

**OKAN UNIVERSITY
INSTITUTE OF SOCIAL SCIENCE**

**HAZARDOUS GOODS RISK ANALYSIS
AND AN APPLICATION IN PACKAGED HAZARDOUS
CHEMICAL STORAGE IN TURKEY**

Sahavet ÇANCI

**THESIS
FOR THE DEGREE OF
PhD OF BUSINESS ADMINISTRATION
IN BUSINESS PROGRAM**

ADVISOR

Prof. Dr. H. Targan UNAL

ISTANBUL, April 2018

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Tezin Enstitüye Teslim Edildiği Tarih :

Tezin Savunulduğu Tarih :

Tez Danışmanı : Prof. Dr. Halit Targan Ünal, Okan Üniversitesi

Diğer Jüri Üyeleri : Assoct. Prof. Dr. Senay Oğuztimur, YTÜ
: Asst. Prof. Dr. Halim Yurdakul, Okan Üniversitesi
: Asst. Prof. Dr. Murat Bolelli, Okan Üniversitesi
: Assoc. Prof. Dr. Abdülkadir Tuna, İstanbul Üniversitesi

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Summary

HAZARDOUS GOODS RISK ANALYSIS AND AN APPLICATION IN PACKAGED HAZARDOUS CHEMICAL STORAGE IN TURKEY

Logistics activities can be divided into two main groups. The first of these; movement-related activities and others can be listed as activities related to inaction, stagnation. Movement related activity can be named as Transportation. If there is not an intensive movement, then the name of the activity is stated as Warehousing, although there are handling movements in a closed area.

Storage activities can be evaluated in two main groups as 'General Cargo warehousing' and 'Special Cargo warehousing'. Dangerous Goods warehousing is included in Special Cargo Warehousing.

Hazardous material warehouses are facilities that need careful evaluation due to their various risks. In this study, the risks that may occur in the hazardous substance storage are assessed.

The study is divided into seven sections. In the first part, a literature search has been done, risk assessment about the transportation and the storage of hazardous materials has been examined according to the basic terminology used.

In the second part, basic concepts are discussed. In the third part, the risk assessment tools are researched.

In the fourth and 5th chapter, the definition and types of hazardous substance warehouses and the responsibilities of them are evaluated in detail.

In the sixth chapter, the physical infrastructures of the hazardous material warehouses, facility settlement issues are mentioned. Section seven is the application section. In the application part, Interviews has been conducted to Managers, responsables of corporate dangerous goods warehouses in Turkey, risk criterias about hazardous goods storage created and has been identified with quantitative methodology AHP. At the same time, it

was emphasized what important details should be considered in the sub-criterias, by creating a check list.

At the end of the study, conclusions and suggestions were made. The findings obtained in this context were put forward and a general evaluation of the study was made.



ABBREVIATIONS

Aiche/CCPS	: American Institute Of Chemical Engineers—Center For Chemical Process Safety
ABC	: Analysis Selective Inventory Control
ADR	: The European Agreement Concerning The International Carriage Of Dangerous Goods By Road
AHP	: Analytic Hierarchy Process
ANSI	: American National Standards Institute
ALARA	: As Low As Reasonably Achievable
ALARP	: As Low As Reasonably Practicable
ATEX	: Atmosphere Explosive Directive
BBS	: Behaviour Based Security
BLEVE	: Boiling Liquid Expanding Vapor Explosion
BS	: British Standard
CAS	: Complex Adaptive System
CAD	: Chemical Substances Directive
CCPS	: Center For Chemical Process Safety
CFPA	: Confederation Of Fire Protection Agency
CHARM	: Chemical Hazard Risk Management-South Korea
CHIP>CLP	: Classification And Labelling Directive
COSHH	: Control Of Substances Hazard To Health
COMAH	: Control Of Major Accident Hazards Regulation
CMA	: Chemical Manufacturers Association
CMR	: Carcinogenic, Mutagenic, Reprotoxic
CPQRA	: Chemical Process Quantitative Risk Analysis
CSCHE	: Canadian Society For Chemical Engineering
DGSA	: Dangerous Goods Safety Advisor
DOE	: Department Of Energy
DOT	: U.S. Department Of Transportation
DSEAR	: Dangerous Substances And Explosive Atmospheres Regulations
ECTA	: European Chemical Distributors Association
ECOSOC	: Economic And Social Council UN
EDP	: Electronic Data Processing
EPA	: U.S. Environmental Protection Agency
ETA	: Event Tree Analysis
FECC	: European Chemical Distributors Association
FIFO	: First in First Out
FMEA	: Failure Modes And Effects Analysis

FMECA	: Failure Mode And Criticality Analysis
F-N	: Frequency-Number
FTA	: Fault Tree Analysis
FSA	: Formal Safety Assessment
GNP	: Gross National Product
GIS	: Geographic Information System
HAC	: Hazardous Area Classification
HAZMAT	: Hazardous Material
HAZOP	: Hazard And Operability Analysis
HMI	: Hazardous Material Incident
HMIR	: Hazardous Materials Incident Reports
HMIS	: Hazardous Materials Information System
HRA	: Human Reliability Analysis
HSC	: Health And Safety Commission (U.K.)
HSE	: Health & Safety Executive (U.K.)
HSEES	: Hazardous Substances Emergency Events Surveillance
IBC	: Intermediate Bulk Container
IMO	: International Maritime Organization
INFOR	: Industry Specific Business Specific Applications
IMDG	: International Maritime Dangerous Goods
IMO	: International Maritime Organization
IPPC	: Integrated Pollution Prevention And Control
IRR:	Institute For Risk Research
ISBN	: International Standard Book Number
ISO	: International Standards Organization
LFL	:: Lower Flammable Limit
LNG	: Liquefied Natural Gas
LPG	: Liquefied Petroleum Gas
LC	: Lethal Concentration
LCL	: Lower Confidence Limit
LD	: Lethal Dose
LFL	: Lower Flammable Limit
LNG	: Liquefied Natural Gas
LPG	: Liquefied Petroleum Gas
LQ	: Limited Quantity
MAPP	: Major Accident Prevention Policy
MIE	: Minimum Ignition Energy
MSDS	: Material Safety Data Sheet
MHIDAS	: Major Hazard Incident Data Service Database
NASA	: National Aeronautics And Space Administration

NFPA	: National Fire Protection Association
NRC	: Nuclear Regulatory Commission
OSHA	: Occupational Safety And Health Administration
OR/MS	: Operations Research Management Science
PG	: Package Group
PHA	: Process Hazard Analysis
PHA	: Preliminary Hazard Analysis
PPE	: Personal Protective Equipment
PRA	: Probabilistic Risk Assessment
PSM	: Process Safety Management
PS	: Picosiemens
QRA	: Quantitative Risk Assessment
QFD	: Quality Function Deployment
REACH	: Registration, Evaluation, Authorisation, Restriction Of Chemicals
SADT	: Self Accelerating Decomposition Temperature
SDS	: Safety Data Sheet
SQAS	: Safety And Quality Assessment Systems
TRA	: Task Risk Assessment
TNT	: Trinitrotoluene
TOR	: Tolerability Of Risk
TOXFIRE	: Guidelines For Management Of Fires In Chemical Warehouses
UN	: United Nations
VCE	: Vapor Cloud Explosion
VROM	: Ministry Of Housing, Spatial Planning, And The Environment, Netherlands
WMS	: Warehouse Management System
3 PL	: 3rd Party Logistics

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INTRODUCTION

SCOPE AND CONSTRAINTS OF THE WORK

The risks in dangerous goods logistics, covers a very large area, such as transportation, forwarding, storage, Because of the wide scope of the subject, the study has been narrowed and it has been limited with the risks in the hazardous materials storage.

Hypothesis of The Thesis

Within the scope of this study, five different variables related to risk analysis in hazardous material warehouses have been established. Previous studies, documents, regulations has been taken into consideration when creating variables and Infrastructure, Management, Material, Human factor and environment were determined as variables.

Expert interviews were conducted to review the variables and it was seen that these variables overlapped with the variables previously mentioned in the literature.

In this framework, the above-mentioned variables are basically taken into account in the hypothesis of the thesis. Two hypotheses have been formed in this context. These hypotheses are given below.

H1: When the risk factor in a warehouse is evaluated, the infrastructure is more important than Management.

H2: When the risk factor in a warehouse is evaluated, the Management is more important than Material.

We have identified only these two most important variables as hypotheses. For other variables only the significance rankings were evaluated.

While there is no database in our country where the warehouse numbers are kept, it is stated during the Istanbul Large Scale Plan studies, that this number is 10750 (2009). This number contain all small and large and all type of warehouses, which is declared to the provincial directorates as warehouse during the licence registration. So they are legally permitted general purpose commercial warehouses and they are the warehouses only in İstanbul.

It is important to specify the warehouse numbers in terms of putting the size of the universe (application area) in the hypothesis. But; It is known that the storage of hazardous

materials is in a much wider range, such as all hospitals, petrol stations, hotels, waste disposal facilities, which use, store hazardous materials. But those are not included in our study. The universe of the hypothesis is the storage facilities which stores chemical substances. And our study is limited with the warehouses , which stores certain amount of hazardous materials in certain square meters and works with certain international regulations.

Although the number of warehouse facilities working in compliance with ADR regulations and other related legislation is not known precisely, it can be said that it is about 20% of general warehouses. In our country, it is seen that a very large part of the warehouses are unregistered and not in international norms. Those that are registered and able to comply with international norms seem to be limited and constitute a very small part of the dangerous warehouse universe.

Hypotheses were tested according to the AHP methodology in the application part of the study, and the results obtained are explained in the application and also in the evaluation part.

Limitations of The Thesis Topic

In our country, there are thousands of warehouses, where different sizes and different materials are stored. Within this research, we have taken the warehouses, which are in compliance with international standards, and also due to their large scale, the hazardous substance warehouses have been restricted in the scope of the study.

The majority of corporate warehouses are general purpose warehouses that provide 3rd party logistics service to provider companies. The customers served by these warehouses are mostly corporate clients serving the producers.

One reason for the limitation of work in this way is that in general there is not enough data available about the warehouses. The corporate warehouses were chosen as the sample because of the relatively easy availability of data and the availability of qualified expert opinions.

Subjective Conditions Of Corporate Warehouses

It is seen that the corporate warehouses are concentrated in the Marmara Region which is intensified due to the industry. In this study, hazardous substance warehouses in the Marmara region, mainly in Istanbul and the border area of Istanbul, industrialised district, named Dilovası, Çayırova were covered. Because this district is the condensed area with the warehouses and the center of whole Turkey in terms of warehousing can be described as Istanbul and this immediate surroundings of Istanbul.



Table 1: Prominent Corporate Warehouses in Turkey

Name	Location	Type of Warehouse		Type of material stored
		Custom Bounded Warehouse	Free Warehouse	
DB Schenker Arkas	Gebze	+	+	G. Cargo
	Halkalı	+	+	"
Hermes	Gebze	+		G. Cargo/Hazardous
	Halkalı	+		G. Cargo/Hazardous
DHL	Gebze	+	+	G. Cargo
IFF Aroma Esans	Gebze	+	+	Hazardous
Ekol Lojistik	Samandıra	+	+	G. Cargo
	Sancaktepe	+	+	"
	Çayırova	+	+	"
	Tuzla	+	+	"
	Sultanbeyli	+	+	"
	Arnavutköy	+	+	"
TCDD	Haydarpaşa	+		G. Cargo/Hazardous
	Halkalı	+		G. Cargo/Hazardous
Turker	Gebze	+	+	G. Cargo
Lider	Gebze	+	+	"
Cobin Logistics	Gebze	+	+	G. Cargo/Hazardous
Aışan Logistics	Gebze	+	+	G. Cargo/Hazardous
	Dilovası	+	+	G. Cargo/Hazardous
	Tuzla		+	G. Cargo/Hazardous
Ayaz Logistics	Tuzla		+	G. Cargo
Elmas Logistics	Tuzla		+	"
Bilin Logistics	Tuzla		+	"
EMS	Halkalı	+	+	"
Ulustrans	Halkalı	+		"
Sağlık Logistics	Halkalı	+	+	"
	Gebze	+	+	

Name	Location	Type of Warehouse		Type of material stored
		Custom Bounded Warehouse	Free Warehouse	
Omsan	Tuzla	+	+	G. Cargo
	Çayırova		+	G. Cargo
	Orhanlı		+	G. Cargo
Park Antrepo	Halkalı	+		"
Solmaz	Ambarlı	+	+	Hazardous
Solmaz	Gebze	+	+	Hazardous
Gokbora	Ambarlı	+	+	General Cargo
Reysaş Logistics*	Orhanlı		+	General Cargo
	Hadımköy		+	General Cargo
	Sancaktepe		+	General Cargo
	Çayırova	+	+	General Cargo
İhlas	Ambarlı	+	+	"
Horoz	Ambarlı	+	+	"
Hisar	Ambarlı	+		"
Netlog Logistics	Ambarlı		+	"
Mars Logistics	Tuzla	+	+	G. Cargo
Akzo Nobel	Gebze	+	+	G. Cargo/Hazardous
Barsan Logistics	Halkalı	+	+	G. Cargo
	Hadımköy	+	+	"
	Çerkezköy	+	+	"
	Samandıra	+	+	"
Gökbil**	Dilovası		+	Hazardous
				Hazardous
TGL TET Global logistic***	Dilovası			
*Intermodal, green logistics, LPG,LNG tanker transport	**Product transfer,IBC tanker,drum filling	***IBC,Tanker cleaning		

RESEARCH METHODOLOGY

Analytic Hierarchy Process can be defined as a quantitative method for ordering and selecting decision alternatives according to multiple criteria. In other words, Analytic Hierarchy Process; is the process of developing numerical values to rank each decision alternative according to the degree of catching the criteria of the decision maker. Analytic Hierarchy Process; the decision maker is to choose the best alternatives within all the criteria.

What are the risk factors that may arise in warehouse and AHP methodology has been adopted as the most appropriate method for this research because of the ease with which it has been determined how effective it is on the risks in these warehouses.

Some of the reason of selection of this method can be listed as follows.

- There are a number of risk factors in the hazardous substance storage. These risk factors can be compared in more than one risk, AHP facilitates the viewing of areas where risks are most intense.

- Some of the risks in the warehouse may not be quantified. In particular, the human factor is a critical factor in determining the risks in storage.

- Another consideration in the storage of hazardous materials is 'Warehouse Management'. This factor, like the human factor, allows for the creation of a database that can not be expressed numerically but can be sorted in relative order. The AHP has been one of the reasons to prefer qualitative criteria.

- The difficulties in finding concrete data have made it quite suitable for the relative evaluation. Experts have been able to compare the risks within the warehouse with each other.

- In order to carry out the AHP application, connections established with 13 different corporate warehouses and opinions has been received from around 50 specialists. These experts have been selected among employees who are in a key position in the hazardous materials warehouses. At the end of the implementation study, a consistency test was also conducted that allows experts to determine whether bias or not.

- This thesis consists of seven main parts. In the first section entitled 'Literature Review' after the introduction section. The scientific studies about this topic have been reviewed up to now and tried to learn this issue has been evaluated in depth.

- In the second chapter, basic concepts related to the storage of hazardous materials are given.

- The third section, named 'Risk Assessment Tools', is the section that holds the theoretical framework of the thesis. Risk assessment tools in general are; Preliminary hazard analysis (PHA), Failure mode and effect analysis (FMEA), Failure Mode, Effects and Criticality Analysis (FMECA), Event Tree Analyses, Fault Tree Analysis (FTA), Human Reliability Analysis (HRA), Probabilistic Risk Assessment (PRA). In addition to these tools, the AHP method has also been evaluated. By the way, the dynamics of the

storage of hazardous materials have also been emphasized and efforts have been made to establish a point of view for the thesis topic.

- The fourth chapter is called 'Dangerous Goods Material Warehouses' and responsibilities and Parties In Dangerous Goods Logistics Warehouses' These type of warehouses are being analyzed. The work processes of the hazardous substance storage are examined in detail and the flows between the processes are shown. Besides, general safety measures in the warehouse are explained for each responsible parties.

- in the fifth chapter 'Infrastructure, Layout and Risk in Dangerous Goods Warehouses' has been evaluated.

- Chapter six is about "Research Methodology: Analytical Hierarchy Process". This is the section where the method of research is presented. In the section on which the conceptual framework of the research is presented, the AHS method and steps used are extensively explained.

- The 7th and final chapter is titled Result and evaluation or "Conclusions and Recommendations". The first part of this section has been put forward concerning developments in hazardous goods storage results in Turkey, and proposals have been developed for them. At the end of this thesis, AHP application forms and other documents are presented in appendices in order to be more useful to the examinees and those who want to do similar research.

THE IMPORTANCE AND PURPOSE OF THE THESIS

Logistics activities in Turkey corresponds to 10% of the GNP, and provides input for many industries. It creates a derivative in every aspect of the economy. It does not play only a part in production, but in all supply phases, from raw material to final consuming point, in all supply phases. Storage is one of the two most important areas of logistics activities, as well as the warehouses of the industrialists and, in many cases, of the 3PL companies warehouses themselves, serve the inland economy. Hazardous substance storage is prevalent as a business that should be given much more importance because of its high risk group in terms of health and environmental risks.

Due to the dangerous substances in various classes, the storage of such goods becomes a difficult subject to be given due to the interaction of each of these classes. A very

important part of the risks that may arise in the storage of hazardous materials is that the storage needs of the standards have not been met adequately.

Each of the hazardous material warehouses in our country is set up for different purposes. The scope and volumes are also of various types. When the hazardous material is measured in scale, there are warehouses of various sizes ranging from large scale producer warehouses to retail warehouses. When evaluated according to the stored materials, materials such as flammable, toxic, abrasive and others belonging to 9 ADR classes can be stored. But in our research, explosives and radioactive materials are out of scope.

When each of these is stored separately, while the hazards and risks are more easily controllable, it is necessary to know some constraints on the storage of materials in different hazard classes. In this case, the control of the risks and risks may become more complex.

Another aspect of the storage of hazardous materials is the lack of a detailed inventory of hazardous materials in our country. The current inventory is limited to the registered work permits only for hazardous materials stored by local authorities.

It seems that a data base system has not been established in which the amount of materials, hazard classes, and current data on chemical reactions in the warehouses can be kept. This leads to major deficiencies in the management of hazards and risks.

The main purpose of this study is to demonstrate what risks may arise in the storage of hazardous materials, to ensure that hazardous materials are stored correctly and to reduce their risks as much as possible.

Another objective with this thesis is to show, what the risks associated with hazardous substances could occur, , it is aimed to scale the risks associated with the hazardous substances through risk assessment tools methodologically.

In our country, the agenda about the hazardous substances is a subject of last 10 years. For the first time the legal frameworks about this matter has been drawn with the ADR convention and Turkey has become a party. But this convention could not be applied to Turkish regulations because of the lack of the physical Infrastructure and legal arrangements and qualified personnel.

Application possibility emerged since 2011 and it became operational in only some areas related to hazardous materials. As it can be seen, this subject has got a critical importance in terms of our country's logistics and its qualification.

Scope of Literature Review

In literature review, primarily the historical development of studies on the subject of hazardous transport has been explained.

The attention to hazardous materials transportation (HAZMAT) research dates back 1980's, mainly due to rising safety concerns in developed countries. (R. Scanlon, E. Cantilli, 1985) and others.

Sustainability is a systemic concept, which related to the continuity of economic, social, institutional and environmental aspects of human society.(G. Atkinson, 2000). And others

Due to the populations living along HAZMAT routes are exposed to transportation risks this situation uncovered the public sensitivity about their rights protection (equity) R. Keeney, L. Winkler, 1985- M.Marsh, D. Schilling, 1994- J. Current, S. Ratick, 1995) and others.

The possibility of accidents required the development of integrated safety management systems to implement mitigation activities, which seek the reduction of the vulnerability, and prevention activities, which try to reduce the hazard (A. Lavell, 2000) and others

Disaster risk management into actions required in the pre-disaster phase and actions needed in the post-disaster period (C.M. Lewis, K.C. Murdock, 1999) and others.

Qualitative risk assessment regards the identification of possible accident scenarios and attempts to estimate the undesirable consequences, (R. Gregory, S. Lichtenstein, 1994) and others.

Quantitative Risk Assessment (QRA) tries to assess the risk in terms of the value of some indicators to be used to actively manage risk, to identify and prioritize technology needs and decision making and, finally, to evaluate regulatory alternatives. (S. Kaplan., J.

Garrick., 1991. B. Bottelberghs., 2000.) Acc.to Erkut (2007), quantitative data can be measured.

(D. Harwood., E. Russell., J. Viner, 1989) define risk on the basis of **historical data**, that's, as:

$$\text{Risks} = \text{Events} / \text{Exposure}$$

QRA involves the following key steps:

- Hazard and exposed receptor identification;
- Frequency analysis; and
- Consequence modeling.

Frequency analysis According to Ang; (A. Ang., J. Briscoe., 1989), the **frequency analysis** involves:

- Determining the probability of an undesirable event;
- Determining the level of potential receptor exposure, given the nature of the event;

Estimating the degree of severity, given the level of exposure.

Each stage of this assessment requires the calculation of a probability distribution. As an example (E. Erkut, V. Verter, 1998), for each unit road segment, determine the joint probability of type of accident, release, incident, and consequence

(P. Leonelli., S. Bonvicini., G. Spadoni, 2000) propose a model that requires the following *high level variables* to assess the **individual risk**:

- Frequency of release,
- Probability of final outcome given a release,
- Wind probability, and
- Vulnerability.

By assuming that each individual in the affected population will incur the same risk P. Slovic., S. Lichtenstein., B. Fischhoff., 1984.; F. Saccomanno., J. Shortreed, 1993) as **societal risk**.

An alternative way to describe the societal risk is the use of the so-called *FN curves*; (J.K. Vrijling, W. van Hengel, R.J. Houben, 1995. - S. Jonkman, P. van Gelder, J. Vrijling,

2003), where F is the cumulative frequency of an accident with N or more either fatalities or evacuated people.,

More than one type of accident, release, incident, and consequence can occur during the HAZMAT transport activity. For example, a release of flammable liquid can lead to a variety of incidents such as a spill, a fire, or an explosion. To accommodate this,(E. Erkut., S. Tjandra., V. Verter, 2007) suggest assessing the risk as **c-type consequence**./ as the **technical risk** (E. Erkut., V. Verter, 1998).

HAZMAT vehicles could be desirable targets for terrorists, and certain HAZMAT vehicles were designated as weapons of mass destruction, see (M. Abkowitz, 2002.) (B. Huang., R. Cheu., 2004.) for incorporation of **security concerns** in route planning.

In general ,the HAZMAT transportation problems on highways received the most attention from the operations researchers. In contrast, HAZMAT transportation via air or pipeline, as well as intermodal HAZMAT transportation has received almost no attention. Intermodal transportation is on the other hand, has got an increasing attention in the last years.

OR/MS models in HAZMAT literature are used mainly in four basic topics such as: Routing/Combined facility location and routing/Risk assessment/Network design.

As Risk assessment; two basic modelling is applied;

- Deriving probability
- Consequence modelling

Deriving probability is applied for Moving hazmat/Fixed hazmat/Both

Consequence modelling is applied for Measuring impact area/Estimating accident consequences

Fixed HAZMAT

(Chow,et al.1990)develop a Bayesian model to predict small and large nuclear accident risk. (Kwan., Miller 2002) use data mapping.

Both

Logical based techniques such as Fault Tree analysis (FTA) and event tree analysis can be used to derive both P_{ij} and NH_i . (Picard., Williams., 2013) present a computer model to estimate rare events.

Measuring The Impact Area

(Akgün et.al 2007) present a model that accounts for weather effects on Hazmat release risks, such as consequence area.

Estimating Accident Consequences

Risk costs are a function of population, property and / or environmental assets within the measured impact area. OR/MS hazmat models often measure consequence costs in dollars (Abkowitz., Cheng, 1988; Abkowitz et.al 2001) including deaths and injuries.

CHAPTER 1

1. LITERATURE REVIEW

1.1 HISTORY OF HAZMAT ARTICLES, RESEARCH

In 1980's, a lot of Hazardous materials (HAZMAT) transportation research has been done. Because, at that time there was a growing sense of vulnerability issue in developed countries. (R. Scanlon., E. Cantilli, 1985) In the 1970s, the american security council reconciled the need for the development of rules for the transport of dangerous goods and the need for a risk-based approach. (Ang et.al 1989) proposed a general framework describing the problem in 3 stages for risk analysis:

- Verify the likelihood of a harmful event (an accident involving the release of hazmat)
- Determine the potential exposure level when considering the nature of the event
- Predict the severity of outcomes. (fatalities, injuries and damages of the environment, property etc) given the level of exposure.

At each stage of the process can be referred to by one or more probability distributions and two of them generates conditional distributions. Practically, the process is rarely applied completely from start to finish (List et.al 1991)

For some time this opinion seemed to have lost its significance. However, due to the difficulty of reaching the right and relevant data, it has gained importance again in recent periods. (V. Akgün., A. Parekh., R. Batta., C. Rump 2007; K. Zografos., K. Androutsopoulos., 2004) This renewed interest is also owed to two factors :sustainability and equity., According to World Commission on Environment and Development; “Sustainability is a systemic concept, which relates to the continuity of economic, social, institutional and environmental aspects of human society.” (G. Atkinson., 2000) “Therefore, sustainability can be named as the long-term compatibility between the economic and the environmental and the social dimensions of development.”

The population living in the dangerous substance route is exposed to transportation risks. They are those, who live near manufacturing facilities and or distribution areas and around the transportation routes. This situation has brought public sensitivity, the rights protection struggle of related people. This movement was started to be mentioned -equity- (R. Keeney., L. Winkler., 1985;;M.Marsh., D. Schilling., 1994, J. Current., S. Ratick, 1995)

A good example of environmental, equity-based public opposition is nuclear fuel deliveries. (W. Vesely., E. Goldberg., N. Roberts., D. Haasl., 1981); (S. Chin., P. Cheng., 1989); (T. Chow., R.M. Oliver., G.A. Vignaux, 1990) (T. Glickman., D. Golding, 1991) (S. Miaou., S. Chin, 1991) (G.M.Sandquist., J.S. Bennion., J.E. Moore., D.M. Slaughter, 1993) (J. Ferrada., R. Michelhaugh, 1994); (J. Moore., G. Sandquist., D. Slaughter, 1995) (H. Neill., R. Neill, 2000) “The hazardous materials transportation requires a risk management process that involves set of crucial logistic decisions such as the organization of the emergency response operations. The logistical decisions on the routing of HAZMAT vehicles and the emergency response must be integrated” . (K.G. Zografos., G.M. Vasilakis., I.M. Giannouli, 2000)

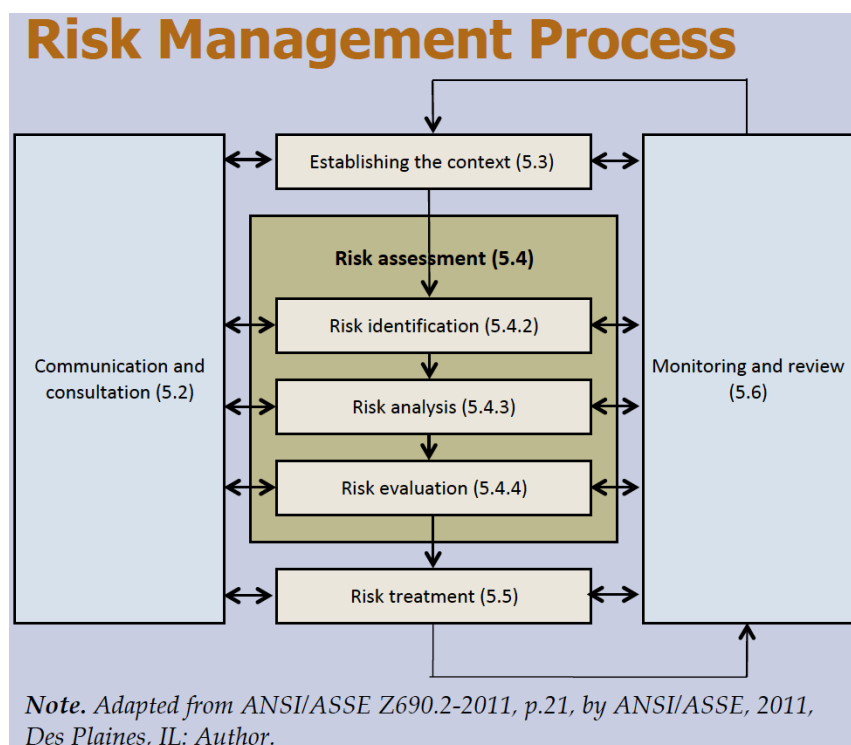
Quantitative determination of the risk ratio during the transport of a dangerous substance is difficult due to the low likelihood of accident of dangerous substances. “Yet, as the consequences of an accident involving hazardous materials can be enormous, the possibility of accidents requires the development of integrated safety management systems to implement mitigation activities, which seek the reduction of the vulnerability, and prevention activities, which try to reduce the hazard”. (A. Lavell, 2000].

Risk management jobs hypotetically can lead to a unique and defined risk and manage it ideally. In the meantime , some occurences activate others. (N.A. Pons., O.J. Pejon., L.V. Zuquette, 2007)say “Urban degradation caused, e.g., by unplanned urban growth, bad construction practices, or immigration of people from the rural areas, tends to disturb the balance in the urban system, influences the interaction process between different hazards and vulnerabilities increasing vulnerability levels, and then creates new hazards factors”.

1.2 RISK ASSESSMENT OF HAZMAT

Risk assessment is an important and sophisticated process used to assess an organization's, Institutions and/or transportation risks so that it can mitigate and reduce risks to an acceptable level. Risk assessment is included in risk management.

Table 2: Risk Management Process



According to ANSI/ASSE Z690.1-2011; “Vocabulary for Risk Management, risk assessment has three distinct components. “

- “Risk identification, which involves finding, recognizing and recording hazards”
- “Risk analysis, which entails understanding consequences, probabilities and existing controls”
- “Risk evaluation, which encompasses comparing levels of risk and considering additional controls. Risk management is a process of Establishing the context, Risk assessment, Risk treatment and and in each phase, monitoring, review, consultation and communication of eachother. This is mainly prepared and valid for the Institutions.”

When a complete disaster Risk Management is concerned;

According to (C.M.Lewis., K.C.Murdock, 1999);

“The key elements of risk management are divided into two phases”:

“the pre-disaster phase and the post-disaster phase.”

“The predisaster phase includes”;

“Risk identification, risk mitigation, risk transfer, and preparedness”;

“The post-disaster phase presents: emergency response and rehabilitation and reconstruction.”

“Table 2 shows the key components of disaster risk management, dividing into actions required in the pre-disaster phase and actions needed in the post-disaster period” (C.M. Lewis, K.C. Murdock, 1999) . A wide ranging risk management program should be a well-planned network of intercommunication between the cross sector organizations that addresses all risk identification, mitigation and disaster recovery process phases. Tasks , that needs an assistance can be listed as follows.

