

1 Introduction

In Morocco, the transport of dangerous goods (TDG) is a critical yet challenging aspect of road safety and logistics. A notable statistic from the Moroccan Ministry of Transport and Logistics reveals a concerning scenario: annually, traffic accidents lead to approximately 3,500 deaths and 12,000 serious injuries, with professional transport, including TDG, accounting for 8.7% of these fatalities. This data not only reflects the inherent risks associated with TDG but also emphasizes the urgent need for comprehensive risk management strategies in this sector. By aligning with international regulations such as the ADR Agreement, Morocco has initiated steps towards enhancing the safety protocols for TDG. Our study provides an in-depth analysis of TDG risks in Morocco and proposes methodologies to mitigate these challenges, contributing significantly to the field of transportation safety [1].

2 Methodology of the FMECA analysis

The methodology of our FMECA study is divided into four phases:

Phase 1:
- Analysis of the failure mechanisms

* Corresponding author : imanemoussaoui97@gmail.com
- Identification of failure modes in an exhaustive manner and their effects: Numerous failures can lead to accidents, particularly in industrial settings. These include Chemical Failures, Environmental Factors, plus Supply Chain and Logistics Failures, an example of the latter is the disruption in supply chains, which can lead to critical shortages of safety equipment or part.

Phase 2:
- criticality assessment
  - assignment of a criticality level to each failure mode effect
  - Determination of critical failure modes by comparison to the predefined acceptable criticality threshold
- determination of a severity scale: is a tool used to rate the potential consequences of each identified failure mode in terms of their seriousness or impact, here’s an example of a typical severity scale, often used in FMECA: Negligible, Marginal, Moderate, Critical and catastrophic.

Phase 3:
- proposal of actions to reduce the risk
- reduction of the criticality level of failures by acting on one or more of the criteria (frequency, detection, severity).
- identification of the potential costs and benefits of mitigation strategies by Estimating costs (Direct Costs, Indirect Costs, Long-term Costs) and analysing Cost-Benefit

Phase 4:
- synthesis of the study, decisions.
- to make an assessment and to provide the elements allowing to define the actions to be carried out [2].

3 Transportation of Dangerous Goods Risk Assessment Strategy

3.1 Regulation
The A.D.R. is the regulation of road transport, it applies to cross-border movements (exports and imports), crossing the country and domestic trade [3-4].

3.2 A.D.R. classification

<table>
<thead>
<tr>
<th>Class 1: Explosives</th>
<th>Explosion, projection, fire</th>
<th>Divided into six divisions based on the type of hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 2: Gases</td>
<td>Flammability, asphyxiation, toxicity, pressure effects</td>
<td>Divided into flammable, non-flammable, toxic, and oxygen</td>
</tr>
<tr>
<td>Class 3: Flammable Liquids</td>
<td>Fire, vapor hazards</td>
<td>I (high danger), II (medium danger), III (low danger)</td>
</tr>
<tr>
<td>Class 4: Flammable Solids</td>
<td>Fire, spontaneous combustion, water reactivity</td>
<td>I (high danger), II (medium danger), III (low danger)</td>
</tr>
<tr>
<td>Class 5: Oxidizing Substances and Organic Peroxides</td>
<td>Fire, explosion risk from oxidizing effects</td>
<td>I (high danger), II (medium danger), III (low danger)</td>
</tr>
<tr>
<td>Class 6: Toxic and Infectious Substances</td>
<td>Toxicity, infection risk</td>
<td>I (high danger), II (medium danger), III (low danger)</td>
</tr>
</tbody>
</table>
4 Case study (Accident due to impact)

The main reason for choosing the shock accident risk for the FMECA application is that shock accidents can be extremely serious. Dangerous goods being transported can be explosive, corrosive, or toxic, and a shock accident can result in significant environmental contamination, fires, or even explosions. Therefore, shock risk assessment is crucial to ensure the safety of workers and the public, as well as the protection of the environment.

4.1 Identification of failure modes

There are several potential failure modes that can cause a dangerous goods transportation accident. These include:

- **hazardous material spill**: The spill may be caused by a failure of the container, pipes or valves, a handling error during loading or unloading, or a degradation of the materials of the container or of the goods transported.

- **Fire**: Flammable materials being transported can be ignited by sparks, short circuits or heat sources. Fires can cause considerable damage to the goods and the transport vehicle.

- **Explosion**: Explosions can be caused by a gas leak, an unexpected chemical reaction, or spontaneous combustion. Explosions can cause considerable damage to the cargo and transport vehicle.

- **Environmental pollution**: Dangerous goods can be toxic or corrosive, and their release into the environment can have disastrous consequences for wildlife and ecosystems.

4.2 Criticality assessment

4.2.1 Risk measurement

**Likelihood/ severity Matrix**: Risk is measured according to two main criteria: likelihood (or probability) and severity (or impact) [2].

- **The likelihood**: Expresses the possibility of the risk occurring, i.e. the potential for the accident to happen.

- **The severity**: In case of an accident, the severity measures the importance of the impacts happened in case of the occurrence of the risk.

