The approach MADS/MOSAR to manage the triptych “technology/normative/management”

F. Muñoz, L. Perrin, J.P. Josien, O. Chery & M. Sardin

Laboratoire des Sciences du Génie Chimique
UPR 6811 - Groupe SISyPHe

CNRS - LSGC - INPL – ENSIC
BP 20451 1 rue Grandville F-54001 NANCY Cedex
I. Introduction

II. The MADS/MOSAR methodology
   I. The origin of MADS/MOSAR
   II. The MADS model
   III. The MOSAR methodology

III. Application in the miner underground sector
   I. Systemic Construction
   II. Dangers assessment
   III. Model of danger
   IV. Reduction of the variety & finding relations
   V. Scenarios & FTA (fault tree analysis)
   VI. Risk analysis
   VII. Definition of prevention-protection goals, location of barriers and their rating

IV. Summary
The Laboratoire des Sciences du Génie Chimique (LSGC), is property of the Centre National de la Recherche Scientifique (CNRS).

• Objective:
  The scientific design and complex systems control, through a conception of processes engineering.

• 7 Research groups
  • Industrial Security and Heterogeneous Particular Systems (SISyPHe)

The base methods...
- Reactions y reactors
- Separation
- Transportation phenomena
- Processes scale up and scale down
- Modeling
- Optimization, control y command
- Acquisition and data treatment
- Unitary operations

... the applications
- Materials
- Quality and security control
- Equipments design
- Optimization and control Software
- Environmental Protection
- Rational use of energy
- Granule solids and media
- Formulation
Introduction

- The context: Law & major industrial’s risk
- Keys words: technology, territory, hazard, risk assessment & management
The Complexity

Stakeholders Addressed in the Guiding Principles

**INDUSTRY**
Owners/shareholders, Managers, Labour
_including:_ enterprises of all sizes producing or otherwise handling or using hazardous substances

**PUBLIC AUTHORITIES**
_including:_
- National authorities
- Regional authorities
- Local authorities
_addressing, e.g._:
- Environment
- Public health/medical
- Civil protection
- Emergency response
- Occupational safety
- Industrial development

**PUBLIC**
including:
- Communities (near hazardous installations)
- Public potentially affected in case of accidents
- General public

**OTHER STAKEHOLDERS**
such as:
- Business organisations
- Labour organisations
- Community-based non-governmental organisations
- Academic/research institutions
- International organisations

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD), Guiding Principles for Chemical Accident Prevention, Preparedness and Response, 2003
The MADS/MOSAR methodology

Analysis Method of Dysfunctional Systems (MADS)

Organized and Systemically Method of Risk Analysis (MOSAR)
The origin of MADS/MOSAR

1970-1980
• A necessity to integrate the risk analysis in scale-up process.
• Formalization of the methodology by the educational structure
  – Atomic Energy Commission (CEA, France)
  – French's Schools of Mining Engineering
  – Technological University Institute (UIT Bordeaux, France)

1980-1990
• Technological University Institute (Bordeaux)
  – Reflection about the problematic of safety and the methodological relation with the pedagogy

1991
• Found the MADS group
  – Objective: Conceptualize a methodology of risk analysis, particularly in an European project COMMETT (Education and Training for Technology)
The MADS model

- **Principle**: One systemic approach (cybernetic origin) to unfolding complex systems and evaluate the potential damage in specific targets.

- **Objective**: Identify and modeling the mechanism of danger between Field of Danger-Source-Target

- **Structure**: Pictograms and fundamental conception in risk science (definitions: flux of danger, targets, sources, barriers, etc.)
The MOSAR methodology

- **Principle**: One systemic and systematic approach, to assess, evaluate, create hierarchies, negotiate, and manage the risk, from one described system in a complex context.

- **Objective**: To highlight the major scenario and to define the barriers of prevention and protection that we have, to set up, to neutralize, or to reduce the occurrence of the undesirable event.

- **Structure**: 2 modules (A & B)
  - **Module A.**
    - 3 listings (hazards, position of barriers and complementary analysis)
    - 3 tables (modeling, barriers identification and barriers position)

The methodology was made with a toolbox conception, and its application depends on each user context (goals, resources, finality, time, etc.)
MOSAR: structure

Module A
Macroscopic vision

Systems identification & modeling

Identify the sources of hazards → Identify the scenarios of hazards → Assess the scenarios of risks → Negotiate the objectives and ranking of the scenarios → Define the means of prevention and qualify the barriers

Negotiate the precise objectives of prevention → Polish the prevention means → Manage the risks

Module B
Microscopic vision

Identify the risks of functioning → Assess the risks
Axioms and Hypothesis

• Axioms
  – The MADS reference model allows the identification of unwanted events, in complex systems
  – An economic sector, inscribed within a national territory is a complex system
  – A risks analysis (MADS/MOSAR) allows the identification of a-priori legislative opportunities

• Hypothesis
  – The MADS/MOSAR methodology supports the scale up in the complex levels
  – A technological risks analysis by activity, permits the evaluation of a national normative system, generates recommendations for its evolution, and it is transferable to other sectors.
Application in the miner underground sector