- Guidelines and plan processing,
 - Improving the valid regulative structure,
 - Activating the collaboration techniques,
 - Empowerment of joining establishments.
 - Domestic operation scheme for reduction programme and organizational progress.

Risk assessments are a necessary part of the process of consolidated natural disaster programs with overall progress intentions. Risk assessment allows policymakers to specifically define the objectives of the risk management programs and to establish vulnerability mitigation targets. Risk assessment helps legislators identify targets for risk management programs in particular, and demonstrate the goals of reducing vulnerabilities.

According to (C.J. van Leeuwen.,T.G. Vermeire,2007), (Risk Assessment of Chemicals), “Risk assessment is a central theme in the control of chemicals. Despite the role of risk assessment as the scientific foundation for many national and international regulatory guidelines, the phrase Risk assessment means different things to different people and is often surrounded by misunderstandings and controversy. Some points of controversy involve the interpretation of scientific studies. Others have to do with science

policy issues. Still others centre on definitions and on the distinctions between risk assessment and risk management.”

Some important definitions can be given as follows.

1.3 DEFINITIONS OF TERMS COMMONLY USED IN THE FIELD OF RISK ASSESSMENT AND MANAGEMENT FOR CHEMICALS.

Hazard is the natural capacity at which adverse effects are observed when a chemical or mixture is exposed by a humanbeing or environment.

Risk is the likelihood of adverse effects that may occur as a result of exposure to a chemical or a mixture of people or the environment.

Risk assessment is a series of actions which covers risk identification, impact assessment, determination of exposure and risk estimation. Only one, several, or all of the specified actions may be included in this evaluation process.

Hazard identification is the determination of the danger, the determination of the adverse effect caused by the natural capacity of a substance, or the assessment of a certain effect in certain situations.

Effects assessment, or a more accurate definition of dose-response assessment, is a measure of the substance's level of exposure and the severity of the effect.

Exposure assessment The effect of exposure is to determine the rates of movement, the transformation and the degradation of emissions of a substance in order to estimate concentrations-doses that can be exposed to populations or the environment.

Risk characterization is a judgement of the frequency and severity of adverse events possibly to occur in a human population or environment due to actual or estimated exposure of a substance and may include risk estimation or quantification of this role.

Risk management is a controlling and directing and managing process that requires risk-based political, social, economic and engineering knowledge to be weighed in order to select the appropriate regulatory intervention against potential health or environmental hazards in order to develop, analyze and compare regulatory options.

Risk reduction is to guard against the risks specified, take precautions to protect the person or the environment .

Safety can be described as the strong likelihood that under certain circumstances a substance will not cause adverse effects, depending on the amount and manner of use. (C.J. van Leeuwen., T.G. Vermeire 2007)

In the case of dangerous goods transportation, the risk is mainly addressed in two ways:

- Likelihood of a status in a happening.
- The results of this happening status.

Risk assessment, in a broad sense, involves a structured procedure , that evaluates qualitatively or quantitatively the level of risk that is imposed by a hazardous facility.

According to Alp (E. Alp., M. Zelensky, 1996), “risk is a measure of the probability and severity of harm to an exposed receptor due to potential undesired events involving a HAZMAT whereas the exposed receptor can be a person, the environment, or properties in the vicinity”. The undesired events are the accidents that could lead to a release of a HAZMAT.

Risk assessment can be qualitative or quantitative. Acc.to (Erkut, 2007) there are two methods to assess the risk. Qualitative and quantitative.

“Qualitative risk assessment regards the identification of possible accident scenarios and attempts to estimate the undesirable consequences”. (R. Gregory., S. Lichtenstein., 1994).

Acc.to Erkut,(2007) qualitative descriptions of risks are used to create data.

Quantitative Risk Assessment (QRA) With the help of some indicators, QRA tries to determine technological needs, to prioritize legal alternatives and to make decisions in the end, and thus manage actively the risk.(S. Kaplan., J. Garrick., 1991. B. Bottelberghs, 2000.) According to (Erkut 2007), quantitative data can be measured.

Table 3: Key Elements of Risk Management¹

Pre – disaster phase				Post –disaster phase	
Risk identification	Mitigation	Risk Transfer	Preparedness	Emergency response	Rehabilitation and reconstruction
Hazard assessment (frequency, magnitude and location)	Physical/ structural mitigation works	Insurance and reinsurance of public infrastructure and private assets	Early warning systems and communication systems	Humanitarian assistance	Rehabilitation and reconstruction of damaged critical infrastructure
Vulnerability assessment (population and assets exposed)	Land – use planning and building codes	Financial market instruments (catastrophe bonds and weather indexed hedge funds)	Contingency Planning (utility companies and public services)	Clean – up temporary repairs and restoration of services	Macroeconomic and budget management (stabilization and protection of social expenditures)
Risk assessment (a function of hazard and vulnerability)	Economic incentives for pro mitigation behaviour)	Privatization of public services with safety regulation (energy, water and transportation)	Network emergency responders (local and national)	Damage assessment	Revitalization for affected sectors (exports, tourism and agriculture)
Hazard monitoring and forecasting (GIS, mapping and scenario building)	Education, training and awareness about risks and prevention	Calamity Funds (national or local level)	Shelter facilities and evacuation plans	Mobilization of Recovery resources (public multilateral and insurance)	Incorporation of disaster mitigation components in reconstruction activities)

¹ C.M.Lewis,K.C.Murdock,1999

(D. Harwood., E. Russell., J. Viner, 1989) describe risk based on historical data, which is, as:

$$\text{Risks} = \text{Events} / \text{Exposure} \quad \text{=====1}$$

The definition of exposure here is not the state of having no protection from something harmful but something measures this exposure, such as here: Truck miles.

and events is the quantity of releases , the level of those releases in terms of it's severity or vehicular accidents.

Those indexes (events/exposure) state combined, unified measure of both frequency and severity of the previous unpleasant situations, so they are generally used in literature to evaluate the risk. The measurement of severity of the events, can be described as a subjectivity and it is an unescapable fragility of these indexes.

Besides, such indexes may be not suited to evaluate the risk of probable forthcoming events, e.g., of technological improvements. Studies of (R. Batta., S. Chiu, 1988; G. Beroggi., W. Wallace, 1991; C. Barkan., T. Treichel., G. Widell, 2000) try to overcome this limitation.

These studies assess the risk by taking various factors into consideration such as the density of population , premise type, substance to be delivered and exposure and they are mainly concentrated on releases that happen on the road or, along railways. Those factors then should be transformed into quantitative values and thus the probability of a hazardous materials accident or incident can be expressed and a measure of the associated consequences (e.g. expected population exposure)in a road and/ or rail system. With this way, the best (safest) routes can be decided.

QRA consists of the following main lines:

- Danger and exposure and e.receptor identification;
- Frequency evaluation; and
- Consequence modeling.

When determining the risks exposed, it is necessary to take into account the different reactions of the individual that are exposed. A major factor is public awareness and opposition, so it is important to quantify and model both factors, which are exposed receptor and perceived risks.

Each line of QRA actually involves some difficulties. A lot of previous studies approximately presumed a steady population density across transport links when applying the consequence modelling in order to find the consequences of an accident to the population.

According to (A.Ang., J. Briscoe, 1989), “ the frequency analysis involves”:

- “Determining the probability of an undesirable event”;
- “Determining the level of potential receptor exposure, given the nature of the event”;
- “Estimating the degree of severity, given the level of exposure”.

It is necessary to account for the probability distribution at each stage of this evaluation (E. Erkut., V. Verter, 1998). Erkut treats the results in each road segment, such as spillage and incident and probability of occurrence of the accident as a whole probability of accident which can be named as joint probability.

A> Accident, involving vehicle of dangerous goods

M> the event of spillage, release ,

I > the incident happening;

D> exposure, the damage type , seriousness to an individual.

The probability of an injury, which could occur after an incident, accident of a dangerous goods carrying vehicle can be acquired as;

$$“P (A, M, I, D) = P (D/A, M,I) P (I/A, M) P (M/A) P (A) =====(2)”$$

p (.) here describes the probability of the event and p(.|.) the related conditional probability.

“Bayes' theorem is a mathematical formula for determining conditional probability named after 18th-century British mathematician Thomas Bayes. The theorem provides a way to revise existing predictions or theories given new or additional evidence”.² Bayes' theorem gives the probability of an event based on information that is or may be related to that event. The formula can be used to see how the probability of an event

² <https://www.investopedia.com> accessed dd March 31th 2017

occurring is affected by new information, supposing the new information is true.
Bayes' Theorem Formula

The formula is written as $P(A|B) = P(B|A) * P(A) / P(B)$. $P(A)$ and $P(B)$ are the probabilities of A and B without regard to each other. $P(B|A)$ is the probability that B will occur given A is true. Finally, the answer, $P(A|B)$ is the conditional probability of A occurring given B is true. Bayes' Theorem .

The literature makes a differentiation between individual and societal risk when assessing the risk.. If there are very few people around during the hazard situation then the the individual risk may be quite high on the contrary , societal risk can be named as zero risk.

- Individual Risk: (J. Mumpower, 1986) “describes the individual risk as the yearly death frequency for an average individual at a certain distance from the impact area”. The individual risk (IR), is defined by the Dutch Ministry of Housing, Spatial Planning and Environment (VROM); “as the probability that an average, unprotected person, permanently present at a certain location, is killed due to an accident resulting from a hazardous activity”.

“ $IR = PfPd|f$; where Pf is the probability of failure and Pd|f probability of dying of an individual in the

case of failure, assuming the permanent unprotected presence of the individual”. A different definition is used by the UK’s health and safety executive (HSE). According to this body, “the individual risk is the risk that a typical user of a development is exposed to a dangerous dose or worse of toxic substance, heat or blast overpressure A dangerous dose is likely to cause the person severe distress or injury, but it does not lead to certain death”.³. The following description of individual risk by Leonelli is rather complex taking more figures into consideration.

The value of Individual risk can be determined numerically and they are generally difficult to express. As an example, (P. Leonelli., S. Bonvicini., G. Spadoni, 1999-2000) propose a model. This model requires high level variables to evaluate the individual risk:

³ Risk criteria for land use planning in the vicinity of major industrial hazards, HSE, 1989

“Frequency of release”,

“Probability of final outcome given a release”,

“Wind probability, and”

“Vulnerability. Then the individual risk is expressed as Individual Risk as”;

“Individual risk: $\sum_i f_{rel}(l, v, j) \int L risk_{unit} = (3)$ ”

being

“Risk unit = $\sum_i p^{out}(i) \sum_k \int p_{wind}(j, k, \theta) \cdot V(i, k, \theta) = (4)$ ”

Where

“* $f_{rel}(l, v, j)$ is the release frequency for link l ”,

“*vehicle typology v in season j ”;

“* $p^{out}(i)$ is the probability of final outcome i given a release”;

“* $p_{wind}(j, k, \theta)$ is the probability for meteorology condition k , season j , wind direction θ ”;

“* $V(i, k, \theta)$ is the vulnerability for outcome i , meteorology condition k , wind direction θ ”.

• Societal Risk: Ichem Institute of chemical Engineering: 1985; defined societal risk as “the relationship between frequency and the number of people suffering from a specified level of harm in a given population from the realisation of specified hazards. Where individual risk gives the probability of dying on a certain location, the societal risk gives a number for a whole area, no matter precisely where the harm occurs within that area”.⁴

(P. Slovic, S. Lichtenstein, B. Fischhoff, 1984.; F. Saccomanno, J. Shortreed, 1993) describes Societal Risk : R_{lm} on road segment l of hazmat m as:

“ $R_{lm} = S_{lm} \int_L \int P_{l(D_{xy}/A, M_m, l)} P_{l(I, A, M_m)} P_{l(M_m/A)} P_{l(A)} POP_{l(x,y)} dx dy = (5)$ ”

$p_{l(D_{xy}/A, M_m, l)}$ defines the probability that individuals on a particular place (x, y) in the influence area L will be dead because of the incident on a route section l

⁴ Ichem Institute of Chemical Engineering. 1985

$POP_{l(x,y)}$ defines the population density on place in around of road section l. It assumes that each person in the effected population will suffer the same risk. R_{lm} can be defined as;

$$R_{lm} = S_{lm} P_l(D/A, M_m, l) p_l(I/A, M_m) p_l(I/A, M_m) p_l(M_m/A) P_l(A) POP_l = (6)$$

The FN curve can be considered as another alternative way of societal risk.

J.K. Vrijling, W. van Hengel, R.J. Houben, 1995. - S. Jonkman, P. van Gelder, J. Vrijling, 2003. explains F as the cumulative frequency of an accident. N describes fatalities or evacuated individuals. "Such FN-curve are drawn by computing, the probability that a group of more than N persons would be impacted due to an HAZMAT accident, for each (reasonable) value of N". CCPS Center for Chemical Process Safety, 1995..

Individual risk is the simply the predicted frequency of the undesired outcome. Societal risk takes account of both the severity of the range of possible outcomes and the frequency at which they each are predicted to occur. It is usually presented as a two dimensional relationship between frequency and cumulative severity of outcome, called an FN curve.

Ball 1998 indicates that F-N diagrams may be used to represent at least three different types of information: (Ball, D.J., Floyd, P.J., 1998)

"*The historical record of incidents"

"*The results of a quantitative risk analysis (QRA)"

"*Criteria for judging the tolerability of risk"

Even If the analyst is dealing with actual (historical datas of accidents) or predicted results, the procedure for structuring the FN slope will be the same. During the analysis to estimate societal risk, the events have an forecasted frequency , f, and estimated number of persons injured, N. (fatality). The mentioned frequency of circumstance is expressed with number of events per year. It is believed by most analysts that social risk outcomes can be seen most effectively in graphical form.. Societal risks may be plotted in two basis:

A separte frequency of experienced N fatalities graph is plotted on the y-axis and is named as **Non-cumulative frequency basis f/N curve**.

A cumulative frequency of experienced N fatalities graph is plotted on the y-axis and is named as **Cumulative frequency basis F/N curve**.

Societal risk are generally demonstrated with cumulative frequency. F/N curve is Important to define acceptable risk and acceptability is mostly defined on the basis of F-N curves.

When constructing the F-N curve, all of the events (Ex) and their related frequencies (fx) and consequences (N,) is put together and classified by reducing value of N.

The equation of an F-N curve may be described as: (Ball 1998)

“ $F \times N^a = k$ or”

“ $F = k \times N^a$ ”

“where, F = the cumulative frequency of N or more fatalities”

“N = the number of fatalities”

“a = aversion factor (often between 1 and 2)”

“k = constant”

The logic for F-N and f-N curves has been explained in a number of publications mathematically. (for example, (Schofield 1993., Hirst 2002); When a slope that is more negative than -1, it is often indicated that the risk aversion has to be considered in an F/N curve, but at the same time Ball points out that F/N curve with slope -1 generally shows a significant degree of aversion to multiple death events.

When we look at the previous formulas used for risk assessment of hazardous substances, up to 6, common feature in all of them is that it is foreseen only one type of accident may happen. However, during the HAZMAT transport activities, several types of accidents might occur and a release for example might trigger others, the consequences, such as incidents, fire, explosion can occur. In order to overcome this gap, (E. Erkut, S. Tjandra, V. Verter, 2007) propose assessing the risk as follows.

A> the accident event

M>release

I>Incidents and

C>All consequences (injuries and fatalities, facility damage, and environmental damage)..All figures can be revealed in monetary terms and may occur on road segment l.

The dangerous goods transport risk related with road segment l can be shown as:

$$R_l = \sum_{a \in A} \sum_{m \in M} \sum_{i \in I} \sum_{c \in C} S_{lm} P_l(A_a, M_m, I_i, C_c) \cdot CONS_c \quad (7)$$

CONS_c here, is the potential c-type consequence.

Analysts consider the worst case loss or with another name; expected loss as a risk measure and simplify their analysis and often ignore conditional probabilities. “The expected value is calculated as the product of the probability of a release accident and the consequence of the incident” (G. List, P. Mirchandani, 1991). Thus, the dangerous goods risk related with a road segment l is shown as

$$R_l = \sum_{m \in M} S_{lm} \cdot p(M_m) \cdot C_{lm} \quad (8)$$

clm means the unpleasing consequence because of the release of hazmat m on road segment l. (E. Erkut, V. Verter, 1998) name this risk formula as the technical risk.

1.4 Security

The catastrophes, the accidents caused by the man made events, were thought to have originated from mistakes in nature. But the Sept. 11, 2001 terrorist attack changed this idea and deliberate human-induced risks came to the agenda. Because of this new concern for security in dangerous goods transportation, the risk assessment methodologies has come to a different direction. “HAZMAT vehicles could be important targets for terrorists, and certain HAZMAT vehicles were designated as weapons of mass destruction.”(M. Abkowitz, 2002.)

(Transportation Research Board, 2002). For example, the US Federal Government and some other countries now require dangerous goods truck owners or drivers to present their fingerprinting and criminal personal inspection (M. Glaze, 2003). Although that, this issue has not yet found enough interest in the operations research.(OR) Nevertheless, as below

indicated, some changes were made within the scope of Operations research after this event happened.

*Changing the route around major cities – Attention has been paid to removing dangerous material vehicles (road and rail) from locations with high urban density as much as possible due to the risk of terrorist attacks. (E. Erkut., T. Glickman, 1997) present with their study that remarkable risk mitigations are achievable via rerouting, and (E. Erkut., A. Ingolfsson, 2000) create new methodology for this purpose..

* Changes in the modeling of incidence risks - Conventional risk assessment of dangerous substances predicts that incidents are caused by traffic accidents or human errors. We are aware that the probability of a terrorist attack or abduction is now different from zero and therefore we think that traditional risk assessment-based route planning is not applicable.

It is not possible that the likelihood of attack is similar, always the same or constant.

For instance, a tunnel, a bridge, or a facility such as an Industrial building or warehouse are possibly to have higher attack probabilities than an unsheltered area. On the contrary, there is the possibility of further abduction in places, where there is less population density. It is not possible to know where a hijacked vehicle will be taken and therefore precautions must be taken to avoid any accident where the population is dense. A probabilistic model of terrorist danger has been created by (E. Paté-Cornell, 2002) and (B. Huang., C. Long., Y. Liew, 2003.) and (B. Huang., R. Cheu, 2004.) are good examples about security interests.

* Modification of methodology in routing - The choice of a minimum risk route with quantitative measures in traditional route planning has become unusable in the new period, as the terrorists estimate this route. In order to prevent the success of a terrorist attack or abduction, the loaders act with game theory and either use alternative routes or change the route on the specified route path in order to mitigate certainty. In order to track the vehicle precisely, GPRS Global positioning systems, communication systems are installed on dangerous goods vehicle thus a satisfactory decisionmaking process occur. (M. Glaze, 2003.) (K. Zografos., K. Androutsopoulos, 2001).

1.5 HAZMAT LOGISTICS LITERATURE

Dangerous goods logistics is a matter that has been considered important and has been studied for a long time. There are many books and journals written about this matter. We can sort the books that go backwards from the most recent ones respectively, as follows.

-Risk analysis and Governance in EU policy making and Regulation by (B. Delagu, 2016) Springer. A guide to risk concept and most relevant methods of risk analysis in EU risk policy and regulatory.

-High Integrity Systems and Safety Management in Hazardous Industries. (J.R. Thomson 2015)Springer. Engineering Management of hazardous Industries such as oil and gas production, nuclear power, manufacture of chemicals and pharmaceuticals and their Safety taking all risk assessment methodologies into consideration.

-Fire Detection in warehouse facilities (Joshua Dinaburg., Daniel T.Gottuk 2012)Springer. Assess the potential role for detection systems and develop a proposed research plan to implement the standards for applying fire detection Technologies.

-Advanced Technologies and methodologies for Risk Management in the Global transport of dangerous goods.(2008) edited by Chiara Bersani, Azedine Boulmakul, Emmanuel Gorbolino, Roberto Sacile. define the risk in dangerous goods transportation and create methodologies to plan the deliveries with attention to exposure of population and impact to the environment and to reduce the hazard risk.

-Risk assessment of Chemicals by (C.J.Van Leeuwen., T.G.Vermeire, 2007). Springer. Introduction to the risk assessment of chemicals and basic Information on sources, emissions and exposure and environment effects in workplace.

-Chemical Risk analysis. A practical handbook by (Bernard Martel, 2004) Butterworth-Heinemann. A considerable technical literature in the fields of hazard and risk assessment, underlying principles of process, hazards, its exposure, consequences, estimation of risk levels and its evaluation and assessment.

-Quantitative risk assessment of Hazardous Materials Transport systems(1996)edited by Nicolet Monnier and A.V.Gheorge. Kluwer Academic publishers. Springer Science; Business, Media. This book gives an overview of the criteria and guidelines applicable to

the implementation of risk assessment and management at different stages and analysis of transport risks of dangerous goods transport on roads, rail, ship and pipeline.

-Guidelines for Chemical transportation risk analysis(1995)edited by American Institute of Chemical Engineers Center for Chemical Process Safety(CCPS) The purpose of this book is to give guidance on conducting, overseeing, and/or managing TRA(Transportation risk analysis) studies, not on specific results or on reduction strategies. It emphasizes accident-initiated releases, but also discusses how non-accident-initiated releases can be incorporated into a TRA. Basic approach to Transportation risk analysis methodology for different transport modes is given.

-Hazardous materials transportation risk analysis(1994) edited by Rhyne WR., Van Norstrand Reinhold. QRA methodologies and their application to HAZMAT transportation.

- Comparative assessment of Risk model estimates for the Transport of hazardous materials by road and rail(1993)edited by Saccomanno, D.Leming and A.Steward assessment of an exercise involving the application of several risk models to a common transport problem mostly for bulk shipments.

- Transportation of hazardous materials(L.N. Moses., D.Lindstrom 1993); Kluwer Academic Publishers. Springer Business-Media. OR Models and techniques, multidimensional treatment of the subject. It explains some of the important aspects of HMTUSA (Hazardous Materials Transportation Uniform Safety Act) and highlights some of the important ways to deal with the risks associated with the transportation of hazmats. It highlights their major contributions, the important ways in which they relate to one another, and how, taken together, they present an integrated, multidisciplinary view of the problems.

- Transportation of hazardous materials. Risk assessment.(F.Saccomanno., K.Cassidy, 1993) Quantitative risk analysis. The models used in risk analysis, accidents incidents and releases, How to apply risk assessment methodologies, how to tolerate risk .

- In 1984, a special paper on Risk Analysis has been published by Management Science (Vol.30, No.4). In this paper five different sections has dealt with HAZMATs and

hazardous facilities. Then, few number of special issues was followed about HAZMAT transportation and / or location problems.

- Transportation Research Record and Transportation Science published respectively two special issues on HAZMAT transportation in 1988 (No.1193) and one special issue in 1991 (Vol.25, No. 2) those included four papers, six papers and another six papers.

- Journal of Transportation Engineering and INFOR and Location Science published special sections on HAZMAT transportation, logistics in March/April 1993 and in 1995 which issue four papers, nine papers and 4 papers respectively.

- Transportation Science published special issues in 1997 and in 1999 about HAZMAT logistics and Locational Analysis with seven papers on (Vol.31, No.3) (Vol.12). Computers & Operations Research printed a special paper about HAZMAT logistics in 2007 with 13 papers.

1.5.1 Classification

The number of papers published between 1982 and 2004 in the logistics area of research, about HAZMAT Transportation has been classified by Erkut et. Al as below indicated table.

Table 3: Main Subjects In Hazmat Transportation Literature

Risk assessment	Combined facility location and routing
Routing	Network design

“One possible classification to provide some structure is the following (in no particular order): C: with security consideration; DSS: Decision Support System model; G: using GIS; M: Multiobjective; S: Stochastic; T: Time-varying; U: Survey/Annotated Bibliography”(Erkut et all,2007)

Table 4: A Classification of Hazmat Transportation Models ⁵

Risk assessment	Road	Cappanera and Nonato (2014) Saat et al.(2014)Raemdonck et al (2013)Tena-Chollet et al(2013)Wang et al(2012)Lopez Atamoros (2011);Lozano et al(2011)Chakrabarti and Parikh(2013)(2012)(2011);Jiia et al(2011)Fabiano and Palazzi (2010) Milazzo (2010) Guo and Verma (2010)Kheirkhah et al(2009)Paltrinieri et al(2009) Erkut and Gzara (2008) Boulmakaul,A(2006) Gheorghea et al.(2005) Jonkman et al. (2003), Martinez – Alegria et al. (2003), Rosmuller and Van Gelder (2003), Abkowitz 2002), Fabiano et al. (2002), (2005)Kimberly and Killmer (2002), Saccomanno and Haastrup (2002), Holister (2002), Hwang et al. (2001), Abkowitz et al. (2001), Verter and Kara (2001), Efroymsen and Murphy (2001), IFC Consulting (2000), Leonelli et al. (1999), Zhang et al. (2000), Pet – Armacost et al. (1999), Caasini (1998), Mills and Neuhouser (1998), Cutter and Li (1997), Groothois and Miller (1997), Lovett et al. (1997), Pine and marx (1997), Alp and Zelensky (1996), Ertugrul (1995), Sissell (1995), Chakraorty and Armstrong (1995), Erkut and Verter (1995), Moore et al. (1995), Gregory and Lichtenstein (1994), Macgregor et al. (1994), Hobeika and Kim (1993), Sanquist et al. (1993), Harwood et al. (1993), Abkowitz et al. (1992), Glickman (1991), Grenney, et al. (et al. (1990), Kunreuther and Easterling (1990), Chow et al. (1990), Abkowitz and cheng (1998), Ang and Briscoe (1998), Harwood et al. (1998), Abkowitz and Cheng (1988), Hिल्sman (1988), Horman (1987), keeney and Winkler (1985), Scanlon and Cantili (1985), Pijawka et al. (1985), Kunreuther et al. (1984), philipson et al. (1983), Keeney (1980), Shapperet al. 1973)
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⁵ Adapted By G.Centrone Et All 2008 And S.Erol 2016

Routing	Local Routing	Road	Kant et al(2014)Pradhanang et al(2014)Mahmoudabadi and Seyedhosseini (2014)Szeto, W,Y (2013)Toumazis and Kwon(2013)Desai and Lim(2013) Samanlioglu,F(2013)Das et al(2012)Reilly et al(2012)Xie et al(2012)Li and Leung(2011)Caramia et al(2010)Androutsopoulos and Zografos(2010) Pradhanang et al(2010)Bianco et al (2009)Verter and Kara (2008)Dadkar et al(2008)(2010)Bonvicini and Spadoni(2008)Akgun et al. (2007), Duque et al. (2007), Erkut and Ingolfsson (2005), huang and cheu (2004), G. Huang et al. (2003), M.Kara et l(2003), Luetke and white (2002),Pate-Cornell (2002), Marianov et al (2002),Frank et al. (2000),Ergut and Ingolfsson (2000), Leonelli et al(2000),Zografos et.al (2000),Ergut and Verter (1998),Tayi et.al((1999),Bonvicini et.al (1998), Mariano and Velle (1998),Verter and Ergut (1997),Sherali et.al (1997), Nembard and white(1997),Ergut and Glickmann(1997),Jin and Batta (1997), Ergut(1996),Jin et.al(1996)Ashtakala and Eno(1996)s,Beroggi and Wallace (1995),Boffey and Karzakis (1995), Glickman and Sontag(1995)Mccord and Leu(1995),Sivakumar et al (1993),
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	Rail	Liu et al(2013)Verma, M (2011)(2009)Anderson and Barkan (2004), Barkan et (2003), Fronzak (2001), Orr et al. (2001), Dennis (1996), Larson (1996), Glickman and Golding (1991), Mc Neil and Oh (1991), Saccomanno and El Hage (1991), saccomanno and El Hage (1989), Glickman and Rosenfield (1984), Glicman (1983)
	Marine	Doulgeris et al. (1997), Roelven et al. (1995), Romer et al. (1995)
	Air	L france – Linden et al. (2001)

		Rail	Verma and Verter (2005)(2007) McClure et al. (1988), Coleman (1984), Glicman (1983)
		Marine	Iakovou (2001), Li et al. (1986) Haas and Kichner 1987)
	Road + Rail	Verma et al(2012),Gilckman (2007)(1988)	
	Road + Rail + Marine	Weigkricht and Fedra (1995)	
Local Routing and Scheduling (on road)	Zografos and Androutsopoulos (2008)(2004), (2002), Miller – Hooks and mashmassani (200), Bowler and Masmassani, Sulijoadikusumo and Nozick (1998), Nozick et al. (1997), Smith (1987), Cox and Turnquist (1986)		
Global Routing	Road	Carotenuto et al. (2007), Huang,B (2006)Dell Olmo et al. (2005), Akgun et al. (2000)(2007), Marianov and ReVelle (1998), Linder – Dutton et al. (1991), Gopalan et al. (1990), Zografos and Davis (1989)	
	Marine	Iakovou et al. (1999)	

Global Routing	Road +Rail + Marine	Bell M(2007) Erkut and Alp(2007)

It can easily be said that a lot of papers are engaged with issues that is present at the crossings of the above subjects and such issues are gaining more attention in the literature. Table 3 shows clearly that the HAZMAT transportation issues on road, on highways has been the highly observed and studied subject by the operations researchers. Contrary, HAZMAT transportation via air or pipeline, has received almost no attention. Intermodal hazmat transportation is being dealt relatively more than air or pipeline. Intermodal hazmat transportation has a growing trend in the last years.

1.5.2 Literary Review Of Article Contents, Models

In Table 4, a classification has been done and the academic literature of HAZMAT is suggested and outlined from the literature. The subjects, which is outlined in Table 3, as main groups: Risk assessment and routing, combined facility location and network design can be reviewed as below.

When reviewing the literature, around 150 articles has been studied and they have been classified according to their working principles, models and their field of study. The field of study of Risk assessment have been classified according to : Transport; Storage and production process area. Production process area can be named as “fixed installations” too. But as our evaluation area is Logistics, we will indicate only few of the articles from the Logistics; Transport and Storage area.

The models, working principles have been classified according to their models; Such as event tree models, cause consequence models; or according to their working principals such as historical analysis evaluation, or such as a general, basic risk analysis, risk assessment content. In some articles risk assessment has been evaluated theoretically, in

some of them as a case study and in some of them -as it can be easily understood from it's name- as compiled from historical datas.

1.5.3 Risk

According to hazmat literature, and specifically in hazmat transportation literature, Risk is an integral part of the subject.

In Hazmat Literature, OR/MS models are mainly used and they are examined in four basic topics as per outlined in table 2. "Risk is defined as a measure of human injury, environmental damage, or economic loss in terms of both the incident likelihood and the magnitude of the loss or injury .(CCPS Center for Chemical Process Safety, 2000)".

