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THE QUANTITATIVE AREA RISK ANALYSIS TO SUPPORT DECISION ON LPG DEPOTS AND LAND USE PLANNING

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Abstract: In Italy, for assessing LPG depots, a simplified method has been used for twelve years. The method is based on the classification of the plant according the MOND index. Standardized accidental scenarios are applied to have damage areas. Land vulnerability and compatibility are evaluated according a method inspired by the IAEA method for land use compatibility. In this paper it has been demonstrated credible, as their results are confirmed by using a higher level method, such as the well known method defined in the TNO purple book.

Keywords: Land use planning, LPG, Mond Index, Major Accident Hazard

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1. Introduction

The net of LPG distribution on the national territory is the second in Europe for number of sale points. Supply of LPG (combustion and traction) is guaranteed by the presence of many operators, firms (of great, medium and small size) and by the great capacity of the existing LPG depots in Italy. For these reasons today in Italy many single privacies, public corporate bodies and firms use LPG. The LPG storage activity is characterized by a high level of standardization. Indeed, the LPG depot design and management structure is quite simple, since it does not require process activities but it consists fundamentally of transferring the product between storage tanks, tanker trucks and bottles.

1.1 The LPG depots in the Italian legislation

Due to the proliferation of LPG depots in Italy and to their high standardization, they have been one of the first activities regulated by means of guide lines and technical rules, for their design, construction, installation and operative management. In the framework of COMAH legislation, for some twelve years a special regulation [7] has been enforced. It introduced an heuristic procedure for assessing the following issues:

- Hazard identification and evaluation.
- Accidental Scenarios, top event and consequences analysis
- Land Use Compatibility

For hazard identification a special version of the well known MOND fire, explosion and toxic index has been tailored for the specific needs of LPG industry. The categorization of the all units is used to classify the depot, in order to evaluate compatibility between the installation and its surrounding land. As thousands of LPG depots in the world have been operating for decades, the potential accidents are perfectly known. According the guide line in [7], basic assumptions for accidental scenarios may be derived from plant category and from stored quantity; consequently potential damage area

may be calculated. The area vulnerability (classified according to a schematic classification model) is matched with the plant safety classification in order to derive the plant compatibility.

1.2 Credibility of the heuristic evaluation method

Twelve years after the decree, its impact on Italian LPG industry is considered very positively. At the first times the method was widely used by regulators to support their decisions about existing and new LPG depots. In order to comply with this legislation, plant revamping or technical system improvement was prescribed to many depot holders. As a consequence of these decisions, a relevant economic effort was done by the whole Italian LPG industry; but now the most depots have got the first safety rating (or the second) and the general perception of this industry is positive. The inspiring idea of the decree was to have simplified of assessment methods, which exploited the high standardization of the LPG industry. Even though it was very successful in LPG industry, the idea was never transferred, in a complete way, to other industries. The simplified methods could benefit other industries than LPG, both in Italy and in other countries; a better understanding is essential for tailoring new versions, which could be popularized in other industry. Furthermore an improvement of compatibility assessment could be required according to a more precautionary approach. A deeper analysis, aiming to understand the credibility of heuristic methods is essential for proposing similar solutions in other industries and in other countries.

2. QRA concepts and methods

Regulators have to reconcile the conflicting objectives of keeping the economic competitiveness of the industrial area and to reduce risks for workers, people and environment. In order to get a shared decision among stakeholders, integrated studies, based on quantitative area risk analysis (QARA) method, are usually performed.

2.1 QARA basic concepts

The quantitative area risk analysis QARA was born in the atomic energy industry and since the late Seventies it had been applied to manage the industrial development of the largest chemical areas with a high number of installations in the framework of the legislation on the control of major

accident hazard (COMAH). Generally speaking, a QARA study is aimed to drive the approval of new installations and major changes of existing plants, the prescription of preventive measures for the establishment owners, the application of inspection programs by competent authorities, the land use and urban planning and the emergency planning. QARA methods are based on the superimposition, for each site, of the top events severity and likelihood on societal vulnerability. As the number of risk source may be huge simplifications are used to achieve believable results, without wasting too much resource.