- Capital: Bogotá
- Area: 1’138.914 Km² (26th)
- Population: 45’600.000 (est. 2005)
- Economy:
  - Colombia has the largest coal reserves in Latin America and it is the world’s fifth largest thermal coal exporter.
  - Colombia offers interesting investment opportunities in mining extracts, such as nickel, emeralds, iron and gold.
Systemic Construction

« le système est une entité constituée d’éléments humains, logiciels, organisationnel et matériels en interaction et combinés pour remplir une mission détermine et répondant à cinq critères de structure, fonction, finalité, environnement et évolution. (Lemoigne, 1990) »

The Key

– TYPOLOGIES
  Common base…
  • …to transfer!
  • …to compare!
  • …to evaluate!

– Typology of Economical Sector
  – ISIC Rev. 3: International Standard Classification of All Economic Activities
Systemic Construction

- Mega-system
  - Colombia
- Supra-system
  - Economical miner sector
- Systems
  - Process in the sector
    - Underground mine (UG)
    - Aboveground mine (AG)
    - Benefit plat (BF)
- Sub-systems
  - Available technology by activity
    - Breaking
    - Mucking
    - Haul
    - Annexed operations
    - Man
    - Environment
- Basic entities for analysis (ex. breaking)
  - Breaking:
    - Manual systems
    - Mechanical pick systems
    - Bossing systems (disks, chains, etc)
    - Haulages systems (rails, wheels, tracked, etc)
    - Drilling systems
    - Explosives
    - Others techniques

Complexity Unfolding
ex. Sub-system Breaking (UG)
Dangers assessment (I)

Basic entities for analysis (ex. breaking)

- Breaking:
  - Manual systems
  - Mechanical pick systems
  - Bossing systems (disks, chains, etc)
  - Haulages systems (rails, wheels, tracked, etc)
  - Drilling systems
  - Explosives
  - Others techniques

<table>
<thead>
<tr>
<th>Code</th>
<th>Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Mechanical</td>
</tr>
<tr>
<td>B</td>
<td>Chemical</td>
</tr>
<tr>
<td>C</td>
<td>Electrical</td>
</tr>
<tr>
<td>D</td>
<td>Fire &amp; explosion</td>
</tr>
<tr>
<td>E</td>
<td>Radiation</td>
</tr>
<tr>
<td>F</td>
<td>Biohazard</td>
</tr>
<tr>
<td>G</td>
<td>Men</td>
</tr>
<tr>
<td>H</td>
<td>Environment</td>
</tr>
<tr>
<td>I</td>
<td>Social &amp; economical</td>
</tr>
</tbody>
</table>

Crossing the basic entities with the typology of hazards (grid 1), we obtain the sources of danger in the MADS model.
Dangers assessment (II)

Process of danger

- We have the sources & their hazards
- We set the targets:
  - People
  - Infrastructure
  - Environment
- We can make the relation to find the danger flux to complete the models

Q) But, what is the tool to establish that?
A) The table A
# Model of danger (I)

**TABLE A**

Establishment of process of danger

SOUS-SYSTEME SOURCE

SSI: Underground working - Breaking

**Initial event:** event which characterizes the change of one system which passes from a state or normal situation towards a state or situation failing.

**Initiating event:** disturbing event which is at the origin of change of state or situation of one system.

**Main event:** event which expresses the matter flow, of energy and information emitted by a system in a failing state or situation.

<table>
<thead>
<tr>
<th>N°</th>
<th>SOURCE OF DANGER (grille 1)</th>
<th>Phase of Process</th>
<th>Initiatory event</th>
<th>Initial event</th>
<th>Main event (flow of danger)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>E</td>
<td>MNT</td>
<td>Post</td>
<td>Internal</td>
</tr>
<tr>
<td>1</td>
<td>By individual tools (spade - pickaxe and the power pick)</td>
<td>X</td>
<td></td>
<td></td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cutting them (coal cutters &quot;shortwall&quot;, &quot;longwall &quot;, towing)</td>
<td>X</td>
<td></td>
<td></td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Reduction of the variety & finding relations**

- We have the models of danger by entity
- We know the unfolding of entities by subsystems
- We can make the reduction of the variety using the *black-box* concept by subsystem (ex. Breaking –UG-)

### Models

**Mechanics**
- By interaction tool (spade – picker and the piece of pick)
- Tooling (tools alone – shaped)
- Tooling (towed – hoes)
- Tooling (tool ended – cut)
- Tooling (tool processed – cut)
- Tooling (tool processed – end)
- Tooling (tool processed – end)

**Chemical**
- Explosive
- Explosive

**Hydraulic**
- Fluid
- Fluid

**Electric**
- Electricity
- Electricity

**Psychic**
- Productiveness of the machine
- Performance of the machine

**Motion**
- Motion of the machine
- Motion of the machine

**Material**
- Material
- Material

**Environment**
- Environment
- Environment

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>Nanos – Spades&lt;br&gt;Spade – Picker&lt;br&gt;Tooling – Tooling&lt;br&gt;Tooling – Tooling&lt;br&gt;Tooling – Tooling&lt;br&gt;Tooling – Tooling</td>
</tr>
</tbody>
</table>
| Chemical  | Explosive
| Hydraulic | Fluid
| Electric  | Electricity |