1.5.4 Combined Facility Location And Routing

The sub topics are:

- Supply Chain Management
- Hazmat disposal
- Risk averse models
- Emergency response

1.5.5 Risk Assessment

- Deriving probability
- Consequence modelling

Deriving probability is applied for Moving hazmat/Fixed hazmat/Both

Consequence modelling is applied for Measuring impact area/Estimating accident consequences

1.5.6 Routing

It is applied for Uncertainty/Timely and adequate delivery/Hazmat risk equity

Summary of the Five Risk Models Suggested in the Literature for Hazmat Transport Risk (Between years 1980-1993)

Approach	Model	Sample References
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Traditional Risk	TR(P)	5 Yı[P piCi Alp 1995, Erkut and Verter 1995b
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Population Exposure $PE(P) = \sum_i [P_i]$ ReVelle et al. 1991, Batta and Chiu 1988

Incident Probability $IP(P) = \sum_i [P_i]$ Saccomanno and Chan 1985, Abkowitz et al. 1992

Perceived Risk $PR(P) = \sum_i [P_i(C_i)]$ Abkowitz et al. 1992

Conditional Risk $CR(P) = \sum_i [P_i(C_i)] / \sum_i [P_i]$ Sivakumar et al. 1993a, 1993b, 1995

Conditional risk model is viewed as a multiplicative and multiattribute model different than all others. Axioms;

- If one or more links added to an existing path, total affect of the path can not be less. (Monotonicity axiom of path evaluation models.)
- All subpaths of an optimal path would be optimal. (optimality principle for path selection models)
- Path is a function of edge, which is not reducing. Incident probabilities and edge consequences have to be evaluated together. (Monotonicity axiom for risk models.)

Among five models, four of them other than conditional risk model, satisfy all those 3 axioms. But conditional risk model has to be used carefully for selection of hazmat routing.

Traditional “expected consequence” model might be inappropriate since it assumes riskneutral public.

1.5.7 Network Design

It examines the needed restrictions and Incentives/Disincentives

There are two methods to assess the risk..Erkut(1997)

Qualitative: These are the descriptions of risks used to create datas.

Quantitative: Those datas can be measured.

There are many OR/MS **risk assessment models**, that simply use historical data to derive the frequencies (Caretonuto,2007) Other models employ OR/MS probabilistic and statistical methods. The risk assessment is usually done with the below variables:

Incident or release, spillage probability.

Consequence level

Public counting(societal or individual affect)

Exposure amount and /or such as amount of dangerous goods transported.

In their study, in their risk equations, authors whose top-level variables are limited, define their own work as simple. As an example ; “a model to assess risk, equity and efficiency in facility location and transportation of hazardous materials” by (J. Current., S. Ratick 1995) can be given. There could be more complex formulations such as ” Routing of a hazmat truck in the presence of weather systems” by (V. Akgün., A. Parekh., R. Batta., C. Rump, 2007). In this study the wind probability and /or Fatality probability (Vulnerability) can be described as more complex variables. In another study (P. Leonelli., S. Bonvicini., G. Spadoni, 2004) use also sub variables and for example the vehicle type and material type has been shown as sub variables when evaluating the release probability. Another example; Risk management of road and rail transport of hazardous materials in Sicily (R. Bubbico., G. Maschio., B. Mazzarotta., M. F. Milazzo., E. Parisi, 2005) using the TRA tool TrHazGis, calculates accident probability, consequence probability together with Individual and societal risk, exposure risk etc. In order to find out all those risks, the following indices are used as variables and subvariables: rail and road (major, minor and main urban roads) networks, accident rates (accidents/vehicle km), on-road and off-road population density, two distances (150 and 1500 m) for the protection analysis, and average seasonal weather conditions (high, medium and low temperature, wind velocity). After an accident, probability of occurrence of two reference release scenarios (medium and catastrophic), is evaluated and different scenarios are created for final outcomes, derived from historical accident databases; information about the impact distances and areas of each final outcome (pool fire, flash fire, VCE, etc.), calculated for different sets of weather conditions, applying consequence analysis. The F–N societal risk curve is determined. (individual and societal risk)

There are few papers, that discuss methods, which can be used to determine probabilities for hazmat releases during transportation. **(Deriving probability)** For **moving hazmat**, commonly used theorem is Bayes theorem.

Erkut defines

A---Events of involving in hazmat transporter.

M---event, that the accident resulted in a release of hazardous materials.

I---event, that the release resulted in hazmat incident.

D---event of an injury to a person.

$$P_{ij}=P(A,M,I,D)$$

$$=P(D/A,M,I)P(AM,I)$$

$$=P(D/A,M,I)P(I/A,M)P(A,M)$$

$$=P(D/A,M,I)P(I/A,M)P(M/A)P(A)$$

When each segment is available, then one may alternatively use discrete choice models (Zografos., Androuloupoulos 2008,Tvain, 2009)for estimating probability. They derive the relative accident probability to represent combinations of various conditions like the ;

- “Number of lanes”
- “The condition of pavement”
- “The slope of roadway link”
- “The type of roadway link(curved or straight)”
- “Traffic characteristics such as capacity,,meximum speed limit and signaling”.
- “The average response time to an incident and other factors including roadway, lighting, public Works and local conditions.”

When probability of a given link is unknown, relative probability is a viable method to use.

It could be quite problematic to use the same data in each similar road segment because it assumes no significant points like intersections, highway ramps and bridges. Therefore researchers need high-quality accident probability data for theoretical and experimental research that will lead to development.(D.Brown.,W.Dunn 2007) Dunn and Brown wrote an example article”Application of a quantitative risk assessment method to emergency response planning” that used quantitative risk assessment methodology for dangerous materials using significant statistical data from past accidents.

Dunn and Brown demonstrated the application of quantitative method and assessed the occurrence of a breathing difficulty in the case of toxic material release and within which distance the surrounding population could be protected. In this article, priority obstacle is given to emergency intervention, but on the other hand route optimization of various hazardous materials and social risk estimation are also included in the framework.

Fixed hazmat

(Chow et al 1990) develop a Bayesian model to predict small and large nuclear accident risk. (Kwan., Miller, 2002) use data mapping to assess customary cause failures, that may result in a hazmat release. Kwan and Lee analyze the spatial-temporal patterns of residents and inspired the development of people based model. Miller was known as a place based methodologist. Miller then compared the place based versus people based Geographic Information Sciences in his article in 2007.

1.5.8 Both

Logical based techniques such as Fault Tree analysis (FTA) and event tree analysis can be used to derive both P_{ij} and NH_i . (Picard., Williams 2013) present a computer model to estimate rare events. (Rare event estimation for computer models). This model can be used to assess the probability of third – level consequences such as the probability of a release of hazmat provoked by a natural disaster triggering another chemical accident.

1.5.9 Consequence Modelling

In the OR/MS field for every P_{ij} and NH_i , there is some associated consequence that represents possible effects of hazmat releases at a link ($C_{ij}(i,j) \in A$) or node ($C_i; i \in N$). The purpose of consequence modeling is to take into account the variability of consequences in different areas. Each quantified consequence is a function of a defined impact area and risk costs (population, property, environmental assets) within that area.

1.5.10 Measuring The Impact Area

A few components, that are assessed to define the size and shape of an impact area such as the type and amount of hazmat, topology, weather, the movement of the hazmat (i.e at a fixed location or during its transportation) and wind speed (and its direction). Hazmat releases at a particular node and at a particular link can be measured as a function that represents potential undesirable consequences at the point at the nodes location.

The main difference in defining the associated impact areas for a node or a link is the movement and amount of hazmat. In most OR / MS models, researchers apply a geometrical shape around the possible incident location to determine the impact area.

The most common shapes used are rectangles (ALK associates,1994/Alk's PC Hazroute. Princeton NJ) or some circular shape (Kara et. al 2003) "accurate calculations of hazardous materials transport risks" other notable Hazmat transportation models include the fixed bandwidth and Gaussian plume model. (Erkut., Verter,1998) "Modelling of Transport risk for hazardous materials" (Verter., Kara 2003) "accurate calculations of hazmat transport risks" which provides away to measure an impact area that modes along the transportation network with the vehicle. One of the central assumptions for these hazmat models is that every person around the danger zone is affected equally and no one outside of this area is affected. (Zhang et. al 2000) "Using GIS to Assess the Risks of Hazardous Materials Transport on Networks." (Kara et. al, 2003) ; (Zagrofos., Androutsoulos, 2004) "a heuristic algorithm for solving hazardous materials distribution"; (Akgün et.al 2007) "Routing of a hazmat truck in the presence of weather systems" present a model that accounts for weather effects on Hazmat release risks,such as consequence area. This model assumes once weather systems pass"every day" release consequences are applicable. This makes this model unreasonable to apply to a NaHaz event.

Estimating Accident Consequences in terms of cost

"Risk costs are a function of population, property and / or environmental assets within the measured impact area. OR/MS hazmat models often measure consequence costs in dollars."(Xu et all 2013) Abkowitz is the one of the important scholar , who studies the risk-cost frame work. The first study of him is from year 1988. Developing a risk cost framework for routing truck movements of hazardous material (M.Abkowitz., P.Cheng, 1988). Another one is written relatively in recent years; (Abkowitz et. al 2001) "Assessing the economic effect of incidents involving truck transport of hazardous materials" including deaths and injuries. Here the affected factors are assessed such as injuries and fatalities, cleanup costs, property damage, evacuation, product loss, traffic incident delay, and environmental damage.

"A framework of the risk assessment for the supply chain of hazardous materials by (V.M.Rayas., M.A.Serrate 2017) It is the one, which assess the risk in closed areas such as the suppliers, outsourcing options and material itself.When analyzing the risk, cost values could be used to decide which activities shall be outsourced.

This subject has been investigated broadly also as a master thesis by (C.Samuel, 2007) Frequency analysis of hazardous material transportation incident.

In Logistics and especially in Transport section, risk is an essential part of dangerous material transportation. Most of the articles written are aimed at reducing Risks in the transportation route and in operational research area. The risk equations in the Operational Risk studies can be described to be relatively easy and are generally forms the release probability of the products and the results of such events. Other articles focus on calculating risk as part of QRA studies; An example about it can be given as “Application of a quantitative risk assessment method to emergency response planning” (Brown., W. Dunn 2007.)

Quantitative risk assessment articles have been reviewed and signed frequently by environmental, chemical and industrial engineers, and meteorological, demographic and chemical databases have been brought together when calculating risk. There is not much of a focus on transport-support activities, such as loading or unloading .

Nevertheless the following articles can be given as examples although there are not many.

(Ronza et al 2003) estimate the frequency of incidents in ports by evolving event trees from historical analysis; investigates the 828 accidents in seaports, which have been selected from a database, has been used to identify the sequences of the accidents. Operating of these data permitted the event trees and the likelihood of diverse accident scenarios to be calculated.. Details of the events taken from different data banks and triggering the formation of accidents were determined and the cause and frequency of the accident were revealed by using the event tree model.

(Z.N.Pintaric 2007); Assessing the consequences of accident scenarios which include dangerous substances. This article describes the basic steps in assessing the consequences of accidents involving hazardous materials in particular during storage, loading and unloading activities. Many accidents involving dangerous materials usually start with an unmanageable spillage of flammable or toxic or explosive substances. To evaluate the results of such accidents, it is necessary to communicate and study closely with staff in the facility, risk assessment experts and other supporting organizations, and this study focuses on such events.

(R.Bubbico., M.Marchini 2008); A case study involving an assessment of explosive LPG release oscillation . The phenomenon mentioned here involves the filling of a liquid petroleum gas . The main subject mentioned here ;during the transfer of LPG from tank of a vehicle to the fixed storage LPG unit of the buyer, the release of LPG and it's results from the pool fire by exploding the tank contents and in the end disintegration of the tank. The results of the events have been investigated using some of the most accepted calculation models in the risk analysis.

Despite the differences in accident scenarios, most of the variables and connections and therefore the general bayesian structures are the same . The vast majority of existing work is aimed at finding and minimizing the risk of potential future events. The hazardous substance literature seems not to be related to past spills, release accidents to reveal the effect of the relevant variables. An important exception in this regard is a paper written by W.Burns ; (W. Burns., R. Clemen, 1993)"Covariance structure models and influence diagrams" Burns and Clemen indicate that sociological, behavioral, and perceptual variables increase the effectiveness of the hazardous substance and explain it through an impact diagram. From this point of view, the decision model recommended by Burns and Clemen can be considered exclusive in the literature of hazmat because of its statistical and investigative qualities. This article is not processed as an analysis of data according to the variables that affect the results. Possibly, it is thought that past experiences are not trustworthy. The situation is further complicated by the fact that there is no consensus on the possibility of general truck accidents and that different researchers can give conflicting numbers.

But although that, several articles using the accident databases are not really rare.

Most common method that are used to analyze the factors that influence Hazmat transportation accidents , are statistical methods ,such as fault tree analysis, event tree analysis and cause consequence analysis. Researchers restrict themselves mostly to collecting, analyzing and interpreting large-scale accident reports or data derived from the accident database.

Some of the examples about accident analysis can be summarised as below:

Shen et all investigated the tank accidents in China in 2013. In China, from 2004 to 2011, 708 tanker accidents involving the transport of dangerous goods were analyzed and

the causes, the areas where it took place, the time of arrival, the hazard class of the relevant material, the results and the probabilities related thereto were investigated. Tanker transports can be much more dangerous and can lead to catastrophic consequences comparing other types of vehicle accidents. Because the capacity of tanker is very high and it's volume and large size increase the danger according to content in it.

In 2006, Oggero et al. examined 1932 accidents, which happened during the carriage of dangerous goods by road and rail. The research included accidents up to July 2004 from the beginning of 1900s and as a result of the investigation, it was determined that the main cause of the accidents were weather condition, human factors such as operator error and mechanical faults.

In their 2007 study, Ronza et al. examined the possibilities of spillage, sparks and explosions in flammable substance transported vehicles in Spain. The study was done by event tree methodology and for both road and sea.

Yang et al. 2010 made a survey between years 2000-2008 and used the statistical methodology of descriptive analysis and societal risk F-N curves. 322 accidents have been listed from internet, safety Journal in China and newspaper reports and have been examined and stored in a database. Four factors have been taken out from this list as the causes of the accidents: External events, management factors, mechanical and equipments failure and human factor like driver error. Major cause seems to be the driver error, which follows with mechanical failure and management factors relatively.

Ellis et al. analyzed the accidents between 1998 and 2008 with information from American and British databases in 2011. The analysis of the accidents and thus incidents was made on the spillage, release of packed hazardous materials carried by sea.

Errors that occurred during activities such as preparation of the products needed for transportation, packing, placement of containers and loading of ships were determined as the main causes of spills, releases and subsequent incidents on the board of Vessel. It is considered that between the years 1998 and 2008, for ship casualties worldwide, 15 percent of all deaths occurred from accidents involving packaged dangerous goods. The most triggering factor in fatal accidents is shown by the fact that dangerous substances are reported with different content, which leads to ignition or self ignition.

Zhao et al. conducted a study on the analysis of the factors affecting dangerous goods transport accidents in 2012 stand on Bayesian network. The bayesian network structure was constructed with the basis of expert knowledge They investigated the interaction between different factors, which is believed that an incident is generally to be the result of several factors, different from tree-based analysis. Tree based analysis analyzes in general the association between an incident and the factors that affect it. Here is the root causes of accidents has been as immediate or contributing. Immediate conditions are unsafe acts of worker and unsafe working conditions in general. The contributing factors is classified as management related factors, environmental conditions and physical and mental condition of workers.. There are subfactors following those main factors.

Articles of route Optimization for Hazardous Materials Transport

In the following section, it is briefly presented some of the closely connected study dealing with route optimization of dangerous goods. Optimal location of routes for vehicles transporting hazardous materials (J. Karkazis., T. Boffey, 1995.) concentrate on the deterioration affected the population when an accident occurs. This research also examines the harmful substances dispersed in the air, which can occur in a dangerous goods accident.

Therefore, the impact area is assessed not by a certain bandwidth, but by the meteorological conditions at the time of the accident and the material being transported.

A framework for risk assessment and decision-making strategies in dangerous good transportation; (B. Fabiano., F. Currò., E. Palazzi., R. Pastorino, 2002) In this study, the risks of the transport of dangerous goods by road are investigated and strategies are being sought for the selection of road, create a right routing. Province data on the selected road was gathered by a systematic survey and data entry was provided for the field-oriented statistics. The improved technique was applied to a pilot area, where both individual and community risk was taken into account with reference to flammable and explosive scenarios. In order to reduce the general uncertainties in the risk analysis, it is recommended to evaluate the routing characteristics and the population exposed to the hazardous substances. Spatial decision support system for hazardous material truck routing (W. Frank., J. Thill., R. Batta, 2000) conducted a research considering a simplified approach to examine the risk quantitatively. This research study concentrates in the

development of a spatial decision support system and this system helps the selection of route for the transport of dangerous goods within the United States of America. Along the route of the hazardous material, both sides of a predefined band were identified as the affected area of the population, that is, the risk element.

Railroad transportation of dangerous goods: Population exposure to airborne toxins (M.Verma.,V.Verter, 2005) In this study, the distinction characteristics of the trains, the volume and the quality of the load and the placement of the load are considered in the evaluation of the risk when transporting dangerous goods and the situation arising from the release of the substances after the accident is examined. The positioning of hazardous cargo is proposed as a risk approximation approach.

A Heuristic Algorithm for Solving Hazardous Materials Distribution Problems. (K. Zografos., K. Androutsopoulos, 2004) regard the population around the affected area as the element at risk. In this study, it is estimated that the population within the domain has the same vulnerability . The objective of this paper is to present a new heuristic algorithm for solving a vehicle routing and scheduling problem. The risk for the population is then described as the product of the individual risk .The proposed algorithm has been supported with GIS.

Computing shortest paths for transportation of hazardous materials in continuous spaces.(J. Diaz-Banez., F. Gomez., G. Toussaint, 2005) In this study, a suitable path for the transport of dangerous goods is determined, taking into account the cost of travel between routes, which is predetermined on the plane as starting-destination point and minimizing the risks associated with transport. The authors compute a path connecting a and b concerning the minimum distance to the targeted point is maximized. This perspective produce effective algorithms to compute shortest paths under different kinds of distances.

A Path-Based Approach for Hazmat Transport Network Design(V.Verter., B.Kara 2008) There are undesirable consequences for accidents during the transportation of dangerous goods, and during transport.

The main responsibility for reducing the risk of intensive population territory belongs to government agencies. and one of the common policy tools is to close certain road links to vehicles carrying dangerous goods.(Regulator) Legislators may decide to close some

paths to minimize the risks of carriers' route choices. The methodology in this article includes the risk concerns of the legislator and the cost concerns of the carrier. Another important issue is equity, which means the public opposition. The perceived differences between levels of exposure to risk in different population zones may cause public opposition to hazmat transport. In addition, the high number of specific motorway segments can increase the likelihood of accidents and, at the same time, the severity of the consequences.

One of the common way to prevent the public opposition (equity) of dangerous goods is to introduce a set of constraints. The multiple routing is a method to reduce the risk, when a large volume distribution is the issue.

Aiding route decision for hazardous material transportation (B. Huang., P. Fery, 2005) In this article, a structure is proposed for the most appropriate route for transporting dangerous goods, and in Singapore, for example, 8 different functions in a road network are evaluated in a case study. 4 different routes are implemented and GIS are used to quantify road route connections.

Multiobjective vehicle routing and scheduling problem with time window constraints in hazardous material transportation (Q. Meng., D. Lee., R. Cheu, 2005) A new vehicle routing and scheduling system is proposed for the transport of hazardous materials for networks with multi-timed changing characteristics. The purpose of this study is to determine the different routes with fixed travel time and fixed waiting times. Three types of practical constraints are considered. Limit operation time, limited service time and limited waiting time. The multiple objective shortest path is revealed with a dynamic and effective program

Fuzzy graphs modelling for hazmat telegeomonitoring (A. Boulmakoul, 2006.) Geographical information systems and decision support systems are used in this study. Land use, infrastructure, urbanization network, industry view are provided by geographical support system and risk is evaluated by decision support system technology and used to minimize the transportation risk.

Intermodal hazmat transportation problem with time dependent travel risk. (E. Floros., A. Ziliaskopoulos., E. Chang, 2006) In this article, the problem of calculating the optimal route by calculating delay, fixed time schedule mode in mode change in a transport

network with different modes, different travel times and varying connection costs is discussed. The program calculates multi-mode shortest path algorithm by combining existing transport modes while calculating for transfer delays and transportation costs.

Routing of a hazmat truck in the presence of weather systems. (V. Akgün., A. Parekh., R. Batta., C. Rump 2007) In this article, the impact of weather systems to dangerous goods has been evaluated. If a vehicle carrying a hazardous substance transits on a single path, the overall effect of weather is analyzed firstly and this This analysis provided a basis for further analysis about finding minimum risk path on a network. Various methods are suggested in order to solve the underlying problems by making calculations and reporting. It makes simple assumptions about the nature of the air system, such as parking the vehicle to avoid the effects of the weather changes.

A new model for the hazardous waste location-routing problem (S. Alumur., B. Kara., 2007) In this paper, authors suggest a new multiobjective location-routing model . In Turkey, in Central Anatolia, it is examined with which technology and where the wastes of hazardous substances can be destroyed or treated..The locations of disposal and treatment centers are questioned where to open. At the same time, the answers are searched to the question of which types of hazardous waste will be directed to compatible technologies. In a sense, this study is a study of both minimizing the risk and reducing the cost.

Different then other similar multiobjective solution technique papers, Alamur and Kara applied their model with 92 generation nodes and with 15-20 candidate sites.

Finding minimum and equitable risk routes for hazmat shipments. (P. Carotenuto., S. Giordani., S. Ricciarelli 2007.) This article deals with the creation of minimum risk routes for the transport of dangerous goods by road from their origin to their destination. At the same time, it is the selection of ways to minimize the likelihood of opposition to dangerous substances that may occur in public. The target of this paper is to plan a route to each dangerous substance dispatch and to minimize the transport delays and to spread the risk spatially and to go on the specified route to prevent the risk of vehicles traveling on the road close to each other and this is formulated mathematically with heuristic algorithm and with alternative routes and experimentally evaluated on a set of realistic test problems over a regional area.

Integrated routing and scheduling of hazmat trucks with stops en-route. (E. Erkut., O. Alp, 2007a) This study examines the problem of integrated routing and scheduling in dangerous goods transport, where accident rates, exposure and connection times in the road network change with each hour of the day. It is aimed that the risk, arising from the probability of accidents multiplied by the exposure, will be minimized and there are few constraints on the total duration of the trip such as driving and waiting periods.

Generalized route planning model for hazardous material transportation with VaR and equity considerations; (Y.Kang., R.Batta., C.Kwon, 2014)

Previous works have examined the problem of the single line usage of dangerous materials during a journey. This study examines how a more realistic risk value is calculated within the context of multiple journeys and multiple hazardous substances, and at the same time, the limitation of community opposition is also taken into consideration. In Albany, New York, a real-life hazardous substance routing scenario is organized with the aid of a computer program. The results show that a high level of risk distribution can be achieved when the risk value is controlled at the desired confidence level.

A multi-objective mathematical model for the industrial hazardous waste location-routing problem..(F.Samanlioğlu, 2013)

In this study, a multipurpose placement, routing model developed and implemented in Turkey's Marmara Region. The aim of this model is to help decision-makers to decide on the location of different types of hazardous waste, recycling centers, which use different technologies. In the mathematical model, three points are assessed: minimizing total cost, that includes total transportation cost of dangerous goods and waste residues and fixed cost of installing treatment, disposal and recycling centers; minimizing total transportation risk linked with the population exposure along transportation paths of hazardous materials and waste scraps; and minimizing total risk for the people in the vicinity and disposal centers. The mentioned total risk is also called site risk. Data related to the Marmara region is obtained by utilizing Arcview 9.3 GIS software and computed CPLEX software.

In general, the studies in the HAZMAT transport literature uses various analytical equations for risk in routing or quantitative risk assessment research.

HAZMAT transportation network design problems consider all involved parties such as government and the carriers and is a young research topic compared to routing or quantitative assessment. There has been an increase in the use of geographic information systems recently. Geographic information systems appear to be a much more effective risk assessment with the use of data entry and optimization models. There are still many important Operation research problems in dangerous goods transportation.

Details are needed with high quality, which are well explored and applied datas, probability datas in the system are very important together with experimental or theoretical research for general improvement in the area.

Sourcing, presenting and applying the data separately at highway ramps, intersections, bridges, etc. instead of being presented as a single one, will bring risk assessment to a high quality.

Presenting different data by different sources in truck accident probabilities is one of the main problems in risk assessment. Despite this, it is much preferred way in risk evaluation.

1.5.11 Warehousing

The articles in the literature on storage are much less than those in transport. Risk analysis is more common during transportation or factory production, as it is thought that the risk is higher in highly mobile materials.

The main risk of hazardous material storage is, of course, excessive, so far there have been numerous fires, deaths, injuries and there are articles on risk analysis too.

(M. D. Christou, 1999) “Analysis and control of major accidents from the intermediate temporary storage of dangerous substances in marshalling yards and port areas”.

This article deals with the issue of large accidents involving temporary storage of dangerous goods. When we refer to temporary storage, the subject that is particularly discussed in this article is dangerous goods stocked in sequential areas at ports. In addition, some past accidents occurred during transport, at the beginning or at the end, were sorted and statistically analyzed. In the end of the article, as a result, a general framework for the control of major accidents is discussed.

(F.Rigas., S.Sklavounus, 2004) “Major hazards analysis for populations adjacent to chemical storage facilities.”

Storage and handling of hazardous chemicals in plants creates a major threat to the health and safety of communities in close proximity to populated areas. Just as there are many other ports in the world, at a harbour in Greece is also stored, loaded and unloaded a high amount of hazardous material temporarily with other materials. Further, harbour warehouses are very close to the populated areas. In this study, various accidents scenarios were produced by taking actual data and the effect on the nearby populated areas was calculated quantitatively. The result is evaluated by adding various typical accident scenarios to a software package called Breeze hazard. Simulations are made in the accident scenarios of the software such as chemical distribution, fire and explosion. Those ending results such as fire, explosion etc. are included in the models of Expert, Degadis and Slab in the mentioned software package.

(Ayana R. Anderson., MPH Jennifer Wu., MS, 2015) “Top Five Industries Resulting in Injuries from Acute Chemical Incidents — Hazardous Substance Emergency Events Surveillance, Nine States, 1999–2008”

In this paper, The Hazardous Substances Emergency Events Surveillance (HSEES) system was operated by the Agency for Toxic Substances and Disease Registry during January 1991–September 2009 to collect data that would enable researchers to describe the public health results of chemical releases and to develop activities aimed at reducing the harm from such releases. Targeting chemical incident prevention and preparedness activities provides an efficient use of resources for reducing chemical exposures. A variety of methods can be used to minimize chemical releases in industries. One example here is the Occupational Safety and Health Administration’s hierarchy of controls model, which focuses on controlling exposures to occupational hazards. The hierarchy includes elimination, substitution, engineering controls, administrative controls, and use of personal protective equipment.

(Z. Török., A. Ozunu, 2010) “Chemical risk assessment for storage of hazardous materials in the context of Land Use Planning”.

In this paper the development of a risk assessment methodology for land-use and emergency planning is proposed for Seveso-type sites, where large quantities of dangerous,

explosive, flammable or toxic substances are stored, handled or processed. Three case studies were considered while elaborating this methodology. These case studies include technological accident scenarios for the storage of common hazardous substances: propane, chlorine and ammonium nitrate. Several methodologies applied in the EU member states were approached and the proposed methodology is based on the results of this research. The proposed methodology in the paper is based on the following techniques and methodologies: - qualitative hazard identification and risk assessment using techniques like HAZOP studies (Hazard and Operability), FMEA (Failure Modes and Effects Analysis), DOW's FEI (Fire and Explosion Index) analysis, risk matrices etc.; - The French methodology for LUP developed by the Ministry of Ecology, Energy, Sustainable Development and Sea in France; - The Italian methodology for LUP developed by the Ministry of Public Works in Italy; - The Austrian methodology for LUP developed by the "Permanent Seveso Working Team" in Austria.

(K.W. Le, 2001) "A methodology for assessing risk from released hydrocarbon in an enclosed area."

This article provides a method for calculating the concentration of hydrocarbon emissions in enclosed spaces. Experimental equations are used for the evaporation rate in this method. The methodology is to assume the hydrocarbon exposure concentration in the air under different conditions. The methodology to estimate risk to individuals, who expose the material, is suggested as probit expressions. The criterias about toxicity and human exposure datas, which are available in databanks were examined and guidelines for risk assessment recommended for volatile materials such as benzene and toluene. Lethal concentration ratios of hydrocarbon mixtures and non-toxic substances are estimated.. The probit calculations are used to estimate guidelines in order to prevent toxicity within enclosed working areas.

(M.U Kim., S. Shin., S.H Byeon, 2015) "Comparison of chemical risk assessment methods in South Korea and the United Kingdom"

The objective of this study was to compare Control of Substances Hazard to Health (COSHH) Essentials (a chemical risk assessment method in the UK) with Chemical Hazard Risk Management (CHARM) (a chemical risk assessment method in South Korea). The differences between the two processes were explored with a particular focus on their

features and distinctions. The results obtained from applying COSHH Essentials and CHARM to 59 carcinogenic, mutagenic, and reprotoxic (CMR) substances were analyzed. The outcomes of the working environment assessments and the collated information about the usage of CMR chemicals were used for the analysis.

(O. Gaci., H. Mathieu, 2011) “Simulation of a Segregation Strategy in a Warehouse of Dangerous Goods by a MultiAgent System.”

Models with structural and behavioural dynamics in supply chain systems are very convenient and complex system approach is one of them as Complex Adaptive System (CAS). This article suggests to apply those related works to study storage activities in a warehouse of hazardous materials. The warehouse is observed as a system with complex warnings, (CAS) and the workers working in it are also modeled by a multi-agent system.. The aim here is to conduct research, simulate accidents and develop further risk management strategies, with the strategy of separating the particularly reactive substances among the hazardous substances in the warehouse.

(O. Gaci ., H.Mathieu, 2011) “Deployment of Communicating Objects for A Dynamic Risk Management in Warehouses of Dangerous Goods.”

The purpose of this article is to suggest new tools to improve the flexibility of the supply chain against interventions and unwanted events. Particularly the positioning of RFID and sensors is described in dangerous goods warehouses. Considering storage constraints, forklift cargo drops and rack errors, these types of adverse events in the warehouses would be monitored in real time, enabling dynamic risk management. The data collected by the sensors are evaluated by a central information system so that alarms or specific procedures are generated by blending data from previous events and improve risk management.

(X. Liu., X. Wang, 2013) “Fire risk forecast and early warning technology for large oil and gas storage & transport tank areas” .

In this study, firstly, the working functions of storage and transportation in large size gas and oil tank areas are examined. With the analysis of the equipments, the possibility of the material leakage, fire, explosion and similar disaster scenarios is worked with the event tree methodology. The failure probabilities of the key equipments and process connections

and the effectiveness of the fire fighting equipment of the tanks are analyzed one by one. Thus, fire and explosion planning and prediction analysis is done with dynamic monitoring methodology.

(W.H Ju, 2016) “Study on Fire Risk and Disaster Reducing Factors of Cotton Logistics Warehouse Based on Event and Fault Tree Analysis.”