2.2 The IAEA method

A widely used method for a fast QARA was developed by International Atomic Energy Agency [3]. Many countries, including Italy, have adapted this method, in the framework of the COMAH legislation, to drive decisions about emergency planning and land use planning.
The IAEA method applies to the risk due to major accidents with offsite consequences in fixed installation handling, storing and processing hazardous materials and in the transport of hazardous materials by road, rail and pipeline. The IAEA method uses matrix to combine frequency terms and consequence terms. The basic steps are the classification of the activities in the area, the inventory of handled hazardous materials, the classification of land type, from which population density is guessed, the estimation of accidents likelihood, based on known average probabilities, incorporating corrections for safety systems. The IAEA method, as well as of all derived methods, is very easy and fast to be implemented, and simple to be discussed with stakeholders, but it is often considered too precautionary. QARA methods are based on the superimposition, for each site, of the top events (severity and likelihood) on the societal vulnerability.

2.3 Customization of IAEA in Italian legislation

In the Italian legislation IAEA method has been successfully applied for emergency planning, for compatibility assessment and for land use planning. The focus of the paper is on compatibility assessment for LPG industry. The main improvements in the Italian implementation are:
1) Scenarios depend on the “safety level” as computed by index method. In IAEA method, for computing the effect distance and the impact area, the quantity of hazardous material, the type of substance and the type of activity are categorized; the very core of the method is a correspondence table,

which finds the category of effect distance, from the input categories (substance quantity, substance type, activity type). Instead in the method that has been tailored for LPG industry, as all potential accidents area perfectly known, according the experience of thousands depots, which have been working for many decades, the category of effect distance is the result of the consequence analysis related to a reference scenario, chosen among accidents with offsite consequences.
2) Edification rate is used instead of population density, traffic safety, frequency of loading/unloading operation considered in IAEA method. Number and size of hospital/schools may be accounted too. These data are much easier to found than the permanent/temporary population.

2.3 The TNO method

The TNO method is made basically by a chain of different models: models for assessing probabilities, models to calculate effects for certain chosen scenarios models to describe the damage of a certain effects [1]. Basically the societal risk is evaluated integrating the individual risk levels and the population density over a grid covering the full area, to obtain the expected value of the number of fatalities. The societal risk for a hazardous activity is defined as the probability that a group of more than N persons would get harmed due to an accident at the hazardous activity [2]. For the complete assessment of individual and group risks, the TNO Riskcurves© may be been adopted. It is a specialised software package, developed by TNO to perform a complete quantitative analysis of complex industrial areas. TNO Riskcurves© contains features and options such as individual and societal risk calculations, analyses of these risks, links to and from geographical information systems (GIS), risk contours, report generator etc. One of the most important features is, of course, the enhanced user interface, which allows to easily enter and modify scenarios an a map background. Based on the renowned TNO Green, Yellow, and Purple Books [4-6] TNO Riskcurves© provides a sound scientific basis to perform a quantitative risk analysis.

3 **The case study**

This paper presents the assessment of risks for a LPG depot. The Depot has got a three storage units with total capacity about 2500 cubic meters (1100 ton). It has also a bottle filling plant. The storage of the products is done in ten buried cylindrical tanks and in a spherical tank above ground. The

establishment area is about 5 hectares. The facility is in countryside and the nearest villages are two kilometres away; but twenty small sized factories and craft shops are present within six hundred meters. The artisan area is expanding, due to the incentive policy of the Municipality. The facility is operated by thirty workers, from Monday to Saturday, twelve hours a day.

3.1 Applying the heuristic method

As described in the first chapter, for the analysis of LPG depot compatibility, the Italian regulation indicates the criteria and the methodologies for the hazard identification and evaluation, the accidental scenarios analysis, and the land use compatibility. The first issue is fulfilled by applying the Index Method, appropriately tailored for LPG sector. Such a method is a complete evaluation of the entire LPG depot, to find out the risk level associated to it through a scrutiny of every unit and their equipment.