**Dispersions**
- Dispersion of the fume and pollutant gases
- Dispersion of the fume and pollutant gases

**Exposure**
- Exposition to the radioactivity
- Exposition to the radioactivity

**Emissions**
- Emission of the substance
- Emission of the substance

**Impact**
- Impact of the load
- Impact of the load

**Specific characteristic**
- Specific characteristic of the material (ex: uranium)
- Specific characteristic of the material (ex: uranium)

**Dangers**
- Danger of fire and explosion
- Danger of fire and explosion

**Nego**
- Nego of objectives and hierarchy
- Nego of objectives and hierarchy

**Subsystems**
- Subsystems
- Subsystems

**Figure 4.** Black box S.S. breaking
Reduction of the variety & finding relations

• We have the main events by sub-system (auto destruction loops & open events)
• We know the sub-systems by system
• We can make the relations for the main events in tree analysis

Main events:
Explosion
Collapsing (total & partial)
Fire
Pulmonary disease etc…

…the undesirable events!!!
Scenarios & FTA (fault tree analysis)

...the events!!!
Risk analysis

- We choose the scenarios
- We use the return of experiences
  - Experts
  - Definition of risk acceptability line for Colombia
- We select and conform the group of experts
- We can make the scenario’s hierarchy & evaluate the risk

**Explosion**: Probable (1/10 year), severity (more than 1 death) “S1”

**Collapsing (post-operation)**: Probable (1/30 years), severity (national impact) “S2”

**Silicosis**: High Probability (between 10-2 y 10-3), severity (more than one death) “S3”

**Conservatory estimation**
Definition of prevention-protection goals, location of barriers and their rating.

- We know scenarios
- We know the flux of danger
- We know the risk
- We know the return of experiences
  - International mining strategies in normative barriers
  - Colombian normative barriers
  - Experts
- We can make suggestions in relation with the barriers (inclusion or elimination) & recalculate the risk to transfer to an acceptable area

<table>
<thead>
<tr>
<th>Impacts of the event</th>
<th>Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>People</td>
<td>Goods</td>
</tr>
<tr>
<td>+ 1 death</td>
<td>Total destruction</td>
</tr>
<tr>
<td>1 death</td>
<td>Damages with stop</td>
</tr>
<tr>
<td>Insulated serious wounds</td>
<td>Damage with partial stop</td>
</tr>
<tr>
<td>Light wounds</td>
<td>Minor damage</td>
</tr>
<tr>
<td>Not wounded</td>
<td>No damage</td>
</tr>
</tbody>
</table>

Barriers suggestions
- Development of an ATEX legislation
- Development of an integral plan of mining activities training
- Development of an integrated system of mining information
- Development of national programs in training and investigation of mining risk
- Construction of a general frame for post-exploitation systems
- Development of a silicosis prevention program
- Implementation of APELL for the mining sector (United Nations Environment Programme -UNEP-. 2001)
- Others
Summary

• We have seen in this study that the MADS model's simplicity allows risk analysis based on local knowledge. Such a model makes it possible to incorporate common concepts related to the danger mechanisms. That makes it possible to start the discussion and to create the outlines of a common language to facilitate regional risk evaluation coming from many sources.

• It is obvious that it is essential to integrate the local knowledge with miner expert knowledge (positive and negative feedback) to create a clear spectrum of the way the local exploration and global aspects are. Having the above-mentioned information, specific strategies can be created, according to the regional miner sector needs. But a prospective exercise for developing countries implies a parallel with the first world. This generates a framework and expert knowledge.

• Using systematic methodologies and their complex unfolding, facilitates identification of logical levels of analysis, and it defines the owner of the imposed barrier on a specific danger flow. The main factors implemented by local authorities for regional risk administration are usually based on prevention. Some of them can be derived from the European ATEX Directives; that makes it possible to have a combined reduction of the risks (barriers of prevention and protection). The products of analysis, such as FTA (Fault Trees Analysis) or risk valuation, create a framework to facilitate similar exercises in other regions. It is of course obvious that a framework construction will improve the miner economic sector, by defining some strategies to administrate residual risks.

• And we should never forget to check the barriers effectiveness; the obligatory stage is the training of the personnel. Not all accidents can be avoided but the risks can however be reduced if proper attention is given to the mining environment with the standards for construction, maintenance, inspection and security. The importance of the human factor in the mine security cannot be underestimated. This is essential to be aware of the dangers, aware of the risks and aware of the procedures for limiting damages when an accident does occur, in order to be sure that the barriers would be completely operational if necessary.
Merci

Felipe MUÑOZ

Laboratoire des Sciences du Génie Chimique
UPR 6811 - Groupe SISyPHe
CNRS - LSGC - INPL – ENSIC
BP 20451 1 rue Grandville F-54001 NANCY Cedex