In this study, the cotton factories and thus the logistics warehouses in China, which have been bouncing in recent years and increasing in number of years, have been mentioned. In China, which is the first country in terms of textiles in the world, logistic warehouses, that store these produced products are also in large numbers and in many of them many fires broke out. Here, specifically a cotton logistics warehouse is examined. First of all, in the previous 100 cotton logistics warehouse fires in China, the causes of fire are investigated, sources of fire hazards are determined and fire safety issues are summarized. As a second step, the physical and chemical characteristics of cotton are investigated. The third step is examining the catastrophic mechanism of cotton logistics warehouse by means of the event tree and fault tree methods and the damage reduction studies are being carried out.

(H.Y. Wang., P. Russo., P. Joulain., A. Carrau 2014) “Risk assessment of a fire involving combustible materials in a warehouse”

This paper presents the results of a numerical modeling into a rack fire in warehouse, and an identification of the visible flame shape when a fire is generalized over a whole warehouse after collapse of the roof. The model described here is a numerical implementation of a thermal and fluid-dynamic theory to predict the rate of flame spread.

At first, the prediction is compared with the experimental data in the rack fire configuration in terms of heat release rate, flame height, temperature and velocity. Large-Eddy-Simulation method is used.

(F. Markert,1998) “Assessment and mitigation of the consequences of fires in chemical warehouses.”

This study is a very important and multinational study on the storage of hazardous materials. The study was financed by CEC (Commission of the European Communities)Environment programme for a 3-year period between years 1993-1996. It is

a project with cooperation from four countries: UK, Sweden, Finland and Denmark and its name is : Guidelines for Management of fires in chemical warehouses.(TOXFIRE). The project contains three main parts:

(1) The performance of four different test methods are compared. The aim is to evaluate the toxicity of fire-causing products.

(2) Evaluation of risks and effects on human health of release of unburned pesticide and pyrolysis products during fire.

(3) Setting up a basis for guidelines for safety engineers and the fire brigades. And also a quick decision system in emergency situations was created.

(K, P. Moder., J, P. Russo., F, Justiniano., W, F. Marshall., T, H, Mcghee., R, Stankovich., W,L, Frank., 2007) “Development of a Hazardous Material Compatibility Storage Guideline and Tool.”

This study developed a storage compliance/compatibility guide and an abbreviated compliance booklet that indicate the compatibility or incompatibility of hazardous materials. CCPS (Chemical process safety) guidance was used when this booklet and guide was being prepared and was considered for the management of chemical reactivity hazards for workplaces using reactive materials. This hazardous material storage booklet helps staff to create optimal storage strategies. The booklet identifies potential hazard combinations of materials for material handlers and identifies strategies to reduce the risk of such combinations. If there is a need for a guidance about hazardous materials in the sites, which store drums, packaged materials, this booklet can be used in storage, in laboratories or in manufacturing buildings through a template.

(P, Baybutt, 2013) “The Use of Risk Matrices and Risk Graphs for SIL (Safety Integrity level) Determination.”

In this study, risk safety matrices and risk graphs are used. The safety matrices and risk graphs are used to determine safety integrity levels during the operation of a safety function.. They are simple, so their use can be a reason for preference, but at the same time they have some difficulties in using them. Some of these difficulties include the areas where hazardous substances are present, the risk of the entire facility, the risk tolerance criteria, and the use of these criteria for calibration. The research suggests that more

quantitative methods can be used to determine the level of security integrity, for example, Layers of protection analysis and search the positive and negative sides of the methods.

(A, Tyldesley., P, J, Rew., R. C, Houlding., 2004) “Benefits of fire compartmentation in chemical warehouses.”

A study has been made of the benefit of fire compartmentation in chemical warehouses and its cost-advantages compared to other fire protection measures. A probabilistic model was developed which considers fire growth within a compartment, fire spread to adjacent compartments and the overall effects of the fire in terms of a damage area–fire frequency product. A simple deterministic assessment was also made of explosion effects on compartment walls resulting from the sudden failure of metal drums containing liquid fuels. Three wall options were considered in the study: a concrete wall, a block wall and a plasterboard wall. The model compares the benefit provided by these wall options with the benefit provided by other fire protection measures such as detection (manual and automatic), automatic suppression, manual fire fighting (including fire brigade action), spillage control and separation.

(P. Kinsman., T.E. Maddison., 2001) “Hazard Assessment for fires in agrochemical warehouses. The Role of Combustion Products”

The combustion products released by fires in agrochemical warehouses are reviewed and a set of elemental conversion efficiencies for production of gases such as hydrogen chloride and sulphur dioxide is recommended for fire hazard analysis. In the absence of better data, it is recommended that the toxicity of the resulting smoke plume is calculated as the sum of dangerous dose fractions for each toxic component irrespective of its action on the body. It is argued that the hazard from combustion products released by many warehouse fires is at least as great as that from vaporized parent compounds, but that actual hazard range is a complex function of warehouse inventory, the way it is distributed throughout the warehouse, the location of the seat of the fire and the rate of spread of the fire.

(A, Menrad., T, Goedecke., K.P, Gruender., M, H. Wagner 2012) “Influence of the Wall Thickness Variation and the Change of the Packaging Behavior after the Impact of Standard Liquids”

The effect of the wall thickness variation of blow-moulded bodies made of high-density polyethylene an internal pressure test after prestoring the packaging with standard liquids was evaluate din experiments and simulations. The objects of the investigation were jerrycans used for the transportation and storage of dangerous goods. The aim of the simulation was to discover whether it is possible to use specimens to predict the behaviour of a packaging both after the influence of standard liquids.

(R.Vrabel., et all 2015) “Mathematical Approach to Security Risk Assessment”

This article presents a mathematical threat methodology that can help to assess security risks. This methodology will assist security advisors in optimizing risk mitigation strategies in factories, nuclear power plants, hazardous materials warehouses, and closed and protected systems. Explosive atmospheres may be present at these locations, hazardous materials such as flammable and combastible gases and liquids may be stored and may be required to minimize risk in the premises. With the security vulnerability model, it is less likely to penetrate protected objects by bypassing security barriers. Risk follow-up and effective decision making are recommended through the topographical placement of the protected objects, their security features, and the probability of the penetration.

(S,Golob., M,Kozuh., 2016)”Methodology or determining the risk acceptance criteria for the Seveso establishments.”

In this paper a new methodology development is presented to make certain a high level of safety in the daily operation of dangerous substances both in the storage and / or in the processes. With this new approach operators are engouraged to think continously about the issues that have an impact on safety. The assessment of effective Daily operation is also used as the risk acceptance criteria for seveso establishments and the presented approach is one of the methodological guidance on how to implmenet the article 19 of the directive, 2012/18/EU of the European Parliament and of the council (The Seveso III directive)

(H,Zhang., et all 2017) “Characterization of post disaster environmental management for hazardous materials incidents:Lessons learnt from the Tianjin warehouse explosion,China”

Hazardous Materials incidents (HMIs) have attracted a growing public concern worldwide. The health and environmental implications associated with HMIs are almost

inevitably severe and therefore needs a sound Management. Existing studies placed focuses mainly on the promptness and efficiency of emergency responses. This study aims critically investigate the environmental results of hazardous material explosion in China and consequently propose a framework and procedures in general for this issue.

(X.Segui., et al 2014)”Methodology for the quantification of toxic dispersions originated in warehouse fires and its application to the QRA in Catalonia(Spain)”

In this paper, a tool for the quantification of the consequences of toxic dispersions coming from fires in warehouses has been developed. This study is based on the criteria gathered in the technical guide BEVI 3.2 and the methodology CPR-15, which is used in Netherlands but implement a different , a modified Gaussian model, that takes the warehouse effect into account. The tool has been tested in different case studies and compared with other methodologies too.

(X.Liu., J.Li., X.Li., 2017)”Study of dynamic risk management system for flammable and explosive dangerous chemicals storage area.”

In this paper, risk analysis for storage area of dangerous chemicals was conducted based on the Bow-Tie model. Dynamic hazards analysis methods and classification system were established based on set pair analysis. Results were updated in real time with storage capacity and accident characteristics and integrated with GIS, detection and sensing Information technology. Based on the database technology, the emergency decision support system was made.

(A.Labib, 2015)” Learning and (unlearning) from failures: 30 years on from Bhopal to Fukushima an analysis through reliability engineering techniques.”

In this paper an analysis is carried out comparing the Bhopal and Fukushima disasters. The disasters have been investigated with the similarities. Reliability techniques such as Failure mode and effect analysis,(FMEA) fault tree analysis (FTA) and reliability block diagram have been used to analyse them

(S.P,Sivapirakasam., M,Surianarayanan., G,Swaminathan., 2008)”Hazard assessment for the safe storage , manufacturing and handling of flash compositions.”

In this work, one of the well-known hazard identification procedures called “what-if analysis” was used to identify hazards in a typical firework manufacturing facility.

Conventional hazard assessment techniques, such as HAZOP, FTA and FMEA could not be applied because there are no piping and instrumentation diagrams.

(H.Si., H.Ji., X.Zeng., 2012) “Quantitative risk assessment model of hazardous chemicals leakage and application”

The main aim of this study is to quantify the risk of hazardous chemicals leakage and take precautions against accidents. Fire-Explosion-Poisoning-Quantitative Probability model has been established. The paper introduced the probability analysis methods to analyze derivative accidents caused by hazardous chemicals leakage, established quantitative risk assessment model and made acceptable risk level analysis.

(E.Palazzi et al., 2014) “Development of a theoretical framework for the evaluation of risk connected to accidental oxygen releases.”

Here, in this paper, a short cut methodology for a fast estimation of hazards from oxygen releases and the evaluation of safety distances is presented. Starting from a historical survey on accidents involving oxygen releases and consequent scenarios, the approach includes analytical models for the quantification of incremental hazards due to oxygen releases, in non obstructed areas, both for continuous and nearly instantaneous scenarios, adopting a simple Gaussian dispersion model.

(Rosa.M., Darbra et al., 2012) “Risk analysis active learning through the investigation of real cases”

This is a paper, which covers an analysis and thus an education program in an Institution. In the exercise, the students play the role of an expert team and summarise the description of the accident, the explanation why and how it occurred and in the end they have to give a conclusions.

CHAPTER 2

1. BASIC CONCEPTS

1.1. DEFINITION OF RISK

According to the Oxford English Dictionary, the classical Latin *resicium* comes from the language of *risquism* and is known from the classical Latin *resecum*, the word of the danger zone. The *resecum* word is also derived from the *resecare* word and its meaning is "that which cuts", so it is understood that it comes from the rock, crag , reef.

According to Bernstein PL 1996; The word is derived from early Italian “*risicare*” , which means courage. It is used by old mariners to warn the helm that the rocks might be near.

According to Giddens, 1999; The word suggests that it was used to sail in sworn waters from Portuguese or Spanish and came to English afterwards: a root of the term "risk" in the original Portuguese means "to dare".

British Medical Association argued in the book *Living with the Risk* , 1987, that the word was derived from the Greek "rhiza" word, and that this situation is at the expense of sailing dangers that are very close to the cliffs, to the opposite winds, to the turbulent downdraughts, and to the returning tides.

Oxford Dictionary and Althaus, 2005; explains different categories of risk and three of them can be described as main categories.

The possibility of loss, damage, injury or other adverse or unintended condition and thus exposure to the people and/or environment. Unintended condition can be described as;

- A dangerous journey, action, an attempt
- A person or thing that is thought to have a good or bad outcome in a certain way;
- A person or thing that is seen as a source of threat or danger.

Every activity, every work, in fact, which a person does, has a danger associated with it. Common threats that all of us are exposed are: • slips, trips and falls; • disease and illness; • Foodborne illness; • transportation: car accidents, pedestrian accidents and bicycle

accidents; • sports: organized sports (football, basketball, soccer) accidents, individual sports accidents (skiing, water sports, skating); • electrical; • fire;

Over these more common, general hazards, each job also has certain hazards associated with it. For example, occupations in dangerous situations, such as firefighting, have numerous hazards associated with daily activities.

Risk is defined in many directions and it is impossible to present all definitions of the risk concept proposed and used in scientific risk areas. Kaplan and Garrick use a series of three questions to take risks.

- What might go wrong?
- How likely is it?
- What are the results?

T.Aven has made a classification regarding main risk concepts, which is advocated by various scientists in various forms like below.

1) **"Risk= Expected value(loss)(R=E)"** (Adams., Campbell. S., De Moivre., De Mensura Sortis., Verma V.Merter., Willis HH)

2) **"Risk = Probability of an (undesirable) event (R=P)"** (J.Haynes., S.Campbell., C.Kirchsteiger)

3) **"Risk=Objective Uncertainty"** (R=OU)(AH Willett., FH Knight)

4) **"Risk=Uncertainty (R=U)"**(Hardy Co; Magee JH., Mehr RI., Cammack E., Magee JH. Cabinet office

5) **"Risk=Potential/possibility of a loss (R=PO)"**(Riegel R, Miller., Atheam JL., Rowe WD)

6) **"Risk=Probability and scenarios/Consequences/severity of consequences (R=P&C)"**

Pfeffer I., Lowrance W., Kaplan S., Garrick Bj., Ale Bjm

7) **"Risk=Event or consequence (R=C)"** Rosa EA., IRGC International Risk Governance Council

8) **"Risk=Consequences/damage/severity of these+Uncertainty (R=C&U)"** Kaplan and Garrick., T Aven., E.Aven

9) **”Risk is the effect of uncertainty on objectives (R=ISO)”**

Risk is a quantitative measure in 1-2-3 and 6 .

Risk is a qualitative concept in 4-5-7-8-9.

The most general interpretation of the probability is to say that it is a measure to represent or express ambiguity by observing the rules of probability calculation. (Aven.T, 2011) According to Aven, there are two alternative interpretations that can be used; the likelihood of an event can be either;

1) A likelihood of occurrence of A, where A is part of the time when A similar population or an unrestricted population of scenarios is analyzed. It can be described as frequentist probability.

2) A subjective (a knowledge-based, judicial probability; refers to the uncertainty of the accessibility of the occurrence of the phenomenon). (degree of belief)

If probability is understood as probability of frequency, the definition is based on a model concept. On the other hand, if probability is a subjective probability, these represent the evaluators' beliefs.

In general:

Probability is defined as a measure of how likely it is that some event will occur.

“A **hazard** is defined as a source of damage, harm or adverse health effects to something or someone under certain circumstances at work.”

“**Severity** is defined as the grade of something unwanted.” “The **consequence** is defined as the effect, conclusion, or consequence of something that has already occurred.” “A security **vulnerability** is defined as a weakness that is a risk of harm, in a system or in a person.”

“The **threat** is defined as a source of danger.” Threats and hazards are considered analogous. (Lee T. Ostrom., Cheryl A. Wilhelmsen. 2012)

1.1.1. Dangerous Goods - Hazardous Materials

“A convenient definition of ‘hazardous material’ is to regard such a substance as one requiring special care to prevent harm from it - usually from accidents.”

“The United Nations Recommendations on the Transport of Dangerous Goods— which most if not all countries are aware of and which Recommendations on the Transport of Dangerous Goods—Model Regulations⁶, some adapt rigorously into their national law— classifies hazardous materials (‘dangerous goods’) into various categories (Table 1).”

UN Model Regulations are ADR (road), RID (rail), IMDG Code (sea –packaged goods), IBC Code (sea – bulk), ICAO TI (air), etc.



⁶ Model Regulations, ST/SG/AC.10/1/Rev.10, ISBN 92-1-139057-5.

Table 5: United Nations Classifications of Dangerous Goods

<i>Class 1: Explosives Division</i>	
1.1.1	Substances and articles which have a mass explosion hazard
1.1.2	Division 1.2 Substances and articles which have a projection hazard but not a mass explosion hazard Division
1.1.3	Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard
1.1.4	Substances and articles which present no significant hazard
1.1.5	Very insensitive substances which have a mass explosion hazard
1.1.6	Extremely insensitive articles which do not have a mass explosion hazard
<i>Class 2 Gases:</i> compressed, liquefied, dissolved under pressure or refrigerated	
2.1 Flammable gases	
2.1 Non-flammable, non toxic gases	
2.3 Toxic gases	

Class 2 Gases: compressed, liquefied, dissolved under pressure or refrigerated

2.1 Flammable gases

2.1 Non-flammable, non toxic gases

2.3 Toxic gases

Class 3: Flammable liquids and liquid desensitised explosives

Class 4: Flammable solids; substances liable to spontaneous combustion; substances which, on contact with water, emit flammable gases

4.1 Flammable solids, self-reactive and related substances and desensitised explosives

4.2 Substances liable to spontaneous combustion Division

4.3 Substances which in contact with water emit flammable gases

Class 5: Oxidising substances; organic peroxides

5.1 Oxidizing substances

5.2 Organic peroxides

Class 6: Toxic and infectious substances

6.1 Toxic substances

6.2 Infectious substances

Class 7: Radioactive material

Class 8: Corrosive substances

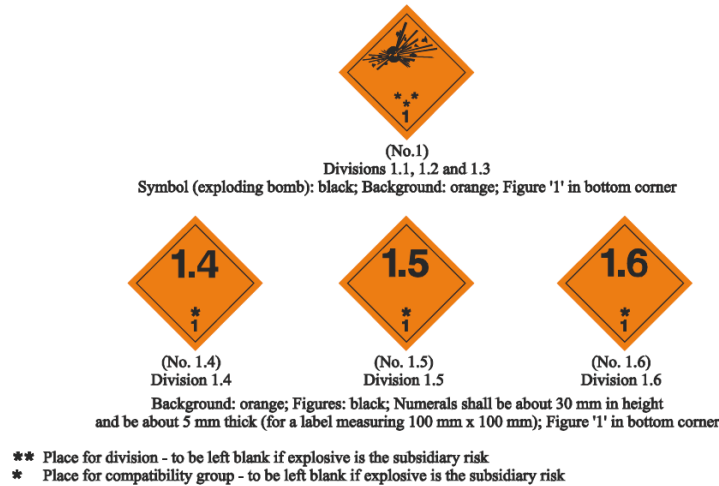
Class 9: Miscellaneous dangerous substances and articles

The increasing traffic intensity caused by globalization also leads to the transport of a greater number of dangerous goods. The prominence of the transport of dangerous goods is inevitably increasing steadily in the supply and use of basic industrial products and services in high-tech European economies. energy (gasoline, diesel, oil, etc.).

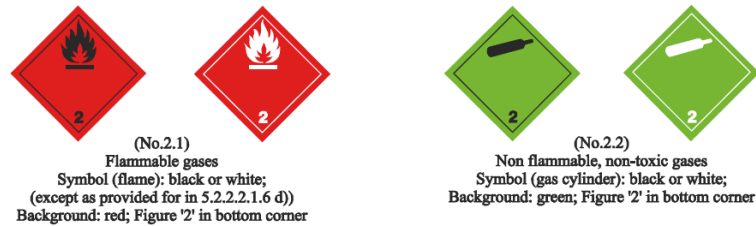
352 million tons of dangerous goods were transported to Germany via trucks, railways and ships in 2007. Regarding the Federal Statistical Office, 12 tonnes (8.5 percent) of all carried on the road, rail and water were dangerous goods. In the US, a total of 1.483 million tons of dangerous goods were transported domestically in the same period, which accounted for 10 percent of the total amount transferred, which was almost the same amount of land transportation within the country.

Table 6: Hazard Labels (ADR Book)

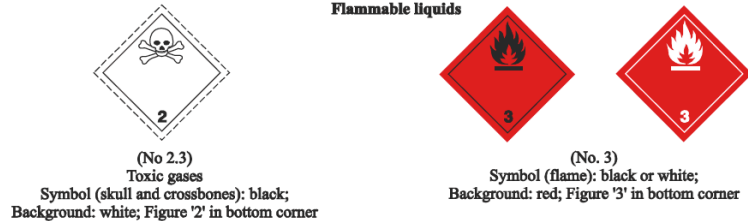
CLASS 1 HAZARD
Explosive substances or articles



CLASS 2 HAZARD
Gases



CLASS 3 HAZARD
Flammable liquids



Although there is no specific statistics in this matter for Turkey, we can assume the general rate is around 10-15. Because we do not transport fuel oil by pipeline and Turkey's

CLASS 4.1 HAZARD
Flammable solids, self-reactive substances, polymerizing substances and solid desensitized explosives



(No. 4.1)
Symbol (flame): black;
Background: white with seven vertical red stripes;
Figure '4' in bottom corner

CLASS 4.2 HAZARD
Substances liable to spontaneous combustion



(No. 4.2)
Symbol (flame): black;
Background: upper half white, lower half red;
Figure '4' in bottom corner

CLASS 4.3 HAZARD
Substances which, in contact with water, emit flammable gases



(No. 4.3)
Symbol (flame): black or white;
Background: blue;
Figure '4' in bottom corner



CLASS 5.1 HAZARD
Oxidizing substances



(No. 5.1)
Symbol (flame over circle): black;
Background: yellow;
Figure '5.1' in bottom corner

CLASS 5.2 HAZARD
Organic peroxides



(No. 5.2)
Symbol (flame): black or white;
Background: upper half red; lower half yellow;
Figure '5.2' in bottom corner



CLASS 6.1 HAZARD
Toxic substances



(No. 6.1)
Symbol (skull and crossbones): black;
Background: white; Figure '6' in bottom corner

CLASS 6.2 HAZARD
Infectious substances



(No. 6.2)
The lower half of the label may bear the inscriptions: 'INFECTIOUS SUBSTANCE' and 'In the case of damage or leakage immediately notify Public Health Authority';
Symbol (three crescents superimposed on a circle) and inscriptions: black;
Background: white; Figure '6' in bottom corner

annual consumption only for crude oil, fuel oil for 2014 is 19,9 mio tons,(Pet-der sectoral report, 2014)it makes 10 percent rate only for fuel, because our annual total transportation tonnage is approximately 200 tons.

Firms must know the danger properties of the raw materials and the chemicals they produce or process in order to manage them safely at every stage of the value chain.

When hazard data are available, companies handle exposures based on the use of a product. To know hazards and exposure, to know how the chemicals can be used safely and thus that could mean a beginning step of a risk assessment

The important points can be stated as follows:

In discussions about chemicals, the words "risk" and "danger" are frequently mistakenly used, as if they could replace each other.

- HAZARD describes the way in which , an object or situation can harm.
- RISK defines the probability that the hazardous effect actually occurs.

For a material risk, it is both a HAZARD and an EXPOSURE that leads to a negative effect. If they are not both, there is no risk.

The risk level is defined at the level at which the buyer is exposed to the risk.

Risk can be major or minor, depending on the likelihood that harm will occur. Risks are all around us in our daily lives: we make judgments, consciously or not, about the hazards involved and assess the risks before taking action whether at home, crossing the road or driving or taking a plane.

Even with the dangerous properties of a chemical, human health or environmental risk can be overlooked, provided that the chemical is handled safely under controlled conditions.

1.1.2. Risk Assessment

The notion of risk and risk assessments has a long history. “Long before 2400 years, the Athenians offered capacity for risk assessment before deciding.” (Bernstein, 1996) Risk assessment techniques and risk management as a scientific field young, not older than 30-40 years. Principles and methods has been developed since then. These principles and methods still represent to a large extent the foundation of this field today but many advances have been made. Analysis methods and techniques, that are new and more sophisticated have been developed in recent years.

In order to analyze individual jobs for risks, risk assessment techniques can be used. Jobs, such as chemical plant workers, electricians and even office workers, are often

analyzed using methods such as job hazard analysis . The focus of the risk analysis here is on the analysis of complex systems. By complex systems, for example, tasks and dangerous combinations of tasks and associated risks can be understood.

The society for Risk analysis(www.sra.org) cover some range of speciality groups such as: Ecological Risk assessment, Dose Response, Emerging Nanoscale Materials, Engineering and Infrastructure, Exposure Assessment, Microbial risk analysis, Occupational Health and safety, Risk policy and Law, Security and Defence.

The risk appraisal process consists of two steps that are defined by the two most challenging processes. However, the analysis of frequencies and risks has, in practice, been greatly simplified by a variety of qualitative or semi-quantitative methods (Carter et al., 2003), eg, Risk matrices. The risk matrices are well established in practice, especially when assessing risks in the workplace.

There is no definite rule as to how a risk appraisal should be done and at what depth it should be done. The NASA PRA guide is available in several proposals and the Nuclear Regulatory Commission (NRC) provides a number of guidance documents on the subject. The OSHA "Process Safety Management of Highly Hazardous Chemicals" directive (29 CFR 1910.119) requires hazard analysis for certain types of chemical treatment and the DOE (Department of Energy) requires risk assessment for certain types. With that, it is up to the organization to decide how deep the analysis should be. And the assessment, what is here concerned is about the chemical hazards .

1.1.2.1. Risk assessments in European Union

Environmental risks are increasingly attracting attention from dangerous material specialists due to accidents and safety reasons, parallel to the increasing number of transports. For this reason, the transport of dangerous goods and security needs and expectations are also in the public interest. In order to apply European standards for the transport of dangerous goods, European countries have to sign and follow the ADR guidelines (Accord européen relative au transport international destinations Dangereuses par Route)

The ADR is a guide regulation to the transnational transport, cross border movements of member states on the basis of UN recommendations. Often, the management or

employees of a company are unaware of the dangerous goods stored in their factories. Or, the relevant regulations and guidelines are not known in detail, which raises an important risk of liability for interested parties and companies.

Dangerous goods can be explosive, oxidizing, easily flammable, very toxic, toxic, harmful, caustic, sensitizing, cancerous, defective for reproduction, depending on chemical, physical, toxicological, physiological, radiological and other properties. They can be also described as mutagenic, harmful to the environment, harmful to water, infectious and / or radioactive, there are many prescriptions to be followed.

It is very important to educate people about the production, treatment, transport and storage of dangerous goods because of these risks of people's health and generally environment-related dangerous goods. Due to the high risk of dangerous goods, there is no "learning by doing" route; Learning "before doing" is a must in the context of basic safety information.

In recent years, some initiatives have been set up in Europe to promote and develop security in the sustainable European industrial growth with the European Industrial Engineering Department (eg European Loss Prevention and Security Initiative Working Group) (www.efce.info/WP_LP.html) .) and the European Platform for Industrial Technology Security (www.industrialsafety-tp.org). Those and some other organizations might provide support to the European Commission Health and Safety policies by implementing various directives in Member States of the European Union, encouraging security training. One of the directives on process safety is the Seveso II directive (96/82 / EC), which aims to prevent major accident risks involving dangerous substances and to limit their consequences for people and their surroundings.

This directive obliges operators to prepare a Safety Report to improve the risk management system in their enterprises. This is a legislation, in the area of prevention of major accidents in fixed industrial installations. However the important areas such as the transport of hazardous substances and intermediate temporary storage outside establishments; the transport of hazardous substances by pipelines and nuclear safety are not included in this Directive.

The European Union published publications containing valuable information on the structure and content of the report on the preparation of this Security Report (Papadakis

Amendola, 1997). There are also other guidelines for risk assessment, CSCChE / PSM (2004), (Process safety management - Canadian Society for Chemical Engineering) General Guidance for the calculation of risks - UNECE 2008; Reference guide BEVI 2009 and so on. However, engineers facing this task often look for more concrete information about the risk assessment procedures demonstrated by similar problems or case studies.

An important management method for determining how and under what conditions a chemical can be used without harm, with safety, is Risk assessment.

Providing labeling products and safety data sheets for chemicals with hazardous properties is a legal requirement in many countries of the world. Depending on the specifications of a product, companies often provide additional information, such as best practice guidelines, to ensure that they are applied and operated correctly.

Safe transport of chemicals is subject to the dangerous substance transport regulation. Specific requirements are first applied to all modes of transport under described and agreed conditions at the UN level. These are then down-scaled with various modes of transport and regional or national legislation. Which methods can be transported, in what type of containers, and in what quantities is defined with the regulatory framework.

Land transport of dangerous goods is regulated by ADR guidelines for international transport of EU member states as well as for their national transport. Standardized rules and regulations enable fair competition between ADR member states and facilitate the transport of goods through all these states. In addition to the simplifications resulting from the ADR agreement, the transport infrastructure network is also an advantage for member states to have unproblematic transports.

The United Nations has developed wide ranging classification criteria and Information methods for the transport of dangerous goods in order to achieve international standards. UNECE (United Nations Economic Commission for Europe) helps countries with regional agreements in order to maintain the successful implementation of these mechanisms for dangerous substances.⁷ The ADR agreement is revised once in every two years because of the development of new technologies.⁸

⁷ (UNECE (2011a), <http://www.unece.org> (2011a), 5 January 2012.)