Generally, the graphical representation of this measure is a matrix whose abscissa corresponds to the severity and ordinate to the likelihood, as shown in Figure (1)
4.2.2 Severity and likelihood rating scale

Severity rating scale [5]:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Minor</td>
<td>The risk has no significant impact on people, property or the environment.</td>
</tr>
<tr>
<td>2</td>
<td>Significant</td>
<td>GHG emissions</td>
</tr>
<tr>
<td>3</td>
<td>Important</td>
<td>Water and soil contamination</td>
</tr>
<tr>
<td>4</td>
<td>Major</td>
<td>Fire/explosion</td>
</tr>
</tbody>
</table>

Likelihood rating scale [6]:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Level</th>
<th>Probability of occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rare</td>
<td>occurrence &lt;1%</td>
</tr>
<tr>
<td>2</td>
<td>Occasional</td>
<td>1%&lt; occurrence &lt;5%</td>
</tr>
<tr>
<td>3</td>
<td>Likely</td>
<td>5%&lt; occurrence &lt;10%</td>
</tr>
<tr>
<td>4</td>
<td>Almost Certain</td>
<td>occurrence &gt;10%</td>
</tr>
</tbody>
</table>

4.2.3 Limit of acceptability

Zone 1: Acceptable or negligible risk
Zone 2: Significant risk
Zone 3: Intolerable risk

4.2.4 Effects analysis (Ishikawa diagram)
5 Results and discussion

5.1 Risk assessment

The analysis with the FMECA method allows us to evaluate the risks from the identification of potential hazards, and define their criticality and their limits of acceptability. The risk studied is located in zone 3 (major risk) which requires action plans to prevent it. To evaluate this risk, it is important to take into account the factors that can contribute to the occurrence of a hazardous material transportation accident. The table below shows the five important recommendations to reduce the effects of the risk in case of a hazardous material spill.

| 1- Identify the danger and get equipped [9] | 1. Identify the spilled product and its potential hazards  
2. Identify and equip yourself with the appropriate protective equipment  
3. Switch off all nearby equipment that could be the source of a fire |
|------------------------------------------------|---------------------------------------------------------------|
| 2- Stop or control the leak of hazardous material [10]. | 1. close or plug the source (if possible)  
2. Contain the spill with compatible absorbent pellets or pads to prevent it from entering the sewer system. |
| 3- Contain the hazardous material spill [9-10] | 1. choose a suitable sorbent according to the type of product spilled |
### Table 2. Recommendations to reduce risk

<table>
<thead>
<tr>
<th>No.</th>
<th>Recommendation</th>
</tr>
</thead>
</table>
| 1.  | Review the product's Material Safety Data Sheet (MSDS) prior to cleaning to ensure product and water compatibility.  
 2.  | Cleaning water should be treated like the spilled chemical: absorbed and disposed of according to its restrictions. |
| 4-  | Clean the area [9] |
| 5-  | PREPARE A SPILL REPORT [9-10] |
|     | The report must contain relevant information about the event:  
 1.  | Date and location of the spill  
 2.  | Description of the incident and description of the damage  
 3.  | Causes of the incident  
 4.  | Description of the damage |

### 5.2 Risk prevention

When managing a dangerous goods accident, it's important to establish key performance indicators (KPIs) to measure the effectiveness of the response and prevention efforts. Here are some examples of KPIs that can be applied:

- **Response time**: This KPI measures the time it takes to respond to the accident, including the time to report the accident, mobilize the response teams, establish a safety zone, and provide assistance to affected individuals.

- **Accident cost**: This KPI measures the direct and indirect costs associated with the accident, including cleanup costs, safety measure costs, material damage costs, and repair costs.

- **Compliance level**: This KPI measures the level of compliance with regulations and safety standards, including adherence to emergency procedures, training requirements, and emergency plans.

- **Number of injuries or fatalities**: This KPI measures the number of injuries or fatalities associated with the accident, as well as the number of people affected.

- **Recovery time**: This KPI measures the time it takes for the company to recover from the accident, including the time to restore normal operations, obtain regulatory clearances, and regain the trust of customers and stakeholders.

By using these KPIs to measure the effectiveness of managing a dangerous goods accident, the company can evaluate its performance and identify opportunities for continuous improvement.
improvement to prevent future accidents and minimize the impact on the environment, people, and property.

6 Conclusion

In conclusion, risk management of the transportation of dangerous goods is a critical aspect of public safety. The use of tools such as the FMECA and the Ishikawa diagram can help to establish two rating scales that allow to identify potential risks and to develop action plans to minimize or prevent incidents based on the detection of the severity of the risk studied. The FMECA makes it possible to evaluate the potential failures of the system and to identify the preventive measures necessary to avoid the risks. The Ishikawa diagram is a visual tool that helps identify the root causes of problems. By combining these two tools, companies can develop action plans to minimize the risks associated with the transportation of dangerous goods. Companies can also develop emergency management plans in the event of an incident.

References

2. « AMDEC : anticiper et évaluer les défaillances en 5 étapes ». Disponible: https://blog-gestion-de-projet.com/amdec/
3. « Site web Institut national de recherche et de sécurité pour la prévention des accidents du travail et des maladies professionnelles INRS » disponible : https://www.inrs.fr/
7. Safia Benmehdi. La contribution de management de la qualité dans la gestion des risques : application des outils de la qualité .p.119