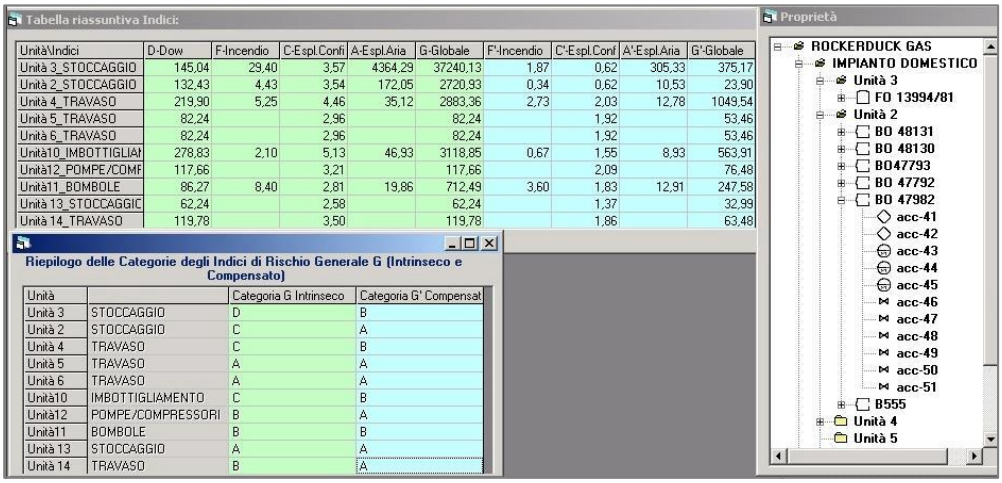

Fig. 1 – MOND index computation. In the up left table penalties are in the first five columns, credits in the last five ones. In the down left table the results are summarized according categories ranging from A to D

For calculating the Mond indexes, the plant has been divided in fourteen units. For each unit the risk index has been derived by using IRIS_GPL. It is a tool for supporting calculating Mond index method, according to Italian legislation [7]. It adopts a plant description organized in a hierarchical and detailed structure, so that the index method application is context sensitive. The Mond Index has been computed for each unit, taking into account

credits. The highest value is used for ranking the depot, according to the conversion table shown in figure 1.
The second issue is the accidental scenarios analysis, for pointing out the top events and their possible consequences. In the case study considered, about ten events have been evaluated, but only two of them have a damage area outside the depot. The table 1 shows the results of the analysis related to these two top events, LPG release from the sphere vessel and from piping, respectively. For each event, the accidental scenario, the frequency and distances are shown in table 1.

Table 1 – Table of top events with external impact

Top Event	Scenario	Freq.	Class	Distances (*m*)	
				Zone I	Zone II
Liquid LPG release sphere (2”)	FLASH FIRE	2.41E-6	D5	70	110
			F2	174	264
Liquid LPG release piping (2”)	FLASH FIRE	8.50E-6	D5	70	110
			F2	174	264

** Zone I higher impact area Zone II damage area. Zone III attention*

According to the Italian method the damage area has to be classified. The classification of the area range from A to F class. In A class the civil building density is 4.5 cubic meters per square meters (highly urbanized area). In E class the building density is less than 0.5 cubic meters per square meters (rural areas). F class is for areas inside the establishment. Comparing the depot classification, resulting from Index computation, with the damage areas impact on the territory, the compatibility may be found out. As the depot has been classified category II and damage area has been classified class E, the establishment has been evaluated compatible by the Competent Authority.

3.3 Applying the TNO method

The TNO method, implemented by the TNO Riskcurves© software is much more sophisticated than the IAEA method. It basically requires the population density to be accounted, considering both temporary (workers, students, etc.) and residential presences. In the damage area there are just a few of residents, but many workers area present in day hours, both at the depots and at the craft shops and small factories in the area. In fig. 2 the population density, is shown over the digital map of the area.

Figure 2 Workers population density around the plant, by TNO Riskcurves (c).