Table 7: UN Numbers (ADR book;UN table)

UN No.	Name and description	Class	Classification code	Packing group	Labels	Special provisions	Limited and excepted quantities		Packaging			Portable tanks and bulk containers	
									Packing instructions	Special packing provisions	Mixed packing provisions	Instructions	Special provisions
	3.1.2	2.2	2.2	2.1.1.3	5.2.2	3.3	3.4	3.5.1.2	4.1.4	4.1.4	4.1.10	4.2.5.2 7.3.2	4.2.5.3
(1)	(2)	(3a)	(3b)	(4)	(5)	(6)	(7a)	(7b)	(8)	(9a)	(9b)	(10)	(11)
0004	AMMONIUM PICRATE dry or wetted with less than 10% water, by mass	1	1.1D		1		0	E0	P112(a) P112(b) P112(c)	PP26	MP20		
0005	CARTRIDGES FOR WEAPONS with bursting charge	1	1.1F		1		0	E0	P130		MP23		
0006	CARTRIDGES FOR WEAPONS with bursting charge	1	1.1E		1		0	E0	P130 LP101	PP67 L1	MP21		
0007	CARTRIDGES FOR WEAPONS with bursting charge	1	1.2F		1		0	E0	P130		MP23		
0009	AMMUNITION, INCENDIARY with or without burster, expelling charge or propelling charge	1	1.2G		1		0	E0	P130 LP101	PP67 L1	MP23		
0010	AMMUNITION, INCENDIARY with or without burster, expelling charge or propelling charge	1	1.3G		1		0	E0	P130 LP101	PP67 L1	MP23		
0012	CARTRIDGES FOR WEAPONS, INERT PROJECTILE or CARTRIDGES, SMALL ARMS	1	1.4S		1.4	364	5 kg	E0	P130		MP23 MP24		
0014	CARTRIDGES FOR WEAPONS, BLANK or CARTRIDGES, SMALL ARMS, BLANK or CARTRIDGE FOR TOOLS, BLANK	1	1.4S		1.4	364	5 kg	E0	P130		MP23 MP24		
0015	AMMUNITION, SMOKE with or without burster, expelling charge or propelling charge	1	1.2G		1		0	E0	P130 LP101	PP67 L1	MP23		
0015	AMMUNITION, SMOKE with or without burster, expelling charge or propelling charge, containing corrosive substances	1	1.2G		1 +8		0	E0	P130 LP101	PP67 L1	MP23		
0015	AMMUNITION, SMOKE with or without burster, expelling charge or propelling charge, containing toxic by inhalation substances	1	1.2G		1 +6.1		0	E0	P130 LP101	PP67 L1	MP23		
0016	AMMUNITION, SMOKE with or without burster, expelling charge or propelling charge	1	1.3G		1		0	E0	P130 LP101	PP67 L1	MP23		
0016	AMMUNITION, SMOKE with or without burster, expelling charge or propelling charge, containing corrosive substances	1	1.3G		1 +8		0	E0	P130 LP101	PP67 L1	MP23		
0016	AMMUNITION, SMOKE with or without burster, expelling charge or propelling charge, containing toxic by inhalation substances	1	1.3G		1 +6.1		0	E0	P130 LP101	PP67 L1	MP23		
0018	AMMUNITION, TEAR-PRODUCING with burster, expelling charge or propelling charge	1	1.2G		1 +6.1 +8		0	E0	P130 LP101	PP67 L1	MP23		
0019	AMMUNITION, TEAR-PRODUCING with burster, expelling charge or propelling charge	1	1.3G		1 +6.1 +8		0	E0	P130 LP101	PP67 L1	MP23		
0020	AMMUNITION, TOXIC with burster, expelling charge or propelling charge	1	1.2K	CARRIAGE PROHIBITED									
0021	AMMUNITION, TOXIC with burster, expelling charge or propelling charge	1	1.3K	CARRIAGE PROHIBITED									
0027	BLACK POWDER (GUNPOWDER), granular or as a meal	1	1.1D		1		0	E0	P113	PP50	MP20 MP24		
0028	BLACK POWDER (GUNPOWDER), COMPRESSED or BLACK POWDER (GUNPOWDER), IN PELLETS	1	1.1D		1		0	E0	P113	PP51	MP20 MP24		
0029	DETONATORS, NON-ELECTRIC for blasting	1	1.1B		1		0	E0	P131	PP68	MP23		
0030	DETONATORS, ELECTRIC for blasting	1	1.1B		1		0	E0	P131		MP23		

⁸ Web: <http://www.businesslink.gov.uk> (2011)

ADR tank		Vehicle for tank carriage	Transport category (Tunnel restriction code)	Special provisions for carriage				Hazard identification No.	UN No.	Name and description
Tank code	Special provisions			Packages	Bulk	Loading, unloading and handling	Operation			
4.3	4.3.5, 6.8.4	9.1.1.2	1.1.3.6 (8.6)	7.2.4	7.3.3	7.5.11	8.5	5.3.2.3		3.1.2
(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(1)	(2)
			1 (B1000C)	V2 V3		CV1 CV2 CV3	S1		0004	AMMONIUM PICRATE dry or wetted with less than 10% water, by mass
			1 (B1000C)	V2		CV1 CV2 CV3	S1		0005	CARTRIDGES FOR WEAPONS with bursting charge
			1 (B1000C)	V2		CV1 CV2 CV3	S1		0006	CARTRIDGES FOR WEAPONS with bursting charge
			1 (B1000C)	V2		CV1 CV2 CV3	S1		0007	CARTRIDGES FOR WEAPONS with bursting charge
			1 (B1000C)	V2		CV1 CV2 CV3	S1		0009	AMMUNITION, INCENDIARY with or without burster, expelling charge or propelling charge
			1 (C5000D)	V2		CV1 CV2 CV3	S1		0010	AMMUNITION, INCENDIARY with or without burster, expelling charge or propelling charge
			4 (E)			CV1 CV2 CV3	S1		0012	CARTRIDGES FOR WEAPONS, INERT PROJECTILE or CARTRIDGES, SMALL ARMS
			4 (E)			CV1 CV2 CV3	S1		0014	CARTRIDGES FOR WEAPONS, BLANK or CARTRIDGES, SMALL ARMS, BLANK or CARTRIDGE FOR TOOLS, BLANK
			1 (B1000C)	V2		CV1 CV2 CV3	S1		0015	AMMUNITION, SMOKE with or without burster, expelling charge or propelling charge
			1 (B1000C)	V2		CV1 CV2 CV3	S1		0015	AMMUNITION, SMOKE with or without burster, expelling charge or propelling charge, containing corrosive substances
			1 (B1000C)	V2		CV1 CV2 CV3 CV28	S1		0015	AMMUNITION, SMOKE with or without burster, expelling charge or propelling charge, containing toxic by inhalation substances
			1 (C5000D)	V2		CV1 CV2 CV3	S1		0016	AMMUNITION, SMOKE with or without burster, expelling charge or propelling charge
			1 (C5000D)	V2		CV1 CV2 CV3	S1		0016	AMMUNITION, SMOKE with or without burster, expelling charge or propelling charge, containing corrosive substances
			1 (C5000D)	V2		CV1 CV2 CV3 CV28	S1		0016	AMMUNITION, SMOKE with or without burster, expelling charge or propelling charge, containing toxic by inhalation substances
			1 (B1000C)	V2		CV1 CV2 CV3 CV28	S1		0018	AMMUNITION, TEAR-PRODUCING with burster, expelling charge or propelling charge
			1 (C5000D)	V2		CV1 CV2 CV3 CV28	S1		0019	AMMUNITION, TEAR-PRODUCING with burster, expelling charge or propelling charge
CARRIAGE PROHIBITED									0020	AMMUNITION, TOXIC with burster, expelling charge or propelling charge
CARRIAGE PROHIBITED									0021	AMMUNITION, TOXIC with burster, expelling charge or propelling charge
			1 (B1000C)	V2 V3		CV1 CV2 CV3	S1		0027	BLACK POWDER (GUNPOWDER), granular or as a meal
			1 (B1000C)	V2		CV1 CV2 CV3	S1		0028	BLACK POWDER (GUNPOWDER), COMPRESSED or BLACK POWDER (GUNPOWDER), IN PELLETS
			1 (B1000C)	V2		CV1 CV2 CV3	S1		0029	DETONATORS, NON-ELECTRIC for blasting
			1 (B1000C)	V2		CV1 CV2 CV3	S1		0030	DETONATORS, ELECTRIC for blasting

“The ADR agreement is kept short and is divided into Annex A, and Annex B. Annex A exemplifies the General provisions and provisions concerning dangerous articles and substances. It is subdivided into 7 parts. Annex B exemplifies the Provisions concerning transport equipment and transport operations and is subdivided into Part 8 and 9”.⁹

The following Distribution exemplifies the Applicability of ADR 2011 that was published by the United Nations: UNECE (United Nations Economic Commission for Europe) is one of five United Nations Regional Commissions directed by the Economic and Social Council (ECOSOC). It was founded in 1947. The aim of this foundation is to help reconstruct post-war Europe, to progress economic activities and to strengthen economic ties between European countries and the rest of the world.

Table 8: Annex A: General Provisions And Provisions Concerning Dangerous Articles And Substances

Part 1: General provisions
Part 2: Classification
Part 3: Dangerous goods list, special provisions and exemptions related to limited and excepted quantities
Part 4: Packing and tank provisions
Part 5: Consignment procedures
Part 6: Requirements for the construction and testing of packagings, intermediate bulk containers (IBCs), large packagings and tanks
Part 7: Provisions concerning the conditions of carriage, loading, unloading and handling

Using the experience of harmonization to facilitate the integration of the central and eastern countries into global markets, the organization is a forum of 56 countries in the West, Central and Eastern Europe, Central Asia and North America and focused on

⁹ (UNECE (2011c), <http://www.unece.org> (2011c))

analyzing the transition process from the beginning of 1990. The Commission provides a regional framework for the preparation and harmonization of standards and norms. One of the most important products of this commission is the ADR Regulation.¹⁰

The last amendments, which came into force on 1 January 2017, were published as a revised, consolidated version of ECE / TRANS / 257, Vol. I and II ("ADR 2017").

Table 9: Annex B: Provisions concerning transport equipment and transport operations

Part 8: Requirements for vehicle crews, equipment, operation and documentation
Part 9: Requirements concerning the construction and approval of vehicles.

Table A in ADR Book 1 is the starting point, which explains all details about the mentioned product. First column indicates UN number of the product which is valid in all over the World. It is designed as 4 digits.

Column 2 is about name and description of the product.

Column 3 indicates the class of the product. This class is assigned in accordance with the procedures and criterias of part 2. This column includes also classification code of the product if there is one.(Class 7-radioactives does not have a classification code)

Other columns contain the following Information respectively: Packing group / Labels /Special provisions / Limited quantities / Excepted quantities / Packing instructions(special or general) / Mixed packaging provisions / Portable tank and bulk container Instructions (special provisions) /Tank codes for ADR tanks (special provision of ADR tanks) / Vehicle for tank carriage / Transport category / Tunnel restriction code / Special provisions for packages / Bulk / Special provisions for carriage (Loading, unloading and handling) / Special provisions for carriage (Operation) / Hazard identification number.

This regulatory contains all details about dangerous products, needed equipments, packagings, vehicles but it is not easy to comment about the book and the content in the book.

¹⁰ <http://www.unece.org> Unece 2017

In order to interpret the book and apply all necessary regulations a new mechanism has been established as indicated also in the book.

1.1.3. Security Plan¹¹

After the events of September 11, 2001, international legislators deemed it necessary to develop and implement security measures for the carriage of goods on land, railways and inland waterways against possible terrorist risks. Security measures, unlike the classical safety provisions, are addressed to all parties involved in the transport chain, listed on a new ADR Section 1.10 on the basis of the relevant United Nations proposal.

These measures came into force on 1 January 2005. The requirements for high-yielding radioactive material in ADR 2013 are reserved for the high-yielding substances of the other classes and are reflected in the 2013 version of this Guideline without affecting the Guideline itself. The current revised Guides were therefore compatible with ADR 2015 and were later amended. The aim of the Regulations is to minimize the risk of abuse of the use of dangerous goods, for the purposes of terrorism, where persons, property or the environment might be jeopardized.

(Dangerous goods) transport safety for road transport and reduction of road accidents is an important issue in today's world. (Cp. Lachmayer., K., Bauer, L. 2008)

“In Europe alone, the annual total cost of road accidents amounts to more than 160 billion Euros, which is the equivalent of 2% of Europe's GNP. "Moreover, financial costs alone are not a daily burden, but many deaths and injuries are accompanied by an unbearable social cost.” (Bekiaris., E.Wiethoff., M.Gaitanidou, 2011) While industrial accidents are rare, serious injuries and sometimes fatalities can occur thus those events can damage to humanbeing and environment. In recent years, some high-impact, high-rate announcements have repeatedly directed process safety. The industry has played a key role in the development of the OECD Process Safety Corporate Governance Guidelines, which targeted senior leaders in the high-risk sectors and launched in June 2012.

Occupational health and safety are the most important issues in terms of employees. Therefore, if the organization is involved in hazardous substances, companies and industry

¹¹ CEFIC (European Chemical Industry Council is one of the most important Institution for Guidance, Regulations implementation in Europe.

associations develop guidance and best practices for specific chemicals. These may include handling practices, health care proposals, controls and inspections, treatment in the event of an accident, and injuries.

It is a general practice for manufacturers and distributors to monitor customer loading-unloading facilities before contracting to supply hazardous substances at a high level. Because loading and unloading are important areas of security focus; An on-site assessment is conducted and training is provided to ensure that the receiving company is properly equipped to handle the product safely, often by its own experts.

Companies in the chemical industry and their partners contribute guidance on Behavior Based Security (BBS), which focuses on Secure Loading and Unloading. The BBS management program aims to increase the safety of operations by affecting the behaviour of all persons involved in the loading or unloading of chemicals through observation, coaching and communication processes positively. Other European enterprises, which target safety in the value chain covers:

- An agreement between FECC (European Chemical Distributors Association) and ECTA (European Chemical Transport Association) whose name is Responsible Care partnership.
- Support for emergency response to national authorities under the ICE program covering most European countries (Intervention to Chemical Emergency Situations), which covers most European countries.
- Developed by Cefic and providing basic product information and free access to emergency services in most European and Asian languages; ERICARDS

An important legislation for the use of chemicals is the Chemical Substances Directive (CAD). This requires employers to assess the hazard and exposure to chemicals and to ensure that the risk is removed or reduced. Access to risk assessment results and safety data sheets, , personal or collective protection measures and medical surveillance training are included in workers' protection, emergency preparedness.

The extent of planning required to deal with emergencies is determined by the amount and type of chemicals retained in an area (Seveso III Directive). Higher hazardous substances in larger quantities are subject to the most demanding conditions. Some sites

that are not subject to such difficult conditions actively participate in local emergency services; Voluntary efforts at national and local level strengthen these activities.

GHS is the United Nations' global system of classification and labeling of chemicals, which provides a harmonized set of rules for identifying, classifying and communicating hazards. Labels and safety data sheets (SDS) are used to inform hazards and thus to protect human health and the environment during the transport of substances. Through the GHS, the chemical industry maintains the requirement to provide a basis for harmonization of rules and regulations at the global level. This is internationally very important when speaking safe chemicals management.

When Risk assessment is the issue, hazard and exposure data is at the center of safety management in the research laboratory, production site or outside. The results of risk assessments and risk management measures are communicated through safety data sheets. Those sheets are to ensure that chemicals are safe for the intended use. Europe's REACH legislation - Registration, Evaluation, Authorization and Restriction of chemicals is the regulation that provides the highest standards worldwide when it comes to chemical safety.

The chemical industry encourages close connection at company and union level with partners in the value chain to ensure that goods are transported safely to production sites and storage areas. Chemical industry has established successful partnerships in the non-manufacturing sectors such as transport and distribution. This partnership's name is Responsible Care and it is valid at European and national level. These include co-ordination of joint activities and co-operation on the development of regularly updated safety-related guidance materials. Triple Responsibilities has three basic elements to be understood from the definitions;

- Human health (the most important element)
- Environment we live in
- Technical Safety

Many manufacturers are collaborating with third-party distributors to offer value-added services to their customers. This needs a strong relationship based on achievements, trust and reliability, especially when dealing with dangerous products. Under the Participation

of Responsible Care in the distribution industry, companies pass independent third-party assessments of quality, safety and environmental performance; alternatively, manufacturers can make evaluations. In addition, suppliers might contribute technical training to the personnel of their distributors.

Responsible care is practiced in more than 60 countries in the World. The last members are included China, Russia and United Arab Emirates. Since 2000, lost time injuries in companies with triple responsibility were reduced by 43 percent, since 2006, chemical related transport injuries by % 36 and greenhouse gas emissions by % 34.¹²

1.1.4. SQAS

Safety and Quality Assessment Systems (SQAS) is a third party assessment programme for storage, logistics, tank cleaning and transport providers, and chemical Industry makes widespread use of SQAS assessments worldwide. SQAS assessments are performed by a European network of accredited independent third-party assessors using a standard questionnaire to assure compatibility. It helps logistics and other service providers to expand their HSE performance by discovering potential areas for development. SQAS was accepted at a very remote location, such as China and Brazil. The scheme is used for chemical distributors, in cooperation with the European Association of Chemical Distributors and for shippers in co-operation with the Chemical Distribution Institute.

The EU-OSHA (European Agency for Occupational Health and Safety) is one of the most important institutions aiming to establish "Healthy Workplaces" in the context of sharing the best practices and materials within the 2012-13 campaign.

1.1.5. Risk Assessment Tool of Hazardous Materials In Europe

Risk analysis is a methodological analysis of all information available to determine the hazards and their consequences for estimating risks, the potential exposure to these hazards, and the likelihood of their occurrence. The end result of a risk analysis provides information about the risk of the operation in question, such as a transport operation or a

¹² [www.cefic.org/Responsible-Care\(2017\)](http://www.cefic.org/Responsible-Care(2017))

fixed installation. The purpose of risk analysis is to obtain the potential consequences associated with certain accident scenarios and their likelihood of occurrence.

Two main evaluation methodologies are used for risk assessment. Qualitative and quantitative; both can be used separately or together. Qualitative risk analysis is to a large extend used as a first step in risk assessment process so that concentration can be given on higher risk scenarios, if necessary, using quantitative risk analysis methods.

Evaluating the risk is the evaluation of whether the risk is acceptable. In order to allow for a systematic risk evaluation, risk criteria must be defined to determine whether a particular level of risk is acceptable.

Risk reduction: If the estimated risk of such transport is deemed unacceptable, measures should be taken to mitigate the risk.

Table 10: Schematic Overview of The Main Steps of the Risk Assessment Process

Risk Assessment
Definition of the system
Hazard identification
Probability analysis Consequence analysis
Risk estimation
Risk Criteria Risk evaluation
Risk Evaluation
Acceptable Risk?
Risk Reduction
(additional) safety measures
Yes
No
Risk Analysis

1.1.6. Qualitative Risk Analysis

Qualitative risk analysis should be used as a starting point in the overall risk assessment process. This allows filtering of low risk events, so attention can be focused on higher risk scenarios. Qualitative risk analysis methods do not use exact numerical values. A widely used method to support the classification of risks in a qualitative approach is the use of a risk matrix. In conducting a qualitative risk analysis, it is important to sustain stability the approach throughout the whole process to make sure that the results are based on the same hypothesis.

The steps to be taken for qualitative risk analysis consists of the followings:

- The description of the transport to be analyzed and the pointing out all the related hazards involved in the transport or fixed establishments;
- Consequence analysis: exploring potential results, taking into account product hazards and the likelihood of exposure to these hazards;
- Probability analysis: determining the likelihood of exposure to definite hazards

1.1.7. Consequence Analysis

The consequence analysis seeks to assess the potential consequences of a transport accident or fixed installation by analyzing the hazards of the belonging product (hazard severity analysis) and the likelihood of exposure to these hazards in the event of an accident (hazard exposure analysis).

Hazard severity analysis: Volume of the shipping container (Bulk or packed), together with the existing UN hazard classification system for the identification of potential product hazards and their severity is important, for example, transport of dangerous goods based on hazard class, package group (PG) and hazard identification number (HIN).

Hazard severity ranking system example taking packaging group, product content into consideration

o Hazardous goods **with a low potential impact**: hazardous goods of Packing Group III transported / stored in bulk and not executing the criteria of very high potential impact goods (see below);

o Hazardous goods **with an intermediate potential impact**: hazardous goods of Packing Group II transported / stored in bulk and not executing the criteria of very high potential impact goods (see below);

o Hazardous goods **with high potential impact**: hazardous goods of Packing Group I transported / stored in bulk and not executing the criteria of very high potential impact goods (see below);

o Hazardous goods **with very high potential impact**:

- Goods that are toxic by inhalation (TIH), transported/Stored in any quantity.
- Goods transported/stored in bulk with one of the following ADR/RID

hazard identification numbers:

o flammable gases with HIN 23, 263, 238 or 239;

o toxic gases with HIN 26, 265 or 268;

o highly flammable liquids with HIN 33, 333, 336, 338, 339, X323, X333 or X338;

o highly toxic liquids with HIN 66, 663, 664, 665, 668, 669, 886, X88 or 668.

Table 11: Example of Hazard Severity Ranking System

Hazard severity (potential impact)	Criteria	Score (A)
Low potential impact	PG III in bulk	1
Intermediate potential impact	PG II in bulk	2
High potential impact	PG I in bulk	3
Very high potential impact	Toxic by inhalation in any quantity - Flammable gases in bulk - Toxic gases in bulk - Highly flammable liquids in bulk - Highly toxic liquids in bulk	4

Table 12: Scientific Researches About Hazardous Goods in Warehousing

Scientific resources about hazardous goods in warehousing			
Risk assessment emergency plan	Integrated approach of ABC, XYZ, analysis and AHP risk analysis	Consequence evaluation analysis	
Assessment of risk of significant environmental contamination from storage And distribution sites. C.R.Pearson 1988 I.Chem E.Symposium series Assessment of fires in chemical Warehouses An overview of the TOXFIRE project Petersen,Markert(1999)	<u>We@re risk method</u> . <u>Security risk level</u> <u>classification of stock</u> keeping units in a warehouse	Assessment of the consequences of accident scenarios involving dangerous substances Pintaric. (2007) Pesticide warehouse consequences:experiences from a Danisah risk analysis study. Hansen. (1993)	For all processes Lessons to be learned from an analysis of ammonium nitrate disasters in the last 100 years Pittmann,Han,Harding etc(2014) International co-operation in hazmat accident prevention: Thomson. (1999) Major industrial accidents regulation in the European Union. Wetih;Porter;Kirchsteiger. (1998) Security and risk based models in shipping and ports:Review and critical analysis. Bichou. (2008)
Scientific resources about hazardous goods in production process area			
Generic event tree model	Historical analysis evaluation	Consequence, risk analysis	
Generic event trees and probabilities for the release of different types of hazmat Vilchez, Espejo, Casal (2011)	An analysis of the database coverage of industrial accidents involving hazardous materials in Europe Haastrup,Romer (1995)	Major hazards analysis for populations adjacent to chemical storage facilities Rigas;Sklavounos . (2004) Major accidents in process industries and an analysis of causes and consequences. Khan;Abbasi. (1999)	

Table 13: Scientific Researches About Hazardous Goods in Transportation

Scientific resources about hazardous goods in transportation			
A priori consequence calculation models	Historical analysis evaluation	Selecting routes with optimisation/optimal path	Risk analysis
Assessment of an explosive LPG release accident R.Bubbico(2008)	Historical analysis of accidents in seaports Darbra,Casal(2003)	Dangerous good transportation by road;from risk analysis to emergency planning Fabiano, Curro, Reverberi, Pastorno (2005)	Risk analysis of transportation on road and railway from a European perspective Hoj,Kroger(2002)
Designing emergency response networks for hazmat transportation.Bernana,Verter,Kara, Rotman,(2005)(optimal design of specialzd team)	Database for accidents and incidents in the fuelehand ind. Olivares, Rivera,Mc.Leod(2015)	Modeling of transport risk for hazardous materials Erkut, Verter(1997)	Risk management of road and rail transport of hazmat in Sicily.(TPA an) Bubbico,Maschio,Mazzarotta(2005)
Toll policies for mitigating hazmat transport risk. Marcotte,Mercier,Savard, Verter.(2009)	Predicting the frequency of accidents in port areas by developing event trees from historical analysis Ronza Felez,Darbra,Caro,Vilchez,Casal(2003)	Designing a road network for hazmat transportation Kara,Verter(2002)	Railroad transportation of dangerous goods. Risk approxm appr:positioning hazmat in train(2005)
Hazard and risk potential of chemical handling at ports. Rao,Raghavan (1995)	A survey on hazmat accidents during road transport in China from 2000 to 2008 Yang,Li,Zhou,Zhang,Huang,Bi(2010)	Risk analysis for road and rail transport of hazmat a GIS approach .Bubbico,Cave,Mazzarotta(2004)	Dangerous goods transportation by road;from risk analysis to emergency planning Fabiano, Curro, Reverberi, Pastorno,(2005)
	A survey of accidents occurring during the transport of hazardous substances by road and rail. Oggero,Darbra,Munoz,Planas,Casa(2006)	Accurate calculation of hazmat transport risks Kara,Erkut, Verter(2002)	
	Historical analysis of accidents in chemical plants and in the transportation of hazardous materials. Vilchez,sevilla,montiel,casal(1995)	Hazardous materials transportation.(Modelling,Op.R) Erkut,Stevanus,Tjandra,Verter(2004)	
	Accident investigation practices in Europe-main responses from a recent study of accidents in industry and transport (2004))	A path based approach for hazmat transport network design. Verter,Kara(2006)	
	Accidents during marine transport of dangerous goods. Distribution of fatalities.Romer,Haastруп,Petersen(1993)	A lead-time based approach for Planning Rail-truck Intermodal transportation of dangerous goods Verter,Verma. (2007)	
	Using transportation accident databases to investigate ignition and explosion probabilities of flammable spills Ronza,Vilchez,Casal(2007)	A framework for risk assessment and decision-making strategies in dangerous good transportation. Fabiano;Curro;Palazzi;Pastorno.(2002)	
	Using major hazard database systems to develop event trees for flammable materials. Vilchez, Casal(2001)		
	The problem of fire in ships transporting chemicals. Analysis of a case.Alavedra,Cistero,Sole,Rovira,Casal(1998)		
			Transport mode selection for toxic gases Rail or road?Bagheri,Verma,Verter,(2013)
			Railroad transportation of hazmat materials Models for risk assessment and managment Verma,Verter. (2013)
			New detailed numerical procedures for calculating risk measures in hazmat Transportation.Leonelli,Bonvicini(1999)

CHAPTER 3

2. RISK ASSESSMENT TOOLS

The main Risk Assessment tools are mentioned below. The purpose of risk assessment is to bring tolerable or acceptable limits to the risk. This assessment is realized in the following steps in several stages.

1. Identifying dangers and/or possible dangers;
2. Defining users and/or tasks;
3. Determination of the risk level; ° low, acceptable ° medium, moderately acceptable ° high, not acceptable
4. Potential controls assessment—displacement, exchange, engineering and administration controls, and/or use of personal protective equipment;
5. Evaluating a report;
6. Application and review.

In this thesis study, the risk assessment tools are used in following classifications:

- Path analysis/Cause analysis
- Consequence analysis
- Event tree analysis
- Fault tree analysis

2.1. PRELIMINARY HAZARD ANALYSIS (PHA)

This method is applied at the very beginning of risk assessment in the conceptual scheme of a new system, process and operation. It is implemented to identify potential dangers or potential threats to a system, process, or business. This method is also useful for assessing the processes that have been taking place over the years to determine the hazards associated with the organizations themselves.

Hazard analysis is generally carried out in early periods of diagram, but can also be carried out at different periods in the lifetime of processes and installations.

The main purpose of the PHA is to describe and define potential hazards known at the outset of a design phase. Partial lists of these hazards are summarized below.

Raw materials, intermediate and final products and their affectability

- Factory equipment;
- Facility settling;
- Working environment;
- Operational actions (test, maintenance, etc.);
- - Interface between system items.

Preliminary hazard analysis describes dangers such as explosions, radioactive materials, pressure vessels or lines, toxic substances, etc. The PHA specifies where each danger will appear, its importance, and the method to be used to remove the hazards from it, or how to control the risk involved. The likelihood of an unexpected dangerous release of energy or material (an accident) will determine the safety of the PHA for its purpose as follows.

Event frequency (per year)

less than 10^{-6} less than reliable: Occurrence is expected not to happen during the lifetime of the facility.

10^{-6} to 10^{-4} Reliable and extremely unlikely: occurrence will not happen during the life cycle of the installation.

10^{-4} to 10^{-2} Reliable and unlikely. Occurrence may happen during lifetime of the installations for example trained workers failure.

10^{-2} to 10^{-1} Very likely: Occurrence may happen frequently, for example corrosion

Nuclear plants generally need to work with quantitative methods. Qualitative methodology is applied for non-nuclear plants. Quantitative measurements per year $0.1-10$ per year $0.001-1$, per year $0.0001-0.001$, per year $0.000001-0.00001$, yılda $0.0000001-0.000001$) { } Rare occurrence.. A PHA tries to rank the dangers in the qualitative measurement of the worst potential result from worker faults, environmental

conditions, design deficiencies, procedural errors, and system, subsystem and component fault The classification are described like below:

1. Class I Hazards: Negligible. The worst effects are a dangerous situation that can result in minor injuries, job related illnesses or system breakage..

2. Class II Hazards: Marginal outcome. It is a danger that the worst effects can lead to minor job related illness or system breakage.

3. Class III Hazards: Critical. It is a dangerous situation where the worst effects are caused by serious injury (such as not being able to return to work), severe job related illness or major financial or system breakage. 4. Class IV Hazards: Catastrophic. It is a dangerous situation that could cause the worst case to cause deaths, injure the staff in a way that can not be reversed, or cause loss of plant or system.

PHAs aim to remove the source or cause of the hazards, which is the most reliable solution. If the source or cause can not be removed immediately, the hazard should be lessen or redesigned as much as possible like below:

- Redesigning, replacing, or replacing equipment (eg, excessive temperature, noise, or pressure) to clean sources.
- Restructuring a process to use less toxic materials.
- Restructuring a work area to lighten physical stress and ergonomic disorders.
- To provide safe and healthy environment, with a a general ventilation of fresh air

2.2. FAILURE MODE AND EFFECT ANALYSIS (FMEA)

This method is applied to develop systems, processes, or operations to indicate probable failure modes in the system, and to ensure that errors are classified according to their severity and probability. It is usually done after a PHA and before further analysis.

FMEA is a more detailed method than PHA and firstly the flow diagram of the procedures is extracted and this diagram is a step-by-step description of the procedures in a sense.

Table 14: Failure Mode and Effect Analysis (FMEA) (Ostrom, C. A. Wilhelmsen.2012)

	FMEA, starting a lawn mower	
Process steps	Potential failure modes	Potential failure effects
Check gas and oil	Unable to remove gas cap Unable to remove oil plug Unable to determine depth of oil Oil or gas spill	Delay in process or personal injury Delay in process Delay in process or the potential to overfill oil level Environmental damage or potential for fire
Fill as necessary	No oil available/Gas station closed/No gas container /Overfillgas/ Overfill oil /Water in gas or oil	Delay in process /Delay in process / Delay in process / Potential for a fire or environmental damage / Environmental damage/ Delay in process or engine damage
Set controls	Controls broken No instruction available Controls out of adjustment	Delay in process Delay in process Delay in process or engine damage
Initiate starter	Starter malfunction Cord broken Engine flooded Ignition system malfunction	Delay in process and/or repairs necessary Delay in process and/or repairs necessary Delay in process Delay in process and/or repairs necessary

2.3. FAILURE MODE, EFFECTS AND CRITICALITY ANALYSIS (FMECA)

FMECA expands the FMEA by incorporating a criticality analysis that is used to graph the likelihood of error modes versus the severity of the results. The FMECA can be used after an FMEA has been operated, together with an FMEA or an FMEA can be used instead of FMECA.

FMECA can often be defined as a criterion based on the views of subject matter experts, but also on the likelihood of coming to the scene and / or on how critical the process errors are, based on the results or effects. For FMECA purposes, it can be improved using rough calculations such as below:

- Historical data;
- A similar technique like Delphi
- Datas of accidents
- Subject matter experts
- the best guess

In this process, firstly it is tested how bad the results may be, what the criticality means, and how critical it may be in the operation steps within the system.

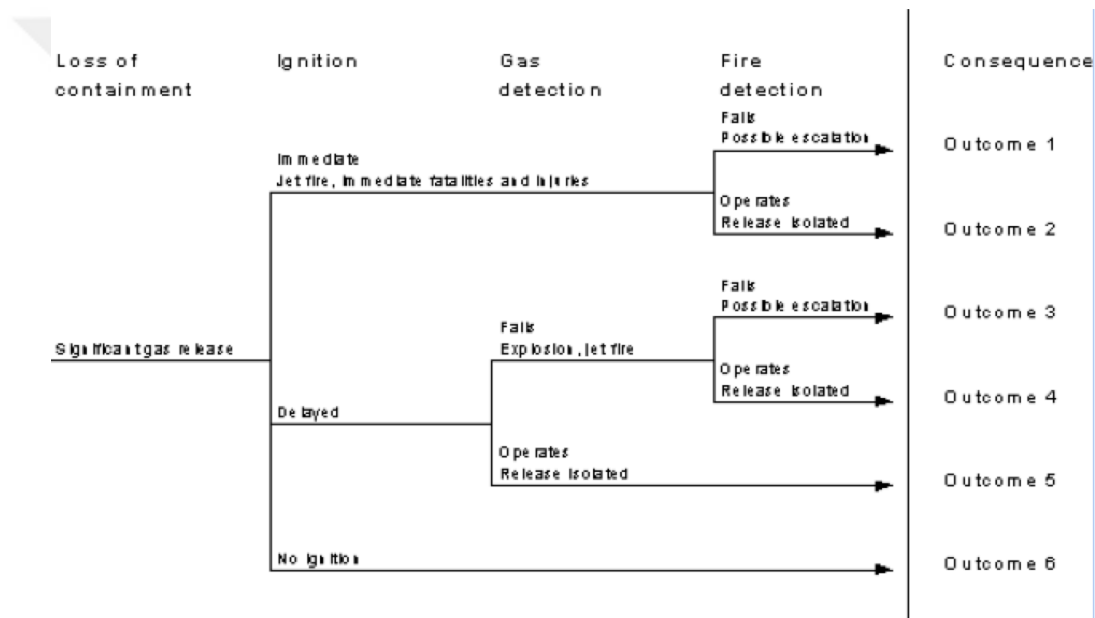
Table 15: Failure Mode, Effects, And Criticality Analysis (FMECA)(T. Ostrom., C. A. Wilhelmsen,(2012)

occasional failures		
Low: isolated failures associated with similar processes	1 in 15,000	0.000067
Very low: only isolated failures associated with almost identical processes	1 in 150,000	0.0000067
Remote: failure unlikely. No failure ever associated with an almost identical processes	1 in 1,500,000	0.00000067
	FMECA Criticality	
Criticality	Relative probability rates	Probability rates
Very high: failure is almost inevitable	1 in 3 to 1 in 2	0.33 to >0.50
High: generally associated with processes similar to previous processes that have failed	1 in 20 to 1 in 8	0.05–0.125
Moderate: generally associated with processes that have experienced	1 in 2000 to 1 in 80	0.005–0.0125

2.4. EVENT TREE ANALYSIS

Event tree analysis is a method that analyses the sequence of events in the potential accident cycle. Many different forms of event trees have been expanded. The event tree approach shows that if the event occurs, the events that occur after the first accident follow a certain sequence. In cases where a particular index is not implied, the "Failure modes and effects" analysis can be used.

Table 16: Loss of Containment



For example, a fire starts in a factory. This is the initiator. Then the fire suppression system is forced again. When the system is in motion, the fire is either quenched or repressed and the sequence ends. If the repressurization system fails, the fire does not reappear or repress and the accident sequence advances.

Table 17: Fire Suppression System Description and Outcomes

Event	Description	Possible outcomes
Fire This is the initiating event — Fire suppression system actuates	This is the initiating event — Fire suppression system actuates The fire suppression system detects the fire and it actuates	Success—system actuates and controls the fire Failure—system fails to control the fire Fire alarm system actuates Fire alarm system detects
Fire alarm system actuates	Fire alarm system detects the fire and sends a signal to the appropriate fire department. Fire department arrives in time to extinguish the fire before major damage occurs	Success—fire s extinguished prior to major damage occurring Failure—fire causes major damage

Table 15: T. Ostrom, C. A. Wilhelmsen.(2012)

Table 18: Event Tree Flows

Initiating Event	Event 1	Event 2	End State	Path Probability
Fire	Fire suppression system actuates	Fire alarm systems end signal to fire department		
<pre> graph LR A[Success] --- B[Success] A --- C[Failure] B --- D[Success] B --- E[Failure] C --- F[Success] C --- G[Failure] </pre>			Minimal Damages	$0.001 \times 0.99 = 0.00099$ or 0.001
			Moderate Damages	$0.001 \times 0.01 \times 0.995 = 0.00000995$ or 00001
			Severe Damages	$0.001 \times 0.01 \times 0.005 = 0.00000005$

Table 16: T. Ostrom., C. A. Wilhelmsen.(2012)

2.5. FAULT TREE ANALYSIS (FTA)

An FTA is a risk analysis method usually applied to determine the causes of dangerous and critical events. It is a logical process that examines all potential events leading to a critical event. As a logical process, the FTA examines the potential accidents that may lead to a critical, dangerous event.

Fault tree analysis is a widespread methodology that correspondences the emergence and sequence of different event types . In the context of the FTA, a mathematical model has been put into former accidents in order to determine the most prominent factors (best events) and guess the impact on the accident rate.

The model, the fault tree, is used to estimate the likelihood of future accidents from top to bottom, ie to the most basic events. In order to calculate the frequencies of the extreme points, the data is managed and probabilities are assigned according to the availability of data. The fault tree starts from the bottom of the tree. This approach from the top down begins assuming that a win has taken place. It then takes into account possible direct causes that may lead to this accident. Later, these causes are rooted. In the end, it searches for ways to stay away from these origins and reasons. The obtained diagram is called a mistake tree because it is similar to a tree.

Basic Fault Tree Events

Table 19: Basic Fault Tree Events

Symbol name	Symbol	Description
basic event		A basic initiating fault(or failure event
undeveloped event		An event that is no further developed. It is a basic event that does not need further resolution
Output event		An event that is dependent on the logic of the input events
External event(house event)		An event that is normally expected to occur. In general, these events can be set to occur or not occur, that is, they have a fixed probability of 0 or 1
Conditioning event		A specific condition or restriction that can apply to any gate
Transfer		Indicates a transfer to a subtree or continuation to another location

Table 19: T. Ostrom, C. A. Wilhelmsen.2012

2.6. HUMAN RELIABILITY ANALYSIS (HRA)

The HRA interpretation refers to the need to understand what error problems are and to take mitigation measures so that people and systems can not be fault-free, and improved reliability can be achieved. HRA aims to quantify the probabilities of human errors for a

given task. HRA assists in describing vulnerabilities within a task, and provide guidance on how to improve reliability for that task...HRA is used in complex operation systems such as aviation, military, medicine, transportation. The HRA explores how the human factor can raise the risk in an operation, in a system, or as a risk instrument on its own. At the same time during the risk assessments of PRAs or PSAs, the importance of human risk source has been understood and the need for HRA as a methodology has also emerged.

While nuclear power plants, are the first places and processes for PRAs and HRAs to be used as methodologies, PRAs are carried out in many processes or tasks. Some of the examples can be sorted as the installation and disassembly of nuclear weapons, oil production operations, chemical processing plants, and the like.

Any system or task involving people is open to human error. HRAs are applied to measure the likelihood of human error. The HRA can also be applied to describe steps or actions in the system that can be aimed for changes that could mitigate the likelihood of human error.

When PRA analyzes the entire failure series, HRA will focus only on human participation.

2.7. PROBABILISTIC RISK ASSESSMENT (PRA)

PRA is the first methodology that comes to mind in order to assess the risks associated with complex engineering systems, processes or operations such as spacecraft, aircraft or nuclear power plants. It is a systematic and comprehensive method of assessing risks.

PRA applied to the most complex systems and uses combinations of all risk assessment tools and techniques and thus forms an integrated risk model. For example, implementing a fully integrated PRA of a nuclear power plant can take years and can be valued at millions of dollars. It is considered as of the most complex systems.

In recent years, new tools, methods have been needed to take these decisions, as key advances in technology require decision makers to identify risks with tools, tools to minimize unwanted events, equipment and human failures.

One of these tools can be named as Probabilistic risk assessment.. Initially used by the aerospace and nuclear energy industry, it has been used as a decision-making tool to enhance safety throughout its use, environmental regulations and industry clearing

decisions, computer security analysis, plant maintenance, and all aspects of industrial design.

It also presents an analysis to demonstrate cost-saving decisions, either by demonstrating the efforts that need to be made to achieve the greatest gains, or where significant amounts of time and resources are spent avoiding spending time or pursuing practical gains.

Two factors with risk in a simple risk assessment model: Probability and outcome are analyzed, evaluated and non-numerical values are given. Non numerical values are characterized as high, medium, low and intermediate levels.

The resulting values in qualitative risk assessment are: none, undesirable, unacceptable, and so-called effect.

Quantitative risk appraisal is a more detailed process when compared to the qualitative appraisal process, and at the same time the expert system / process information is a prerequisite to start the appraisal process. This expertise is closely related to system information, event / process information. Information such as which events are normal, which cases are abnormal, what operating procedures may be in case of casualties, what error information may be in certain cases, and what specific error information may be obtained; such questions are obtained through research and experience, so those all information shows expert knowledge.

Quantitative research is a methodology that statistically analyses numbers. It uses statistically analysed numbers to reach the results. Hard science uses quantitative research to answer specific questions. 4 types of numerical quantitative research tool can be described.

1. The descriptive consists of data to answer questions or test a hypothesis.
2. Correlation tries to determine whether there is an association between two or more quantitative variables. Because only a correlation coefficient between 0.00 and 1.00 is sufficient, therefore there is no cause and effect relationship.
3. Cause-comparative methodology is a method, which compares the relationship between cause and result. During this comparison, the cause is not manipulated.

4. In Experimental methodology, again a cause and effect relationship is established. but this time the reason is manipulated during comparison. Experimentally, the cause or argument is dependent on the independent variable, which creates the difference and effect.



CHAPTER 4

3. DANGEROUS GOODS LOGISTICS WAREHOUSES

3.1. DEFINITION OF DANGEROUS GOODS LOGISTICS WAREHOUSE

Tracking logistics movements accurately is very critical logistics activity, which has direct impact to performance of any line of business. When the business line deals with hazardous goods, this becomes an even more critical field of expertise which has to be structured with good processes and infrastructure with safe storage capabilities and technical capabilities to register and trace movements timely.

In a very competitive business environment, logistics companies, when providing hazardous goods storing services to their customers, should not only focus on good services on process, safety and technical capabilities but also should create efficiencies leading to reduced costs on customers commercial operations.

Hazardous Material Storage covers the end to end services which deals with a product within the life cycle of the product starting from raw material, semi finished product to the finished product which are either stored in warehouses or transferred to distribution centers.

Hazardous storage efficiency is traced by a company's logistics system which helps management of a company monitor the production timelines, stock levels, stock turnover.

Hazardous Material Storage can be done either in open or closed areas depending on the requirements of the goods. The services provided under warehousing these products can be categorized as inbound, storage, picking and delivery.

Like it is expected from any other warehouse management, it is expected from a hazardous material warehouse to be most efficient when processing, packaging and delivering goods. While focusing on efficiency to provide lost cost servicing, Hazardous Warehousing also requires a very high standard on risk management due to the nature of the products that are being stored.

In order to meet the efficiency requirements and reduce the risks, delivery of goods are done via distribution centers where stocks are kept at minimum level just to meet customer

requirements on time. Distribution centers are located closer to the customers, which helps just in time delivery. In high efficient distribution centers, information is gathered in real time. All these factors add up to profit optimisation for customers

The Hazardous Materials Warehouses and distribution centers operate under the ruling of Customs Undersecretaries and their owner must be a legal entity or an organization. These warehouses can store nationalized import goods or export goods, all classified under Hazardous Materials category.

Storage of Hazardous Substances takes place within the flow, which is from the product raw materials procurement until the end product to the end user's delivery, adding different ingredients to the definition in line with changing requirements in this process, and therefore is a matter of wide scope.

3.1.1. Role of The Dangerous Goods Warehouse in Logistics Processes

Hazardous Material Storage and warehouse management has become an integral part of Logistic services and has been developed as a separate field of expertise. Hazardous Material Storage strategy, with the costs of the logistics process, has a very significant impact on customer service.

Storage is a ring of goods movement, which is stopped for various purposes. This movement has to be in a regular state so no complexity occurs and the flow will be systematic.

Warehouses are treated as cost centers however when managed efficiently, the impact to the profit of the business may be remarkable.

It is not only the warehousing process that creates benefit to a business but the end to end logistics process including the warehousing. A systematic set up with minimum complexity within the cycle of logistics will lead to optimization of costs.

Another aspect of the functions of hazardous substance warehouses is the role of logistics service providers. While logistics service providers carry out their logistics processes, there are two main activities in delivering goods from the buyer to the customer. these; Activities related to movement (transport) and other activities related to waiting

(storage). Dangerous goods warehouses can be said to be one of the important activities of logistics service providers in this respect.

3.1.2. Types of Stock in Dangerous Goods Logistics Warehouse

The materials stored in the storage of Dangerous Goods can be basically divided into raw materials, semi-finished products and finished products.

Raw materials: Such materials are raw materials that provide input for production. Semi products; It is the materials that are in the process of processing.

Finished product: Such products are available for sale to existing customers. Whatever material is used, it is also used at the beginning of important functions of the warehouses to buffer the output from the foreseeable or unpredictable market demand.

This is also the case for Hazardous Warehouses. Another function of the warehouses is the places where the value added activities are made. There may also be value-added activities such as the division of dangerous goods into smaller lots into the warehouse, the addition of inserts in the packaging.

Other hazardous material inventories in the warehouses, which are classified according to their functionality can be expressed as:

Consumables: Bulbs, cleaning materials, oils, fertilizers, paint, dunnage (packaging materials) and so on. They are used in many processes and are usually processed like raw materials.

Safety inventory: This type of inventory can serve a variety of purposes, including: Compensating for supply and demand uncertainties. "Decouple" and separate the different parts of the operation so that they can work independently of each other.

Transit input-output inventory: It is an ordered material made during the shipment of the products, not ready for use and sale yet.

3.2. WAREHOUSE BUSINESS PROCESSES

3.2.1. Receiving (Material Acceptance)

Material Acceptance is a very important process in hazardous material storage. It is one of the bases of warehouse operation to ensure that the correct product is picked up at the right time and in the right condition. This indicates the supplier - manufacturer compatibility. The warehouse manager assesses the quantity and quality of incoming materials in terms of packaging and tonnage in the case of accepting the materials in the warehouse.

When the material arrives at the point of warehouse destination, many points may be late for correction. Due to this, many steps must be taken before material acceptance.

3.2.2. Pre-receipt (acceptance)

Suppliers are expected to deliver materials in good quality and quantity. The pre-acceptance officer of the hazardous material warehouse is the person who checks the materials to be appropriate in terms of packaging and number. Otherwise, the materials are not accepted to the warehouse. They are returned.

The important Information details about the materials , which should be agreed between the buyer and seller or supplier are ; the type of the packagings, ; for example whether they are in drums, bottles, jugs, IBC ‘ s, bottles in cartons , whether they are in pallets or nonpalletized, the sizes of the packaging (length, width, height), carton quantities of the items, description of the materials, MSDS of the materials etc.

According to the description and the packaging of the items the necessary equipments such as forklifts and/or manual lifting vehicles should be ready for the acceptance of the materials. Identification of the materials are very important and if there are barcodes on the packagings and RF radio frequency system in the warehouse, those systems ease and speed up the processes.

If the materials are palletized, this speed up the process of loading and unloading.

If the items are loaded with pallets, the dimensions of pallets are very important such as the materials dimensions. Because the stocking will be made according to the incoming pallet dimensions and the locations of the pallets in the racking systems. At the moment different markets and organisations use different pallet sizes in the world.

According to ISO standards (ISO 6780) 6 pallet dimensions are used in general worldwide. Those are shown in the below table¹³.

Table 20: ISO Pallet Dimensions

Dimensions in mm (W × L)	Dimensions in inches (W × L)	Country of use
1219 × 1016	48.00 × 40.00	North America
1000 × 1200	39.37 × 47.24	UK and Asia; pallet commonly referred to as a UK or industrial pallet
1165 × 1165	44.88 × 44.88	Australia
1067 × 1067	42.00 × 42.00	Most countries
1100 × 1100	43.30 × 43.30	Asia
800 × 1200	31.50 × 47.24	Europe; pallet commonly known as a euro pallet

The loading bay in today's contemporary warehousing is an ordinary facility and for the risky materials such as chemicals it is also necessary to mitigate the risk.

If there is no loading bay in the facility, then the equipments for unloading should be ready such as tail lift and the vehicles should be side loading vehicles.

In General, it is known that 20% of the suppliers constitute 80% of the entry problems in the warehouses. Because the labour cost can be the biggest cost in the operation (50-60%) depending on the operation, automation on the operation, the effective management of the operation, specifically in-handling and taking the precautionary actions in pre receipt process, would reduce the cost.

Therefore continuous coordination, monitoring and correction in the system between the warehouse, procurement, customer services and supplier will provide great benefit in firstly prereceipt and then in whole process.

¹³ Web.www.ifeuk.com/downloads/Palletspecinfo.pdf accessed:02.02.2017

The first thing to be provided in the preparation process prior to acceptance; the supplier must send the ready-to-buy materials to the warehouse when the warehouse owner or buyer requests it, not when the materials are ready or when the supplier wants .

According to the tonnages, quantities in the loaded vehicle, the needed time of length for offloading has to be calculated and planning of the offloading bay has to be made. The workers has to know the items and their content and WMS (Warehouse Management systems) has to allocate locations for materials prior to arrival. From experience, although it will take longer, it is more correct to count the product and compare it with the delivery paper. Only after a certain time, if a confidency occur between the supplier and buyer/warehouse owner, good faith receiving can be organized and if discrepancies found afterwards, the missing items cost can be charged to supplier or the missing items can be asked free of charge. The random checking also can be done only after a trust have been provided between parties.

The supplier can be asked to load the same items together, which increase the productivity by up to 50 %. This is more important among the dangerous goods that react with eachother.

If the items has to be transported with temperature controlled vehicles, the temperature history of the vehicle has to be controlled and the items has to be entered to the warehouse only after this process.

During the in-handling, standard recordings such as the product code, description and quantity of the items is needed. For risky products such as dangerous chemicals, batch, lot numbers has to be added to the recordings and in this concept barcode scanning is ideal.

3.2.3. Quality Control

Accepted materials can be subject to quality inspections by warehouse management. For this purpose, samples are taken randomly at a certain percentage. The lot passing through the quality inspection is placed in the warehouse.

Certain products are considered to require more stringent control when they are received. These include high value products, food, hazardous goods, heat sensitive products and pharmaceuticals. In addition, new suppliers are considered in this class. Materials from the warehouse should be located in an area close to the warehouse entrance

area to check-in. As soon as the goods are accepted, it needs to be done as quickly and efficiently as possible in order to get the products to the system quickly. If there is material going to the test for quality assurance, the products must be taken to a specific quarantine area and the test results expected.

3.2.4. Stocking

Products with warehouse acceptance are stored at the locations defined in the system according to Barcodes on the labels in WMS system warehouses. For risky chemicals, the WMS contained warehouses should be taken as examples. The rules in the warehouse follow FIFO rules and/ or In the storage of the chemicals, the charge number produced by the material and the date of the production should be entered into the system and the first release of the first produced product should be executed The products are handled on pallets and stacking machines.

In today's warehouses, the products allocations are done by WMS just before the items physically entered to the warehouse. In order to do this allocation correctly, a great deal of Information is needed. The following Informations can be included into the system; if an effective system is expected.

Dimensions of the packagings, if they are palletized, palletized goods, ABC analysis results of the products; family product groups, actual sales situation, weight capacity of racks, pallet locations sizes, hazardous goods contents and allowed racking instructions.

The fastest moving items has to be located near to the dispatch area, slow moving items towards to the end of the warehouse and at the highest shelves. The IBC s should be located on the floor or at the lowest shelves if they are fastest moving items and if the content is dangerous and if leaks not to give any danger to the below located packagings. The products, which appear together with another product in the picking list, should be located side by side, so the cost of time will be lessen. .

Palletized products which have been taken into the acceptance area are taken on the stock area and placed according to the instructions on the shelves. Stockpiling products should be stocked with a certain space left on the wall. Warehouse Inventory count of the products are made according to the Inventory Counting Instructions.

The amount of products coming in from the supplier is controlled by the amount of products in the warehouse. Whole stocks are checked daily on paper. If there is a discrepancy, physical counting is done at certain intervals of time.

Cleaning of the warehouse should be done regularly. Materials stored in the warehouse during cleaning are made according to the hazardous materials storage instructions. The empty pallets are certainly stored in the warehouse, not in the corridors, in the defined pallet area. No material is kept indoors in defined areas in the corridors.

When the stacking machine is not being used, it should be kept on "Battery Charging Area". Maintenance, cleaning, battery charging operations should be done in this area. All products are kept in the warehouse as specified in the dangerous goods instructions at the correct defined locations on the pallets according to the product size and type.

3.2.5. Material Preparation

Customer Sales Orders are forwarded to the relevant store through WMS (warehouse management system). An order status report is received from the system. The batch is prepared accordingly. The prepared batch is shared with the customer. It updates the batch summary by processing the Vehicle plate and driver information in the batch summary. Shipment Collection Lists are prepared according to Batch summary and loading order.

3.2.6. Loading into Vehicle

The products prepared according to the Shipping Preparation Instruction are brought to the loading area. The vehicle information to be loaded into the WMS system is entered. The ramp of the vehicle to be loaded is determined via WMS. The vehicle driver is informed. Vehicle information on the ramp is checked. The driver's license and vehicle driver's license are processed in the system. Installation is done.

The floor of the vehicle is controlled in terms of damage, hole or dust or dirt on the floor. Then, if everything is ok in terms of safety, the loading is realized with loading equipments.

3.2.7. Cross Docking

Cross docking is a process, that the products are transported directly from producer to the despatch areas. Clear labeling and advance Information is very important in this type of delivery not to have a complex, faulty delivery. In this type of delivery, there is no need a picking and a place to stock in the warehouse. The need is only alert the warehouse acceptance and delivery personnel with the exact delivery Information. The delivery note shall be issued in 5 copies. Counterparts;

The first copy (original) is approved by the customer and remains on the customer. The second copy will be approved by the customer and will be delivered to the customer for shipment to the store or warehouse. The third copy is approved by the customer and returned to the warehouse. The fourth copy is archived for the customer. The fifth copy will remain in storage. When the vehicle leaves the facility, the vehicle driver delivers the original copy of the Vehicle Load Document to the security personnel.

The security officer confirms the accuracy of the seal number on the Vehicle Loading Document against the seal number on the vehicle, and provides the vehicle by writing the departure time of the vehicle. Security staff archives documents. The vehicle driver confirms the seal with the goods receipt person, the order number and the signature of the customer to which the goods to be delivered. The approved 3rd copy is taken to deliver it to the 3PL warehouse.

The vehicle driver who delivers within the city delivers to the transportation system operator the same day after the delivery. All records held during the shipment of products are archived according to the Records Control Instruction.

3.2.8. Unloading

On arrival, the vehicle information must be checked according to the booking reference. A vehicle must be checked against the delivery of its seal.

The vehicle must be directed to the unloading ramp at the destination. Appropriate equipment must be available for the material to be unloaded. When unloading the hazardous material, Hazardous Material Unloading Instruction is applied.

3.3. RESPONSIBILITIES AND PARTIES IN DANGEROUS GOODS LOGISTICS WAREHOUSES

The law on the roads of the Dangerous Goods sets its duties / participants in responsibilities. Participants with certain legal responsibilities are the shipper, carrier, driver and vehicle crew, packer, filler, loader, unloader, tank-container / portable tank operator, buyer and DGSA.

Usually there are several participants / officials in a particular transport chain. A person or company may be an officer, depending on the activity, or may assume the responsibility of several duty holders. For example, when a conveyor belt cleaning material supplier is a producer or manufacturer (industrialist) and if this material is a dangerous property, when it is delivered to the customer for shipment, this manufacturer is shipper. If this company is using a driver and a company truck, then they can be mentioned as carrier and as a driver. This participation obligation can be equally realized by different companies (eg the producer gives the product to a courier which takes responsibility for the carrier)

If any officer is acting on behalf of a third party, an express transport contract specifying all duty transfers under the legislation must be accepted and signed by all parties concerned.

3.3.1. General Safety Measures

ADR, express all participants;

"Participants in the transport of dangerous goods will take appropriate precautions to avoid natural disasters or injuries and, if necessary, to minimize the effects of natural events and will take appropriate measures to cover the foreseeable hazards.

In any case, they must comply with the requirements of the ADR in their area. In the case of an urgency and risk, this public safety can be compromised, attendees will immediately notify emergency services and provide them with the information they need to act.

In general, one participant should:

* It has to be certain that someone who works for the company, who is involved in dangerous goods, has been properly trained and whose records are kept.

- * Must comply with the prescribed legal duties.
- * Appropriate precautions should be taken to prevent damage or injury.
- * Emergency services must be informed and acted promptly to ensure public safety.

3.3.2. Shipper (Consignor)

The sender (shipper) has control of the dangerous goods before shipment and may act on behalf of a third party, such as a manufacturer, supplier and shipment warehouse. If the shipment is carried out within the scope of a transport contract involving the transfer of one or all legal duties, then the term "shipper" means sending goods to the contract. The shipper must have a place of business in the state. If the person does not meet this requirement, the buyer (customer) of the goods undertakes the tasks of the sender.

When the shipper acts on behalf of a third party, the latter must inform the shipper in writing of the inclusion of dangerous goods and give him all the information and documents necessary to fulfill the obligations of the sender.

The sender specifically:

- *has to ascertain that Dangerous goods are classified and approved for transport in accordance with ADR.
- * must supply the information and data and necessary transport documents and the accompanying documents to the carrier. The sender must provide the carrier in advance of the receipt of the goods, the nature of the dangerous goods to be delivered, and the necessary documentation when the driver arrives.
- * has to use only containers, large packages, intermediate bulk containers (IBC) and tanks (Tank vehicles, demountable tanks, battery vehicles, MEGCs, portable tanks and tank containers) which are approved and suitable for transporting the relevant substances and bearing the marks specified by ADR.
- * The requirements for shipping vehicles and shipping restrictions must be observed. * It should be ensured that empty, cleaned and non-degassed tanks or vehicles, or even small volume containers, are properly marked and labeled, and that non-empty dirty tanks are sealed and impermeable at the same time when they are closed and full.
- * Safety precautions must be observed as it is supposed to be.

- * When the dangerous goods are delivered to a driver, it must be ensured that there is a suitable driver training certificate and photographic identification document

- * has to be ensured that emergency procedures are in place.

- * has to be ensured that all employees are appropriately trained prior to any application involving dangerous goods.

If the sender is using the services of other participants (packer, uploader, filler, etc.), appropriate measures should be taken to ensure that the shipment meets ADR requirements. The sender can rely on the data provided by other participants.

3.3.3. Carrier

A carrier is an entity that carries out the actual transport of a dangerous goods on or through a transport vehicle (with or without a transport contract), such as a logistics company carrier, vehicle owner / operator. (working in his / her own business)

- * The carrier is particularly:

- * should determine that the dangerous goods required for carriage are authorized for carriage in accordance with ADR. (with the approval of the sender)

- * has to ensure that all information specified in the ADR concerning dangerous goods must be provided by the sender prior to transport and that the specified documents are in the carrying unit or that electronic data processing (EDP) or electronic data interchange (EDI) techniques are used instead of paper documents.

- * has to ensure that Vehicles and loads are not subject to obvious defects, leaks or cracks, missing equipment, etc. and that this is done by implementing a monitoring / auditing procedure to evaluate the vehicle and equipment

- *has to ensure that the validity period of the next test for tank vehicles, battery vehicles, demountable tanks, portable tanks, tank containers and MEGCs does not end and that the inspection procedure is followed for monitoring.

- * has to ensure that the vehicles are not overloaded.

- * has to verify that the danger labels and markings foreseen for the vehicles are affixed.

- * must determine that the equipment and fire extinguisher conditions specified in the written instruction for the driver are in the vehicle.

- * should observe appropriate safety precautions

- * has to verify that the emergency procedures are on the agenda.

- * has to be ensured that both the driver and the crew are properly trained before any work associated with dangerous goods. Drivers should also have a suitable driver training certificate.

Where appropriate, the inspection of the vehicle or containers should be carried out in accordance with the information provided by the transport documents and accompanying documents and / or where appropriate, according to load. Approved procedures, including periodic inspections, will ensure that the vehicle and other transports are carried out. Documented procedures, including periodic inspections, will ensure that the vehicle and other transport equipment are in a condition suitable for use. The carrier can rely on the information and data provided to him by other participants.

If the carrier observes that it violates the requirements of the ADR, the item should not be shipped as soon as it is rectified.

If, during this journey, there is a violation which could jeopardize the safety of the operation, the shipment should be stopped as soon as possible, taking into account the safety of the shipment and the safety of traffic for the safety of public. Shipping can only be carried out if the shipment is in compliance with the relevant regulations. If any violation arises from any party, the shipment may be prevented by either party.

3.3.4. Driver and The Vehicle Crew

Immediate control of the car belongs to the driver, as a participant and who performs the driving function. Team members also have their roles, tasks and all team members must have appropriate training in line with their duties and responsibilities. The vehicle must have a suitable driver training certificate.

Drivers and / or team members, in particular:

- * must have the necessary training certificate in their own personal work.

* has to be sure to read and understand the transport documentation provided prior to any transport. If there is a problem with the documentation, the crew will have to correct any issues before driving.

* Emergency instructions must be available and stored in the cabinet.

* has to make sure that the orange plates, banners and markings are kept clean and all tools are properly covered, marked.

* has to make sure that damaged or leaking packages are not installed.

* has to ensure that no vehicle suspected of being involved in any particular situation has been dealt with before the vehicle has been subjected to national legislation or ADR.

* has to ensure ,that except for members of the vehicle team, passengers must not be transported in transporting units carrying dangerous goods. Passenger carriage has to be forbidden.

* has to make sure that a package carrying dangerous goods must not be opened.

* has to ensure that any torch or lighting apparatus used does not display any metal surface responsible for generating sparks.

* has to make sure, that except when the law of the country in which the vehicle is being used, permits such use, or when pumps or other devices must be used during loading or unloading the vehicle, it is necessary to ensure that the motor is switched off in process of loading and unloading of vehicle.

* has to make sure that no vehicle carrying dangerous material is parked without braking. And trailers without brakes should avoid moving by rubbing at least one wheel.

* should ensure, that In a transport unit equipped with an antilock braking system consisting of a motor vehicle and trailer, the electrical connections always connect the towing vehicle and the trailer during carriage.

* has to verify that In the case of tank filling and unloading operations, there is a good electrical connection to the ground prior to unloading and filling.

* Care must be taken not to leave tanks filled, stuck with residues of hazardous material.

* has to be sure that during the loading process, dangerous goods are properly secured around the start or during transport. If a part of the delivery is released, unloaded, the remaining hazardous assets must be fixed.

* has to be sure to follow the vehicle inspection provisions.

3.3.5. Packer

The packer (an individual or business) is the responsible party for the final packaging of dangerous goods before the transportation. (If different than manufacturer). The packer has to;

*follow with requirements concerning packing provisions, or mixed packing provisions (these requirements vary and may require input from DGSA.

*meet the specified requisities about marking and labelling on the package, like above.