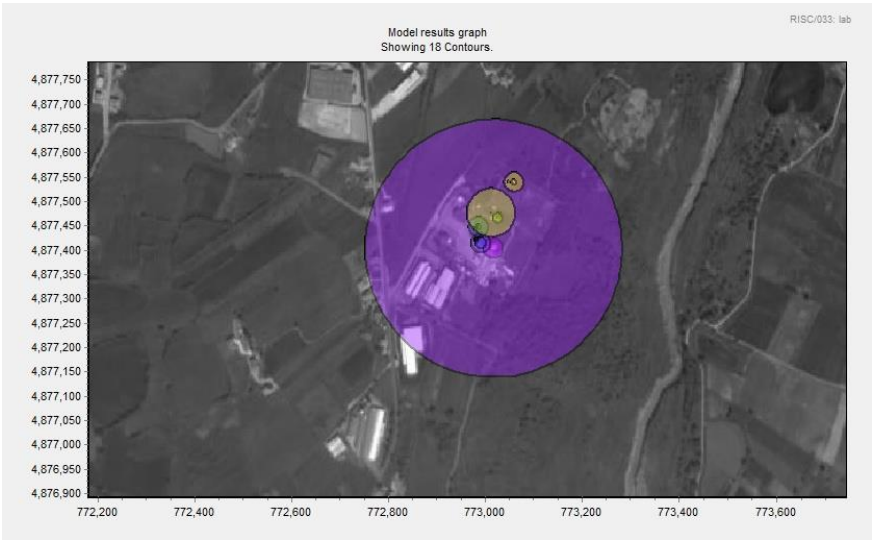

Figure 3 Damage areas of accidental scenarios.

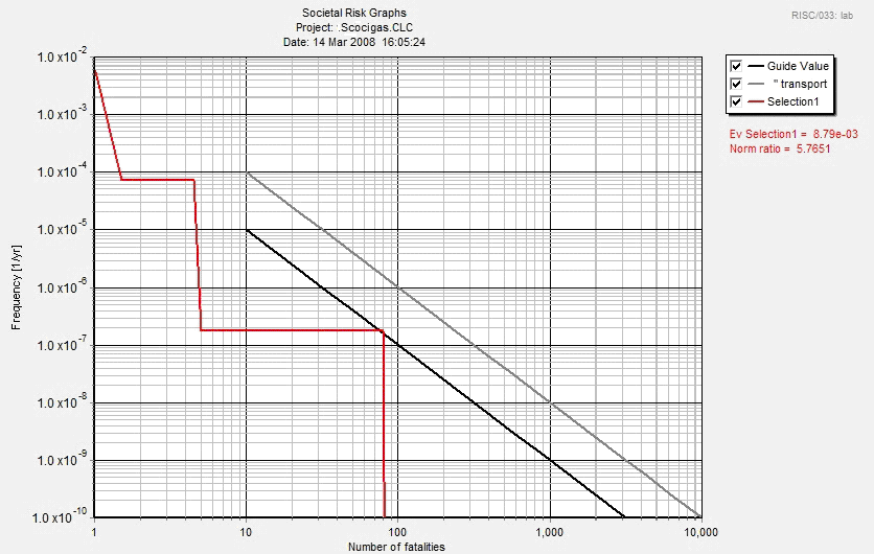

Figure 4 the FN curve

For the accidental scenarios, the shortcut of using the standard scenario according to the "heuristic method" has been adopted. Both internal and external scenarios have been considered, as the workers of the depots are the first victims. The damage areas are show in the figure 3. At the end the FN curve has been produced. The FN curve plots on a double logarithmic scale the cumulative frequency of events having N or more injuries. It is the best representation of societal risk. In a few countries, including the Netherlands and the United Kingdom, two reference FN curves are used as criteria for judging the tolerability of societal risk. The "reference curves" discriminate three regions in the FN space, the acceptability region, the tolerability if as low as reasonably practicable (ALARP) measures has been adopted and the unacceptability region. As shown in figure 4 the FN curve, as computed by TNO Riskcurves (c), is definitely in the acceptability area.

4. Conclusion

In this paper heuristic methods for Land use compatibility of LPG depots has been demonstrated credible, as confirmed by using a much more sophisticated methods and tools. Simplified method could be tailored for other industries and other countries. They could be very useful for Regulators for making transparent decisions about hazardous plant compatibility. Simplified method could be validated by highest method,

such as Riskcurves (c). Simplified methods are useful for assessing the compatibility of single plants. If complex areas have to be studied they could be less credible.

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