3.3.6. Filler

The filler is (individual or business) is the responsible party for filling tanks or containers (for carriage in bulk) with dangerous goods prior to transportation.

The filler must in particular make sure:

- before the filling of tanks that both tanks and the equipment in it are in a satisfactory technical characteristics that the date of the next test for tank vehicles battery vehicles, demountable tanks, portable tanks, tank containers and MEGC's has not expired

- to fill the tanks which are authorized to carry dangerous goods

- while filling the tank, follow with the requirements concerning dangerous goods in connected departments

- During the filling of the tank, the maximum permissible degree of filling or the maximum permissible mass of contents per litre of capacity for the substance is not violated. The maximum content and capacity to be allowed to fill during the filling of the tank must be observed and should not be exceeded.

- after the filling the tank, that the closing devices are leakproof.

- that no dangerous residue of the filling materials do not stick the outside of the tanks.

- During dangerous goods for bulk transport preparation, the installation of orange plates and foreseen plaques or labels, in vehicles, in tanks, in large and small containers, care should be given as requirements asked for vehicles or containers are to comply with the relevant rules of ADR when filling hazardous materials.

3.3.7. Loader

The loader is the (individual or business) is the responsible party for loading dangerous goods onto a vehicle before the transportation.

The loader must in particular make sure;

- The dangerous goods are handed over to the carrier only if they are authorised for carriage according to ADR.

- When handling containers for dangerous goods or unclean empty packages, it has to be checked that the packaging is not damaged. If the packaging is damaged, especially if it is not leakproof and / or there is a leak, the package must not be delivered until the damage of dangerous substances package has been repaired.

That the rules of loading or handling must be complied with when loading hazardous items into a vehicle or large or small container that hazard signs and labeling rules must be observed after loading hazardous materials in a container. When loading packages, dangerous goods in vehicles or large containers, separation requirements must be considered, dangerous goods should be loaded into the vehicle according to the requirements for the separation of foodstuffs, other consumables or animal feeds and the prohibitions on mixed loading in ADR legislation must be observed.

3.3.8. Tank Container/ Portable Tank Operator

The person responsible for the operation of a tank container/portable tank is called the tank container operator. (individual or business) The tank container/portable tank operator should especially make sure:

- compliance with the requirements for construction, equipment, tests and marking.
- the preservation of cages and their equipment, tests and marking.

That there must be an exceptional check and repair in case the safety of the cage or its equipment is potentially deteriorated by a change or an accident.

3.3.9. Unloader

The unloader is (individual or business) the responsible party for the transfer of dangerous goods from a vehicle, or for the unloading or discharge of dangerous goods from a tank, container or vehicle.

The unloader must make sure:

To verify that the correct goods have been evacuated by comparing the relevant information in the transport document with the information on the package, container, tank, MEMU,¹⁴ MEGC¹⁵ or vehicle. That before and during unloading, check that the packages, tanks, vehicles or containers have been damaged at the time of the hazardous discharge and ensure that unloading has not occurred until proper precautions have been taken. .

All requirements regarding unloading must be observed. That immediately upon evacuation of the tank, vehicle or container,

If there is dangerous debris adhered to the outside of the tank, vehicle or container during unloading, should be removed

- that the closure of valves and inspection openings are closed

- to provide foreseen cleaning and decontamination of vehicles or containers If the unloader use of the services of other partys (cleaner, decontamination facility etc) he or she must take appropriate measures to ensure that the requirements of ADR are met.

3.3.10. Consignee (Customer or Recipient)

Upon receipt, the participant (individual or commercial) receiving the responsibility of the dangerous goods is called the Consignee. The consignee's obligations are as followsAcceptance of goods on time, when there is no compelling reason and after confirmation that the buyer fulfills the ADR requirements after discharge. In the case of a container, and in the case of a violation, the container is returned to the carrier after the violation has been resolved and;

¹⁴ MEMU means a vehicle meeting the definition of mobile explosives manufacturing unit.

¹⁵ MEGC means multiple element gas container

- If the buyer uses the services of the other participants (unloader, cleaner, decontamination facility, etc.), he shall take appropriate measures to ensure that the conditions with the ADR are met.

3.3.11. Dangerous Good Safety Advisor (DGSA)

Dangerous Goods Safety advisor guides the companies, third party Institutions about the dangerous goods transportation, loading and unloading activities. Any enterprise, including land transportation of dangerous goods or related packaging, loading, filling or unloading activities, shall designate one or more safety advisors for the transport of dangerous goods. Safety Advisors are responsible for:

- to help to prevent risks that may arise in Human, property and environmental activities
- Monitor the compliance of the institutions with the requirements governing the transport of dangerous goods.
- Prepare a yearly report to the public authority and / or management of the undertaking about the activities.
- Preparing the procedures about the needed actions of ADR regulatory.
- Reporting the incidents/accidents of undertakings to the public authorities.

CHAPTER 5

4. INFRASTRUCTURE, LAYOUT AND RISK IN DANGEROUS GOODS WAREHOUSES

4.1. STORAGE OF DANGEROUS GOODS

Temperature, ventilation, segregation, ignition control and identification may be considered as typical storage steps. To be able to avoid incompatible materials from the danger of inadvertent contacts, a proper segregation is essential. When this prevention is not considered, the result will be explosion, fire, toxic gases or violent reactions.

While a warehouse is being designed, constructed or maintained, the environmental factors should be essentially considered. Elements in weather such as heat, wind, frost or humidity should not be in contact with dangerous materials, goods, wastes, substances in storage to provide safety.

Hazardous materials should be identified and be subject to an assessment in compliance with the ATEX Directive .Where gas cylinders are present on site, they should be stored, used and handled in accordance with national standards. Particular care should be taken where the presence of acetylene cylinders on the site cannot be avoided.

Oxidizing chemical flammable liquids, aerosol products or the other materials like these are hazardous materials. While these goods are stored, some information about them such as their quantities, mode of storage, their locations should be easily available to the emergency services. At the same time, while these kind of materials, some other precautions should be taken. Before the storage, insurers should be consulted so that any kind of risk control measures should be done.

To be able to prevent the employees and the environment from every kind of risk, some requirements have be established on dangerous goods and dangerous substances during the storage. The requirements starts with the building's construction such as fire walls, catch basins, fire doors, etc. The next requirement is about inventory lists of the stored goods. This is because providing plans, which will be used in case of emergency and preparing some information for teams, which are responsible for emergence situations such as employees and fire brigade. Besides that, employees should be trained for being able to

cope with these dangerous materials and to know what they should do in case of emergency.

During the storage, segregation of the dangerous substances and goods must be observed as another important requirement.

In a storage facility, every employees must be sure that the storage area is;

- a. Prevented from public entry,
- b. Including materials which are labelled and identified as dangerous goods/substances or waste dangerous goods/substances according to “Transportation of Dangerous Goods Regulations”. These labels must be used during transportations of these dangerous materials and during storage by separating from each other in the facility. The information about these dangerous materials must be in each buildings, rooms or areas.
- c. Equipped with any equipment necessary for handling emergency cases of dangerous goods and dangerous substances of waste dangerous goods and substances in the warehouse.
- d. Composed of trained employees who are responsible for emergency of dangerous good and dangerous substances or waste dangerous materials in storage.
- e. Prevented to spilling or leaking of dangerous goods/substances or dangerous wastes not to enter the environment or cause any risk and dangerous effect.

4.1.1. Storage Of Dangerous Goods Layout And Risk-Safety Measures

It is mostly considered that fire is the most dangerous hazard once a warehouse is the subject. The reason for this consideration is that the affections of radiated heat, missiles, harmful smoke and fumes can directly be effective on many people. Besides the warehouse, the storage area is considered as the other hazard area. Even though it is rarely experienced, some certain stored substances can be decomposed in case of fire, and this will be caused an explosion.

Common causes of cases are:

- Unawareness of the dangerous substances belong to the properties
- Operator error caused by untrained human factor or other human-induced cases

- Lack of appropriate storage technics without consideration of hazard factors
- Insufficient installation, design or maintenance of equipment or buildings
- to be exposed to heat caused by fire or other sources such as electrical equipment smoking; hot work and smoking materials and inadequate control of these factors
- Horseplay, vandalism and arson.

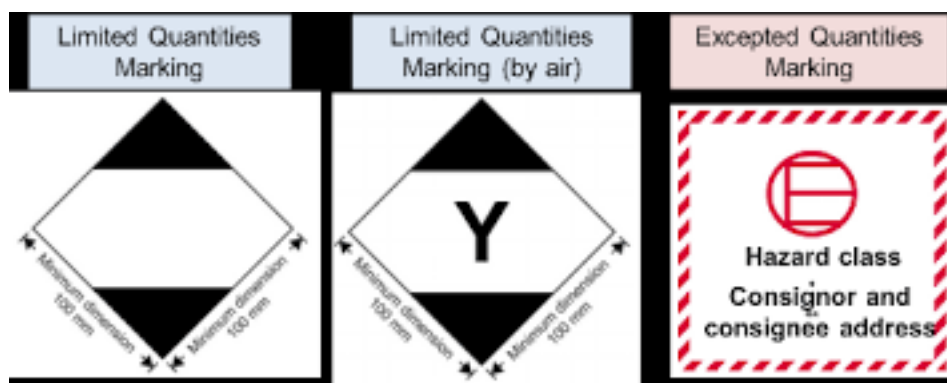
4.2. HAZARD CLASSIFICATION

There are other hazard factors for packaged dangerous goods. These goods have special, defined hazards. The hazards are generally detailed on the “material safety data sheet” (MSDS), and have a special storage method to provide safety. The hazardous information related to a product is summarized in section 15 of MSDS according to CHIP labelling requirements. Besides these hazards, some types of these packaged dangerous materials are required more precautions in the warehouse. Therefore, while storing these kind of packaged products which needs additional hazards preventions should be considered because they should be secured with sufficient segregation and other risk control strategies. At the same time, the interactive contacts of dangerous substances can cause some other hazards.

While dangerous substances are placed to a chemical warehouse, this work should be done by a qualified person who knows possible dangers and risks of these materials and has detailed information about how to store and segregate these materials according to their sizes, quantities and physical and chemical substances.

The rules in Carriage Regulations must be applied on most dangerous substances by using labels or marking system. These regulations are compatible with ADR regulation regime. This system refers to a global classification and it is widely used in industry. This system can be easily operated. Because of this advantage, many chemical warehouse apply this system while classifying that kind of dangerous materials. However, many dangerous goods are not labelled with the carriage labelling carriage system because they are transported in limited quantity packages, so they are marked with limited quantity label. This kind of packages will have United Nations (UN) number or numbers and this mark is a label black on a white background. If there should be multiple numbers, then this will be shown with ‘LQ’.

Table 21: Examples of limited quantity marks are shown in Figures.



Examples of limited quantity marks

For very small quantities in special packages, a new “Excepted Quantities package” has been introduced in 2009.

CHIP > EU GHS is the second hazard classification system. This system is about the supply of the substances. This second system can be compared with the ones used for carriage but they are not the same tests because those have another purpose. Sometimes a substances can have different requirements for both carriage and supply in terms of hazards. For such materials, the responsible staff should take account the two hazard classification categories while placing them in or carrying to the storage area. When a substance is in its outer package, then the label about carriage system on the package should be considered, in opposite cases, the CHIP label should be considered. According to the classification, packaging and labelling regulations (CLP Regulation) there should be make some differences between the two systems. This system does not need to fulfill the more specific requirements of DSEAR which is a position for Class or Division and gives place for name of consignor or consignee. CHIP regulations were revoked from the date of 01.06.2016 and CLP regulations took place instead. But the foundation of regulations of CLP is CHIP.

Table 22: Marking for Excepted Quantities packages



The symbols used in CHIP system are generally black on orange-yellow danger sign and related words as shown in Table 1.

The hazard classification categories are given below.

4.2.1. Classification System

The type of hazards involved in indication of danger statement (s) is like following:

EXPLOSIVE (E) Explosive and pyrotechnic products

VERY TOXIC (T+) or Acutely toxic chemicals TOXIC (T) or

Carcinogens, mutagens and toxic by reproduction (not normally dangerous for carriage)

IRRITANT (Xi) Non-corrosive chemicals which may create inflammation. In addition they can be used for skin sensitisers

HARMFUL (Xn) known as chemicals with some harmful effect as well (their transportation may be not dangerous). They are used for inhalation sensitisers, too

CORROSIVE (C) Chemicals which may destroy living tissue on contact

EXTREMELY FLAMMABLE or Liquid substances with very low flashpoint and boiling point, and flammable gases

DANGEROUS FOR THE ENVIRONMENT Chemicals that may present an immediate or delayed danger to one or more environmental compartments

OXIDISING Chemicals which give rise to highly exothermic reaction in contact with other combustible substances

HIGHLY FLAMMABLE Chemicals they may become hot and catch fire OR solids which may readily catch fire after brief contact with an ignition source OR liquid chemicals which have flashpoint below 21 °C OR which when wet give off flammable gas in dangerous quantities

The identification of chemicals, which have flashpoints from 21 °C to 55, is made by R10 Flammable risk phrase.

CLP Regulation includes most industrial chemicals. The other chemicals, which need more specific requirements, are under more specific regulations.

The following chemicals are not under the CLP Regulation:

- Radioactive substances and mixtures
- Substances and mixtures subject to customs supervision
- Non-isolated intermediaries
- Substances and mixtures for scientific research and development

which does not exist on the market and the ones are only used in controlled conditions

- Waste

The following chemicals are the ones which are in finished states and ready for final users. So these chemicals are not under CLP Regulation either:

- Medicines
- Medical devices
- Veterinary medicines
- Cosmetics
- Food
- Feeding stuffs (i.e. food additive; food flavouring; feeding stuffs used in animal nutrition)

4.2.2. Class 2: Gases, Compressed, Liquefied, Or Dissolved Under Pressure and their storage

There are indications on product additional to various labelling regulations such as the Carriage Regulation and GHS. These are cylinders, which show the contents with colour-coded indications. European standard BS EN 1089-3: 200416 is for the colour coding of transportable gas cylinders.

Table 23: List of High Consequence Dangerous Goods

Class	Division	Substance or article	Quantity		
			Tank (l) ^c	Bulk (kg) ^d	Packages (kg)
1	1.1	Explosives	a	a	0
	1.2	Explosives	a	a	0
	1.3	Compatibility group C explosives	a	a	0
	1.4	Explosives of UN Nos. 0104, 0237, 0255, 0267, 0289, 0361, 0365, 0366, 0440, 0441, 0455, 0456 and 0500	a	a	0
	1.5	Explosives	0	a	0
2		Flammable gases (classification codes including only the letter F)	3000	a	b
		Toxic gases (classification codes including letters T, TF, TC, TO, TFC or TOC) excluding aerosols	0	a	0
3		Flammable liquids of packing groups I and II	3000	a	b
		Desensitized explosives	0	a	0
4.1		Desensitized explosives	a	a	0
4.2		Packing group I substances	3000	a	b
4.3		Packing group I substances	3000	a	b
5.1		Oxidizing liquids of packing group I	3000	a	b
		Perchlorates, ammonium nitrate, ammonium nitrate fertilisers and ammonium nitrate emulsions or suspensions or gels	3000	3000	b
6.1		Toxic substances of packing group I	0	a	0
6.2		Infectious substances of Category A (UN Nos. 2814 and 2900, except for animal material)	a	0	0
8		Corrosive substances of packing group I	3000	a	b

Table 23:ADR (2017) Transport Unece

There is a more possibility to disperse of minor leaks, which emerge from compressed gases, when the cylinders are kept in open areas. Cylinders, contains liquefied gases, are stored vertical position to prevent leaking of gas or vapour rather than liquid. Once cylinders are become upright position, then they should be prevented to any possibility of toppling.

Even in the cases, the cylinders do not contain hazardous contents, if they expose to intense heat, they will explode and create a great risk for people around. Because in

acetylene cylinders there can be self-decomposition of the product, the explosion possibility after exposure to heat is more. In addition, there will be no any warning before explosion in these kind of cylinders. At the same time, these cylinders can explode in case of dropping or struck forces.

In some cases flammable, asphyxiant or toxic gas cylinders are hold in buildings. In such situation, a good air conditioning is essential to prevent minor leaks from cumulating. While preparing goods for storage and determining their locations and ventilation criteria, it should be consider if the gases are lighter or heavier than air.

According to the actual “OSHA standard numbered 1910.253(b)(2)(ii)”, cylinders, which are inside, should be stored in a good ventilation, good protection and dry location and they need to be at least 20 (6.1m) feet away from highly combustible materials such as oil or excelsior or classes 1,3,4,5,6,7,8,9 etc. The storage place of cylinders should be definitely away from stairs, elevators or gangways. Cylinders should kept in places, which are prevented from knocking over, damaging by human or other object based factors and away from unauthorized persons’ tampering. They should not be kept in places like cupboards of lockers because these areas are unventilated.

4.2.3. Class 3: Flammable Liquids

Liquids, which have a flashpoint under 60 °C, are labelled as flammable according to the Carriage Regulation. However, the ones has a flashpoint of 100 °C, are in flammable class and some of them are diesel, gas oil and heating oil (light) (UN 1202).

There are three types of classification of liquids: flammable, highly flammable and extremely flammable. This classification is based on their supply according to CHIP>GHS. Once the container has a damage, fire emerging from flammable liquid will rapidly grow and when the stored material continues to flow, fire will quickly spread. When this fire contact with any other flammable material around, it will grow and controlling the fire will be more difficult in such a case. When sealed containers expose to intense heat, they may explode. If there is any leak from the container and it cannot be detected, liquid can flow some distance.

4.2.4. Classifications of Flammable and Combustible Liquids

Flammable liquid is the one which at or below 199.4 °F (93 °C) flashpoint. The following categories are divided the flammable liquids:

These are divided according to the OSHA definitions about flammable and combustible liquids.(OSHA 2017)

Category 1: it is for liquids with flashpoints below 73.4 °F (23 °C) and their boiling point is at or below 95 °F (35 °C).

There are liquids, which have flashpoints under 73.4 °F (23 °C) and boiling point above 95 °F (35 °C) in the second category, Category 2.

In Category 3, there are liquids with flashpoint between 73.4 °F (23 °C) and below 140 °F (60 °C). If a Category 3 liquid with a flashpoint at or above 100 °F (37.8 °C) is wanted to be used then it should be heated within 30 °F (16.7 °C), it should be handled according to the requirements for a Category 3 liquid which have below 100 °F (37.8 °C) flashpoint.

Category 4 are for liquids which have flashpoints above 140 °F (60 °C) and at or below 199.4 °F (93 °C). If the a Category 4 flammable liquid is needed to be used then it should be heated within 30 °F (16.7 °C) of the flashpoint, it should be handled according to the requirements for a Category 3 liquid which have below 100 °F (37.8 °C) flashpoint.

When liquid having a flashpoint bigger than 199.4 °F (93 °C) is heated for use to within 30 °F (16.7 °C) of its flashpoint, it should be done with the requirements for a Category 4 flammable liquid.

According to NFPA 30 the classification is as follows:

Flammable Liquids are the ones having a flashpoint below 100 °F and a vapor pressure not exceeding 40 psia at 100 °F and these are considered in Class I liquids. These liquids are categorised as in the below charts:

- Class IA liquids have a flashpoint under 73°F and a boiling point below 100°F.
- Class IB liquids have a flashpoint under 73°F and a boiling point at or above 100°F.
- Class IC liquids having a flashpoint at or above 73°F and below 100°F.

4.2.4.1. Combustible Liquids

These are liquids having above 100°F flashpoints. These liquids are like following:

Class II – Liquids having a flashpoint at or above 100oF and below 140oF (e.g., kerosene, fuel oil no.1);

Class IIIA – Liquids which have a flashpoint at or above 140oF and below 200oF (e.g., fuel oil no.2, aniline, creosole); and

Class IIIB - Liquids having a flashpoint above 200oF.

To burn combustible and flammable liquids, themselves are not enough. When a mixture of air and their vapours is created, the burning happens. For instance, gasoline has flashpoint of -40°C (-40°F), and it is a flammable liquid. However, even when its temperature is below 40°C (-40°F), it creates a vapour enough to burn when mixes with the air. As another instance, we can say phenol. It is a combustible liquid and its flashpoint is 79°C (175°F). Nevertheless, to be ignited in the air, it has to come a heat above this value.

In the range of 300°C (572°F) to 550°C (1022°F), many common combustible and flammable liquids automatically come to temperature to ignite and this is autoignition temperature. Some other liquids have lower autoignition temperatures. For instance, ethyl ether's autoignition temperature is 160°C (356°F)¹⁶

¹⁶ <https://www.ccohs.ca/oshanswers/.../flammable/flam.html> accessed dd 03.12.2017

Table 24: Danger - Risk Description Numbers and Their Meanings

20	asphyxiant gas or gas with no subsidiary risk
22	refrigerated liquefied gas, asphyxiant
223	refrigerated liquefied gas, flammable
225	refrigerated liquefied gas, oxidizing (fire-intensifying)
23	flammable gas
238	gas, flammable corrosive
239	flammable gas, which can spontaneously lead to violent reaction
25	oxidizing (fire-intensifying) gas
26	toxic gas
263	toxic gas, flammable
265	toxic gas, oxidizing (fire-intensifying)
268	toxic gas, corrosive
28	gas, corrosive
30	flammable liquid (flash-point between 23 °C and 60 °C, inclusive) or flammable liquid or solid in the molten state with a flash-point above 60 °C, heated to a temperature equal to or above its flash-point, or self-heating liquid
323	flammable liquid which reacts with water, emitting flammable gases
X323	flammable liquid which reacts dangerously with water, emitting flammable gases ¹
33	highly flammable liquid (flash-point below 23 °C)
333	pyrophoric liquid
X333	pyrophoric liquid which reacts dangerously with water ¹
336	highly flammable liquid, toxic
338	highly flammable liquid, corrosive
X338	highly flammable liquid, corrosive, which reacts dangerously with water ¹
339	highly flammable liquid which can spontaneously lead to violent reaction
36	flammable liquid (flash-point between 23 °C and 60 °C, inclusive), slightly toxic, or self-heating liquid, toxic
362	flammable liquid, toxic, which reacts with water, emitting flammable gases
X362	flammable liquid toxic, which reacts dangerously with water, emitting flammable gases ¹
368	flammable liquid, toxic, corrosive
38	flammable liquid (flash-point between 23 °C and 60 °C, inclusive), slightly corrosive or self-heating liquid, corrosive
382	flammable liquid, corrosive, which reacts with water, emitting flammable gases

823	corrosive liquid which reacts with water, emitting flammable gases
83	corrosive or slightly corrosive substance, flammable (flash-point between 23 °C and 60 °C, inclusive)
X83	corrosive or slightly corrosive substance, flammable, (flash-point between 23 °C and 60 °C, inclusive), which reacts dangerously with water ¹
839	corrosive or slightly corrosive substance, flammable (flash-point between 23 °C and 60 °C inclusive) which can spontaneously lead to violent reaction
X839	corrosive or slightly corrosive substance, flammable (flash-point between 23 °C and 60 °C inclusive), which can spontaneously lead to violent reaction and which reacts dangerously with water ¹
84	corrosive solid, flammable or self-heating
842	corrosive solid which reacts with water, emitting flammable gases
85	corrosive or slightly corrosive substance, oxidizing (fire-intensifying)
856	corrosive or slightly corrosive substance, oxidizing (fire-intensifying) and toxic
86	corrosive or slightly corrosive substance, toxic
88	highly corrosive substance
X88	highly corrosive substance, which reacts dangerously with water ¹
883	highly corrosive substance, flammable (flash-point between 23 °C and 60 °C inclusive)
884	highly corrosive solid, flammable or self-heating
885	highly corrosive substance, oxidizing (fire-intensifying)
886	highly corrosive substance, toxic
X886	highly corrosive substance, toxic, which reacts dangerously with water ¹
89	corrosive or slightly corrosive substance, which can spontaneously lead to violent reaction
90	environmentally hazardous substance; miscellaneous dangerous substances
99	miscellaneous dangerous substance carried at an elevated temperature.

Table 24:ADR (2017)

4.2.5. Class 4 Flammable Solids, Substances To Liable Spontaneous Combustion, To Emit Flammable Gases

There are three subsection of Class 4 including flammable solids, substances accountable for spontaneous combustion and substances emit flammable gases in contact with water:

- Division 4.1: Flammable solids
- Division 4.2: Substances liable to spontaneous combustion
- Division 4.3: Substances which, in contact with water, emit flammable gases

Flammable solid is an item, which can cause a fire by a friction, absorption or moisture, spontaneous chemical change or which are in the ignition temperature below 212 F (100 C).

Spontaneously Combustible material is a pyrophoric material. This means that it is a solid or liquid and it can ignite in 5 minutes after contacting with self-heating material or the air. This kind of materials can heat on its own when coming in contact with air, it does not need any other energy supply.

Sulphur, alkali metals, matches, some metal powders, and activated carbon are commonly transported, class 4 dangerous goods.

This class includes a number of physical properties and a variety of hazards. Some of them are solids, which melt in a low point, or are held under a protective layer of ineffective gas or liquid.

The supplier should give some advices on each type of substances. The information should be on the storage conditions such as, temperature limitations, sensitivity to friction, water, impact or impurities.

4.2.6. Class 4.1: Flammable Solids

These solids can readily be combusted even in a short contact with any ignition source and they are sensitive to friction. After the contact with any ignition source, flammable solids continue to burn. Firelighters, matches, nitrocellulose and Sulphur can be given as examples of this group.

In comparison with combustible materials such as paper and wood, these materials can burn more easily. The fire starts rapidly and fiercely. It creates a huge heat. Some solids in class 4.1 are called desensitised explosives, which are wetted trinitrotoluene (TNT). These could be in Class 1 otherwise. Some of them are self-reactive. This kind of solids is tent to chemically break down when they expose to some certain temperature or shock. These can dissolve in the evolution of heat and fumes at a mild temperature. For example, AZDN and various azo compounds.

Desensitised explosives are also a division of this group. There are sufficient solvent, water, plasticiser in these materials and these compounds suppress explosive properties in them. For these materials, it should be ensured that water of solvent-wetted explosives are not left in a storage conditions making them dry out. Picric acid and urea nitrate are examples of desensitised explosives.

4.2.7. Class 4.2: Self-Reactive And Related Substances

A spontaneously combustible, pyrophoric substance has an air-excluded package so that to prevent it any contact with air. When a damaged package takes air in it, the burning may start even at room temperature or in a little heat. Yellow phosphorus and some metal alkyls are examples of them.

As for oxidative self-heating substances, they can show reaction when they are contacting with the air. By raising the present temperature to enough heat for combustion, fire may start. Because of this process is slow, it can be controlled by monitoring temperatures, excluding air, limiting storage duration or restricting the pack size. Carbon dust and oily natural products and some forms of them are the examples of this group.

Metals and metal alloys in powdered or other flammable form, accountable for spontaneous combustion, are placed in Class 4.2.

4.2.8. Class 4.3: Substances Dangerous When Wet

When such materials contact with water, they evolve some flammable gases. So these materials should be saved from tackling with water or fire involving places. Calcium carbide, magnesium, aluminium metal hydrides, sodium are the examples.

Metals and metal alloys in powdered or other flammable form, which touching with water and emitting flammable gases, are placed in Class 4.3.

4.2.9. Class 5: Oxidising Substances And Organic Peroxides

These substances are not directly combustible materials on their own. They cause the burning of other materials when air is not included. In case of fire, such substances decompose and give off oxygen. The catastrophic results appear in an increased rate of burning it should be considered that organic peroxides can burn and generally it is explosively.

There have been a little number of cases, which these materials caused fire directly. In those cases, they have been in relatively large package forms such as ammonium nitrate and sodium chlorate and when they have been engulfed with fire, they have been exploded violently. In the Storing, there is a guidance to show maximum stack size of ammonium nitrate and there is another, which shows how to handle ammonium nitrate and sodium

chlorate in Storage, and there are use of sodium chlorate and other similar strong oxidants in them.

4.2.9.1. Class 5.1: Oxidising substances

Most of oxidizing substances are the ones which react extremely. They may be both solids and liquids. Their storage places are different than flammable materials. Moreover, they need to be prevented any kind of contamination or possibility of being involved in fire. Their storage can be with other strong oxidizing materials.

4.2.9.2. Class 5.2: Organic peroxides

They can be considered as a particular reactive type of oxidizing substance. They can be in form of liquid, solid, paste or any other form as following:

- Liable to explosive decomposition;
- Burn rapidly and intensely even in the absence of oxygen;
- Sensitive to impact or friction;
- React dangerously with other substances;
- Decompose at comparatively low temperatures; and/or
- Cause spontaneous ignition if spilt onto combustible material.

On some of these substances, there should be labels, which show a subsidiary explosion risk. The storage of organic peroxides should be separated from corrosive, toxic and flammable materials. Organic peroxides are in generally both solid and liquid forms in industry. When peroxides spill onto wood, paper, cotton or other combustible materials, it can create a fire. Organic peroxides, which are available commercially, can be self-heating and runaway decomposition. Variable toxicity in several substances are included in organic proxides. The corrosive ones of them can damage skin, eyes, mouth, throat, gullet, stomach and other mucous membrane. When a cloud or spray emerges for any reason or it creates a huge pressure, this can be cause difficulty while breathing, especially in people who are tend to asthmatic attacks. In these cases, the advices given by the supplier should be cared for handling with the contact of these materials with eye or skin.

Self-accelerating decomposition temperature (SADT) is known as exothermic runaway decomposition. And each packaged organic proxide has its own temperature as SADT.

For particular packaged proxides, the advice on safety data sheets or advice taken by the supplier should be cared.

4.2.10. Class 6: Toxic Substances And Their Storage

Health, physical and environmental hazards are three major group of GHS system. Health hazards group includes toxic materials. Also toxic and very toxic materials are classified in different groups. Acute effects are the name given to health effects which rapidly happen after a single exposure. In different cases, health effects are shown after a while the exposure takes place. This is called as chronic effect. It can last hours, days or even months after a exposure. In a general definition, while acute effect occur in a single and high exposure; relatively chronic effect emerges in lower exposures and longer time period. There are both acute and chronic health effects in toxic materials at the same time.

The GHS system designed a way to classify toxic and highly toxic materials. This classification is made of their health hazards¹⁷

- Acute toxicity (e.g. LD50, LC50)
- Skin irritation/corrosion
- Respiratory or skin sensitization
- Serious eye damage/eye irritation
- Mutagens (material can cause changes into cells)
- Carcinogens (material can cause cancer risk)
- Reproductive toxicity (material can cause a negative effect on reproductive functions for both male or female or on a developing fetus)
- Specific target organ toxicity - single exposure (materials producing an intense impact on organ systems in the body as a result of a single exposure)
- Specific target organ toxicity - repeated exposure (materials producing an intense impact organs in the body as a consequences of repeated exposure)
- Aspiration hazard (a solid or liquid material which can enter the respiratory system of body directly by the nose or mouth)
- Chemical mixtures

¹⁷ Web.CCOHS Toxic materials Hazards How are toxic materials classified under GHS last updated june 8, 2009 accessed dd 05.12.2017

The failure of containment is the major risk factor for toxic substances in the storage. To be able to minimize this risk factor, a well-designed pre-planning will work.

However, in case of fire, many containers can fail because of heat and flame, and this can compromise the protections. At the same time, while this kind of fire causes damages on people around the field such as firefighters, it can also spread rapidly to wider places due to smoke emerging from the fire or with watercourses formed in firefighting operations.

The precaution taken to control these risks should depend on varieties of toxic materials. For examples, their toxicity degree and persistence in the environment or quantities of them should be taken into consideration.

Toxic substance varies widely according to hazards created by them. Because of loss of containment, the main hazard during the storage of toxic substances is relatively acute exposure. Chronic effects occur in low level and long-term exposure. For the primary hazards and precautions the labelling system done according to Carriage Regulation forms the basic advices, but for more information a material safety sheets must be formed.

4.2.11. Class 8: Corrosive substances

Corrosive substances are one of the dangerous materials, which can cause skin burning, or other harm for people when contacting with it. Many of these substances can show a reaction when contacting with unsuitable or incompatible metals or packages in storage. If a corrosive substance has a leak, it can touch to packages of other dangerous materials and then further leaks can occur. Different types of corrosive substances should not be stored with together. This is not safe. When they react with each other, the hazards will be greater than one of them will create. Those, which are available to be stored together safely, should only be hold in the same storage area.

4.2.12. Class 9: Miscellaneous Dangerous Substances

There is diverse substance in this group of substances. Asbestos and other dangerous materials for environment (eg PCBs), air bag inflators and lithium batteries are in this class. Before storage of these substances, their specific requirements must be taken into consideration.

As a one of the most significant risk control measure, using the above classifications for storage can assist segregation of dangerous substances.

4.3. FLAMMABLE LIQUID STORAGE¹⁸

During the storage of flammable liquids, some of precautions should be taken. These are storing them in dry and cool place and away from heat, ignition sources and storing in safely closed and specifically designed containers for this purpose. Containers should be used in small storage places which does not have sprinkler system. The open air storage is preferable, besides this, in all cases good ventilation is necessary to disperse possible vapours from leaking containers. Spillage should also be controlled.

The principle basis of the standard is the “National Fire Protection Association's publication NFPA 30, Flammable Liquids Code 29 CFR 1910.106” which applies to storage, handling and use of flammable liquids having a flash point below 200°F(93,33 oC). Flammables shall be stored as follows:

Flammable liquids shall be kept in closed containers or tanks. Only approved containers and portable tanks should be used. Also portable tanks are needed to have a provision for emergency venting according to 29 CFR 1910.106 also requires portable tanks or the same purpose.

Container: any drum, barrel, or can.

Closed container: a container which is so sealed so that a lid or other device that neither liquid nor vapor will escape at ordinary temperatures.

The quantity of liquid which can be located outside of an inside storage room or storage cabinet in a building or in any one fire area of a building should not surpassed:

- 25 gallons(94,63 lt) of Category 1 flammable liquids in containers
- 120 gallons(454,25 lt) of Category 2, 3, or 4 flammable liquids in containers
- 660 gallons (2498,37 lt)of Category 2, 3, or 4 flammable liquids in a single portable tank.

¹⁸ Web.<https://www.osha.gov> Flammable Liquids 29 CFR 1910.106 access dt:15.11.2017

According to HSE, thus the European legislation (HSE., HSG 51, 2015); The storage technic of flammable liquids should be in separated placed from other materials and substances and they should be stored where they cannot be touch any kind of fire in the vicinity. If these rules are not considered during storage, then the ones with high flashpoints may be kept with other materials and these should not be incompatible substances. Combustible materials like packaging cannot be stored with flammable liquids. This prepares a potential environment for ignition and fire. So they should be held safe from flammable liquids.

As for finished products with low flashpoints, their storage should be in well-designed storage areas

- Outdoor storage,
- Dedicated building, or
- Storeroom.

However, when the following conditions are subject, these kind of products can be stored in loading bays for a temporary time:

- the loading bay is not part of a workroom;
- while storing the finished products, work activities are carefully controlled to avoid any incident in the loading bay

If flammable liquids are held in places where are under or above their flashpoints, then it must be ensured that there is no any source to cause leaks from flammable liquids and the place is cleaned from any kind of source of ignition, under “DSEAR the potential extent of the flammable atmosphere”.

Heat, mechanical, electrical and chemaical energy forms or other various energies can be potential sources for ignition. At the same time they may be presented by mobile, plant and fixed equipment, or transient activity.

The followings are the examples:

- naked flames, including welding and cutting equipment;

- smoking and smoking equipment;
- electrical lighting, power circuits and equipment;
- personal electrical equipment including mobile phones, computers and tablets;
- processes that involve the generation of sparks;
- hot surfaces;
- static electricity;
- lightning.

If lightning protection is the starter of a potential major incident, then the need for it must be fulfilled. (HSE, HSG 51, 2015)

In the case, the used containers are made of plastic materials, electrostatic discharge can cause ignition. This happens especially when these containers are filled with conductivity flammable liquids.

To be able to ignite a flammable liquid vapours, a small amount of ignition energy is enough. “The typical minimum ignition energy (MIE)” is in the range of 0.1 to 10 mJ. This can create various kind of energy such as heat, electrical, mechanical or chemical. Besides that the cause of ignition can be an external equipment for flammable liquids, also flammable liquids itself can create an incident if they are not stored or handled in a suitable way. For instance, when there has been low electrical conductivity (it is less than 50 picoSiemens (pS)), it becomes potentially a cause of ignition for the flammable vapour because it is resisted against incendive electrostatic discharge. Leaks of flammable liquids create a potential extent for flammable atmosphere when they are stored above or at their flashpoints. So this atmosphere should be controlled and all possible ignition sources must be excluded from the area. This is called as “hazardous area classification (HAC)” (see hazardous area classification)

ATEX-certified system are productive and equipment system which complies with “Equipment and Protective Systems”. In hazardous areas, this system should be applied.

According to the conditions, extend and type of the hazardous areas, a detailed determination should be done. The nominal capacity of flammable liquid-based finished products is 0.5 liter. If the container is filled with not more than this capacity, the

accidental spillage is expected to be more limited. Therefore to keep these containers with the other materials in the storage facility at the premises is permissible. Nevertheless, to be able to prevent the potential explosion or fire, appropriate precautions should be fulfilled. These precautions can be counted as follows:

- only sealed/unopened containers should be stored;
- the store should be separated from production areas (if there is; and small quantity from laboratory areas too) by using partitions of appropriate fireresisting construction.
- incompatible materials, such as peroxides and other oxidising agents, must not be kept in the store;
- combustible packaging materials, which will not be used immediately, should not be kept in the store;
- adequate ventilation should be provided, ideally to the standard recommended for storerooms (see ventilation);
- sampling or dispensing into other containers should not be carried out in the store;
- the containers should not be sited above electrical fittings (including lighting) or heating appliances, and are at least 0.5 m horizontal position from and vertical under these unless ATEX certifies them, unless the HAC(hazardous area classification) indicates the opposite.

4.4. FLAMMABLE SOLIDS STORAGE

The use and storage of flammable solids should not exceed the amounts which maximum allowable quantity are in each control area.

A “control area” concept is used to allow quantities of materials presenting a physical or health hazard to be separated by either fire-resistive construction or larger distances between one maximum allowable quantity grouping or another.

Pile (stack/mass) and size limits and location of flammable solids stored indoors and in quantities greater than 1000 cubic feet(28 m³) shall be separated into piles each are not bigger than 1000 cubic feet(28 m³)

Aisle widths between piles should not be less than the height of the piles or 4 feet (1219 mm) whichever is greater. Flammable solids should not be stored in basements.

Locations above 20 feet (6029 mm) of a building or public street way is only suitable for outdoor storage of flammable solids. The storage area should be covered with 30 inches (762 mm) above extend and there should be no openings or penetrations. The wall of the storage should be independent from the exterior wall of the building adjoint to the area.

Outdoor stores of flammable solids should be divided into piles not larger than 5000 cubic feet (141 m³) each. Piles should be divided by aisles in a minimum width of not less than one-half the pile height or 10 feet (3048 mm) whichever is greater.¹⁹

4.5. CORROSIVE STORAGE²⁰

Corrosives shall be stored as follows:

- Store compatible corrosives according to the Chemical Segregation and Storage Chart;
- Store corrosives in chemical-resistant, lipped trays so as to keep any spills contained;
- Inspection of damaged containers should be done every six months for corrosives;
- Corrosives in excess of ten gallons (37,85 lt) should be stored in a Corrosives Cabinet;(In small storages without sprinkler)
- PVC is the best material for corrosive ventilation.
- Corrosion resistant should be done for containers and equipment, which are used for storage and processing of corrosive material.²¹
- Corrosive chemicals must be kept below eye level, if possible near the floor to be able to minimize their falling danger from shelves or cabinet.
- Acids and caustics (i.e. bases) must be separated from each other. And the Secondary containers or trays must be used to separate acids and bases or other incompatible corrosives within a corrosive cabinet.
- Oxidizing acids must be separated from organic acids and flammable/combustible materials (oxidizing acids are particularly reactive with organics and flammable/combustible materials).
- Acids have to be separated from active metals (e.g., sodium, potassium, and magnesium) and from chemicals which might generate toxic gases (e.g., sodium cyanide and iron sulfide).
- Corrosive gas cylinders must be returned for disposal every two years.

¹⁹ webhttps://www2.iccsafe.org/.../oregon/.../Chapter%2036_Flam accessed dd 04.12.2017

²⁰ webhttps://protect.iu.edu/doc/environmental.../lab_chp_sop_4.p...accessed dd 04.12.2017

²¹ webhttps://protect.iu.edu/doc/environmental.../lab_chp_sop_4 accessed dd 03.12.2017

- Ammonium nitrate storage²²²³

DOT (Department of Transport) classifies AN as a Division 5.1 oxidizer if it contains maximum 0.2 percent combustible substances, or is an AN fertilizer blend, if it contains maximum 0.4 percent combustible substances.

These items are very dangerous because of this, the appropriate regulations should be taken and even in history there has been several disasters emerged by ammonium nitrate. Therefore, the storage of these items should be done according to the necessary conditions.

The development of high temperature is based on localized heating. Then these conditions should be prevented. For instance, the heat source such as hot ducts, radiators, steam pipes, light bulbs are the dangers for AN so these should not be hold in the same store. The bins filled with materials should be changed in certain periods so that caking could be minimized. Explosives, dynamite or blasting are too dangerous to use to loosen or break up caked AN.

Organic substances or combustible materials such as dust, seed, waxes, packing materials should be avoid to contaminate with AN. At the same time, dust-producing organics such as seeds, grains should not be held with AN and bulk AN in bins. If they will be kept together then at least 30 feet distance or a firewall should be provided. Also contamination with inorganic materials can cause sensitivity of explosion for AN. Chlorides, chloroium, aluminium powder, copper, nickel, cobalt and some other fine-divided metals are in these group. For the stacks' stability and movement 50 kg bags can be palletised. Self-confinement of straight ammonium nitrate in large stacks can increase the risk of a detonation of the whole stack in a fire, so stacks limit can be arranged to a maximum of 300 tonnes. Lefting 1 m between stack and the wall, stack and the roof, stack and electric lights, stack and heating pipe or between each stacks helps to prevent fires or any other heat sources to affect ammonium nitrate which is stored.

The choosing the materials of the storage area should be done with care for all of bins cribs and other items. Bins made of wood must be designed to prevent impregnation. Metal

²²web<https://www.epa.gov/chemical-advisory-solid-ammonium> Accessed 04.12.2017

²³webwww.hse.gov.uk/pubns/indg230.pdf Accessed 04.12.2017

items can corrode so they must be avoid any corrosion. These kind of story buildings should be composed of on floor with no basement. If there is a basement, it must have at least one open side. It is mostly preferred non-combustible construction to build a store. The walls for fire resistance should be build feet of combustible materials or buildings. Also non combustible flooring and handling areas should be used. The field of storage should be dry and prevented from any kind of water seepage possibly come from walls, roofs or floors. AN stores should be placed in separated buildings to hold them away from incompatible substances. In these buildings there should be fire resistant wall which is minimum 30 feet distance and 1-hour size. In case of fire, pressurization is an important issue. To be able to avoid it to happen the buildings should be constructed for self-ventilation. All electrical components/systems should comply with “the National Electrical Code”. The standardization 29 CFR 1910.109 of OSHA is applied.

AN should be placed into the stores only if the temperature of the product is 130°F (54.4°C) or below.

4.6. STORAGE OF STRONG OXODIZERS (SODIUM CHLORATE)(HSE,1998)

Sodium chlorate is another dangerous substances when it is near a source of ignition. Therefore, the storage of it should be done away from these kind of sources and at the same time, sodium chlorate should be stored separately from flammable liquids so that the elimination of contamination can be possible. Keeping sodium chlorate with food, drink and animal feedstuff should also not be allowed.

In dedicated stores, sodium chlorate cannot be contacted with incompatible materials. The storage should be either fully closed or open on a concrete pad, with or without a roof. Enclosed stores provides caking or packaging of sodium chlorate to damage from exposure to rain.

- The materials with the features such as unburning, non-concreting, brick or steel should be used in any structure.
- The floor of the chlorate store should be structured withh impervious non-combustible material and their surface should be soft.

- Stacks of chlorate should be limited to a maximum of 25 tonnes, to be able to reduce the risk of detonation because of self-confinement. This helps preventing fire spread, keeping a 3 m gap or a thermal barrier (such as a brick wall) between stacks of chlorate.
- Stacks of sodium chlorate should be kept separated from each other using a distance of at least 10 m or a substantial thermal barrier (double brick wall or equivalent).

4.7. STORAGE OF ORGANIC PEROXIDES (HSE,1998)

As we mentioned in Organix peroxide section, self-accelerating decomposition temperature (SADT) describes the storage temperatures of packaged peroxide products advised by the supplier. Maximum temperature for the storage, which is recommended by SADT, is called as 'control temperature'. And the 'emergency temperature' is the one, which requires being applied the emergency procedures. The temperature values are shown in the following table:

Table 25: Control Temperature

SADT	Control temperature	Emergency temperature
20°C or less	20°C below SADT	10°C below SADT
Over 20°C to 35°C	15°C below SADT	10°C below SADT
Over 35°C	10°C below SADT	5°C below SADT

Table 25: ADR (2017)

The primary storage recommendations are like following:

- Keep in original containers;
- Hold within the predetermined temperature limits;
- Keep in dedicated stores;
- Prevent contact/contamination with other materials such as acids, alkalis, amines, accelerators, combustible materials, metals, reducing agents etc;

Minimise the quantity at the workplace so that no more is present than is necessary for the job in hand.

Packaged peroxides are sectioned for four types according to their flammability to provide guidance about storage of them. The types are shown below:

Type 1 - This contains both 'Explosive' labelled packaged peroxides and packaged peroxides which burn very intensely.

Type 2 - This contains packaged peroxides which burn in a way which is intermediate between Types 1 and 3.

Type 3 - This contains packaged peroxides which burn in the range 'gently' up to something akin to solvents and hydrocarbons.

Type 4 - This contains packaged peroxides which are noncombustible and from which the available oxygen is not more than 5%.

Quantities up to 5 kg (Types 1 and 2) and up to 10 kg (Type 3)(HSE 2015)

Sometimes there may be need for taking a small amount of these substances for the purpose of test, experiment and control. While these are taken a dedicated fire resisting metal cupboards or lidded bins are used. They are designed for retaining spillages. These can resist to high temperatures (in excess of 750°C) and prevent the substances with the touch of hot gases or the passage of flame. When the substances should be kept in refrigerator then the ones, which are suitably designed, should be used because these devices are produced with the electrical equipment, which is separated or protected from possible internal pressures with an open door or a lid. They are equipped with some devices to give alarms in high temperatures and to monitor the movement in them so that a clear indication can be done outside the fridge for inside temperatures.

Quantities up to 150 kg (Types 1 to 3) and Quantities over 150 kg

Outdoors stores require security. In the construction of walls and floors, non-combustible materials should be used and the store should be protected from direct sunlight and should have a weather protection system. The preferable sizes of the store are at least five meters distance from buildings and boundaries. It can have the following features alternatively:

- The wall made of concrete, masonry or brick construction should be provide a minimum of one half-hour fire resistance according to BS 476
- There should not be openings on the wall for at least two metres horizontally from the store; and
- The store should not be under any openings so that it can be affected by a fire in the store.

The following features are recommended for a dedicated indoors storeroom:

- The materials used in floors, walls, any other internal ceiling should be non-combustible construction. All of them should be placed at least half-hour fire resistance
- The floor should be waterproof, concrete;
- To be able to prevent organic peroxides from direct sunlight, some precautions should be taken account.
- The room access should be done throughout door/s in the outside wall. Inside doors can be alternative but they need to be supported by strong fastenings and hinges;
- If the storeroom is in one stored building, then the roof of the storage should be made of lightweight construction, so that it can act as explosion relief.
- If possible, electrical equipment should be out of the storage area. Switches should be in external places and socket outlets should not be in the store;
- If there is need to install some electrical equipment inside the store, then it should be protected against any effect emerged corrosive vapours or dusts.
- If there are organic peroxides which are capable of creating flammable vapours in the storage, then electrical devices should be used in Zone 2 area and the construction of it should be compliance with “BS EN 50014 - BS EN 50020” standards. A Zone Area 2 is the place where normally operations do not create an explosive air mixture or vapour. In the case of an explosion, it will last for a short time in Zone 2. All equipment here should have surface temperature below the ignition temperature of the vapour.
- Where the combustible dusts have potential for accumulations, electrical equipment should have the standart of BS 6467. This provides restriction of dust ingress and keeps surfaces on maximum temperature. (Note: Zone 2 equipment is not useful to protect against access of dust and, as the same way, dust-proof equipment is not useful for use in a Zone 2 area);
- About smoke or heat detectors installation, it is recommended that they should be attached to an alarm system or sprinklers
- Liquid organic peroxides has the door opening which should be with a raised threshold so that it can involve the entire liquid contents to the storage area. This

limits and minimise the size of fire caused by peroxides and potential thermal radiation effects.

- Because of those flammable liquids are liquid organic peroxides and their store must have ventilation system to prevent vapours from contacting with spill or leaks. The recommended standard for this is at least five air circulation each hour. This can be with air bricks or louvres in one external walls at least. To be able to provide it, the openings should be normally kept a total area of at least 21/2 % of the walls and roof's total area.
- A refrigerated room or a freezer/refrigerator are suitable to keep refrigerated organic peroxides in. In a refrigerator room, the refrigeration unit shall be located outside the room and there must be a high temperature alarm system to warn the related location immediately;
- Some of organic peroxides can need some form of heating in specific circumstances. This will provide to maintain the store temperature above minimum heat. The necessary heat should be controlled with thermostats and water radiators. Organic peroxides which should be held in containers need to be stored at least 0.5 metres away from water radiators (fixed barriers are recommended). The surfaces of these radiators should be maximum 60° thermostatical valves must control C and them. While the temperature of the room becomes overheated, an automatic alarm for high temperature or a cut out must be used.

Risk assessment can be broken down into five steps:

Table 26: Steps of Risk Assessment in Warehousing

Step 1 Identify the hazards
Step 2 Decide who might be harmed and how
Step 3 Evaluate the risks and decide on precautions
Step 4 Record your findings and implement them
Step 5 Review your assessment and update if necessary

The following consideration rules are according to the regulation 5(2) of DSEAR which assess risks from dangerous substances.

- The hazardous properties of the dangerous substance(s);
- Safety information about dangerous substances which is provided by the supplier, and safety data sheets which includes detailed information;
- The circumstances of the work, eg the movements of dangerous substances in storage and their activities for transport;
- Particular activities having a high level of risk such as maintenance or movement of transport of dangerous substances;
- The effect of any measures gained and maintained as a result of DSEAR;
- The possible existing of explosive atmospheres and the classification need for hazardous area;
- The possibility of ignition sources such as electrostatic discharges which can exist; the scale of the predictable effects of an explosion or a fire;
- Any places having access to places thorough openings and possibility to create explosive atmospheres;

The most important steps are regular revising and reviewing risk assessment done by employers. After the review, some changes such as changing on management or equipment and nature or quantity of substances may be required.

According to the Management Regulations, employers who employ five or more people must record The significant findings after the risk assessment. However, Recording these

findings after any kind of case occurred and keeping them available for all relevant regulators and employees will be good practice.

The employees, representatives, or both of these groups should be involved by the employers into the assessment process. Their contribution will be good to give information about what happens during the work. Kaizen type methodology is valuable in such circumstances.

The company safety policy should include the means, which are used to control the possible risk of dangerous packaged substances in a written form. For these matters, the reviews should be done periodically, especially when a change happens in the storage conditions.

The risk control measures should be done according to this order: Elimination, substitution; control; and mitigation.

The warehouses where chemical materials are stored may not be suitable for elimination and substitution. Maybe it can be possible by using substances used as part of the storage operation, such as cleaning materials. In the case of the elimination or substitution are not enough to avert the risks completely; the employers should work on control and mitigation so that the safety becomes ensured. If still the correct storage conditions are not provided although all measurement has been done, then these dangerous materials cannot be permitted on the site.

The other duty of the risk management at all sides is to control all risks and means used for control. Where multi-hazard goods are stored together, the high-risk activity requires high-level management.

The recommendation for all warehouses is that there should be an individual risk management policy or other premises to use during storage of packaged dangerous substances. This kind of policies has their own details depending on different factors as follow:

- Quantities stored
- Specific hazards of the materials;
- And location of warehouse(s).

The main responsibility for a safe warehousing operation is to have a safety management.

The responsible employees should be well trained on this field, competent for the job and have sufficient knowledge about the issue.

In written operating procedures, the matter such as dealing with spillages, selecting storage locations, and security arrangements should be included.

For the companies managing their works with help of a risk assessment, it can mean using risk assessment for safety management such as COSHH. This identifies some procedures to cope with the spills and forklift truck operation, the permit to works system and segregation of hazardous substances. In such cases, there can be references some formalized methods to determine the risks. However, a risk assessment is not enough for a major analysis but it can help when detected with reports. Assessor should always keep in mind that quantification is not involved in risk and that qualitative risk work in the demonstration of safe operation. The examples of non-quantified approaches are like following: (HID, 2017)

- Hazard studies.
- Job safety analysis.
- Reference to industry standards.
- Safety reviews.
- Human error identification.

In the case, there have been more dangerous substances than the qualifying inventory for COMAH/Seveso; the Competent Authority should be informed about this.

The COMAH Regulations composes of lists of specified quantities of dangerous substances that are used for determining whether an establishment is top or lower tier. Some of the duties imposed by COMAH do not apply to lower-tier establishments. The HSE publication “the Control of Major Accident Hazards Regulations” is a guide to decide if the Regulations apply to the establishment, and whether the establishment is top tier or lower tier.

Operators of COMAH sites need to take necessary precautions to prevent major accidents based on the principle of reducing risk to ALARP. (as low as reasonably

practicable).ALARP is not a certainly requested regulatory model. But Operators must have a major accident prevention policy (MAPP) if they are a upper tier establishment. The MAPP is a written document. For upper-tier operators it must be included as a separate document in the safety report.

Schedule 1-part 2:Named substances

Where a substance of group of substances listed in this Part also falls within a category of Part 3, the qualifying quantities set out in this Part must be used.



Table 27: COMAH Low and Upper Tier Table(HSE, Comah 2013)

Column 1	Column 2	Column 3
<i>Dangerous substances</i>	<i>Quantity in tonnes</i>	
Ammonium nitrate (as described in Note 1 of this Part; see also Note 8(1) and 8(2))	5,000	10,000
Ammonium nitrate (as described in Note 2 of this Part; see also Note 8)	1,250	5,000
Ammonium nitrate (as described in Note 3 of this Part; see also Note 8(2) and 8(3))	350	2,500
Ammonium nitrate (as described in Note 4 of this Part; see also Note 8)	10	50
Potassium nitrate (as described in Note 5 of this Part)	5,000	10,000
Potassium nitrate (as described in Note 6 of this Part)	1,250	5,000
Arsenic pentoxide, arsenic (V) acid and/or salts	1	2
Arsenic trioxide, arsenious (III) acid and/or salts	0.1	0.1
Bromine	20	100
Chlorine	10	25

Nickel compounds in inhalable powder form (nickel monoxide, nickel dioxide, nickel sulphide, trinickel disulphide, dinickel trioxide)	1	1
Ethyleneimine	10	20
Fluorine	10	20
Formaldehyde (concentration $\geq 90\%$)	5	50
Hydrogen	5	50
Hydrogen chloride (liquefied gas)	25	250
Lead alkyls	5	50
Liquefied extremely flammable gases (including LPG) and natural gas (whether liquefied or not)	50	200
Acetylene	5	50
Ethylene oxide	5	50
Propylene oxide	5	50

Column 1	Column 2	Column 3
<i>Dangerous substances</i>	<i>Quantity in tonnes</i>	
Methanol	500	5,000
4, 4-Methylenebis (2-chloraniline) and/or salts, in powder form	0.01	0.01
Methylisocyanate	0.15	0.15
Oxygen	200	2,000
Toluene diisocyanate	10	100
Carbonyl dichloride (phosgene)	0.3	0.75
Arsenic trihydride (arsine)	0.2	1
Phosphorus trihydride (phosphine)	0.2	1
Sulphur dichloride	1	1
Sulphur trioxide	15	75
Polychlorodibenzofurans and polychlorodibenzodioxins (including TCDD), calculated in TCDD equivalent	0.001	0.001
The following CARCINOGENS at concentrations above 5% by weight:		
4-Aminobiphenyl and/or its salts, Benzotrichloride, Benzidine and/or salts, Bis(chloromethyl) ether, Chloromethyl methyl ether, 1,2-Dibromoethane, Diethyl sulphate, Dimethyl sulphate, Dimethylcarbamoyl chloride, 1,2-Dibromo-3-chloropropane, 1,2-Dimethylhydrazine, Dimethylnitrosamine, Hexamethylphosphoric triamide, Hydrazine, 2-Naphthylamine and/or salts, 4-Nitrodiphenyl, and 1,3 Propanesultone	0.5	2.0
Petroleum products:*		
(a) gasolines and naphthas;		
(b) kerosenes (including jet fuels);		
(c) gas oils (including diesel fuels, home heating oils and gas oil blending streams)	2,500	25,000

Schedule 1 Part 3 : Categories of substances and preparations not specifically named in Part 2

Column 1	Column 2	Column 3
Categories of dangerous substances	Quantity in tonnes	
1 VERY TOXIC	5	20
2 TOXIC	50	200
3 OXIDIZING	50	200
4 EXPLOSIVE (see Note 2) where the substance, preparation or article is an explosive within UN/ADR Division 1.4	50	200
5 EXPLOSIVE (see Note 2) where the substance, preparation or article is an explosive within UN/ADR Divisions 1.1, 1.2, 1.3, 1.5 or 1.6 or risk phrase R2 or R3	10	50
6 FLAMMABLE, where the substance or preparation falls within the definition given in Note 3 (a)	5,000	50,000
7a HIGHLY FLAMMABLE, where the substance or preparation falls within the definition given in Note 3 (b) (i)	50	200
7b HIGHLY FLAMMABLE liquids, where the substance or preparation falls within the definition given in Note 3 (b) (ii)	5,000	50,000

8	EXTREMELY FLAMMABLE, where the substance or preparation falls within the definition given in Note 3 (c)	10	50
9	DANGEROUS FOR THE ENVIRONMENT risk phrases:		
	(a) R50: "Very toxic to aquatic organisms" (including R50/53)	100	200
	(b) R51/53: "Toxic to aquatic organisms: may cause long term adverse effects in the aquatic environment"	200	500
10	ANY CLASSIFICATION not covered by those given above in combination with risk phrases –		
	(a) R14: "Reacts violently with water" (including R14/15)	100	500
	(b) R29: "in contact with water, liberates toxic gas"	50	200

Receipt of goods: The information about receipt of goods should be given to the employers before they arrived into the warehouse. After the goods arrived, the consignment paperworks, actual delivered materials, and integrity of the goods, packaging of them for any leaks should be checked.

While substances are not identified or have any other problem, it cannot be send to the storage area. Another procedure should be applied for these kind of problematic substances and the employers should contact with the supplier for help. These materials can be taken into a temporary area during this procedure. When there have been unsatisfactory responses from the supplier, the materials should be removed out of the site. All staff should be familiar with and trained on these procedures.

The dangerous goods, which should be transported in, expected/limited quantities, should be labelled with this information and the way it is described before.

The transportation of substances should be compliance with the Carriage Regulations. The chemical warehouse should receive goods, which are marked according to ADR regulations (labelling and marking: CLP)

4.7.1. Separation and Segregation of Dangerous Goods

The goods should be assessed for determination the hazards they pose before they arrive the site. This is a part of receipt procedure. After this process, the goods are determined where to be stored in the chemical warehouse in accordance with local segregation policies. If there is a possible condition, incompatible materials should be segregated in the reception area. After this procedure, they should be send to the storage as soon as possible. In the case of necessity, interim storage should be assigned.

The potential or escalation of an incident should be in the segregation policy. Generally, the source of ignition in a fire is not dangerous substances themselves, rather, it is other materilas such as pallets, rubbish, discharged packaging or a spark from a hot work or a discarde cigarette. Therefore, the warehouse should be cleaned of such materials or they should be held in a separate compartment.

Where incompitable materials are together, the possible fire will be more intensive and more grown. For instance, oxidizing agents has a power to increase the severity of a flammable liquid fire. For another example, when packaged free-flowing flammable powder are at height and if fails, the fire will increase. Besides this, the fire can involve dangerous substances which are not combustibile. Toxic materilas can spread in smoke plume or firefigtining water widely and can cause serious consequences for people around or the environment. To hold these dangerous substances in a dedicated warehouses and suitable parts of the warehouses will help to prevent such potentials.

In the following table, the recommendations of segregation types of dangerous substances are given according to hazard classification. The table is in compliance with the Carriage Regulations. It is globally recognized because of its simplicity in operation and being understood by industry with its details. There are nine classes in this system. For the materials, which have more class than one, a hierarchical order is shown. The table excludes Class 1 (explosives), Class 6.2 (infectious substances) and Class 7 (radioactive substances).

Table 28: General Recommendations for the Separation or Segregation of Different Classes (HSG 71, 2009)

General

recommendations for the separation or segregation of different classes of dangerous substances

	CLASS	2	3			
						
Compressed gases						
2.1 Flammable	2		KEEP APART	Segregate from or KEEP APART	Segregate from	
2.2 Non-flammable/non-toxic			KEEP APART	KEEP APART	KEEP APART	
2.3 Toxic			Segregate from or KEEP APART	KEEP APART	Segregate from	
Flammable liquids	3		Segregate from	KEEP APART	Segregate from	
Flammable solids						
4.1 Readily combustible	4		Segregate from	Separation may not be necessary	KEEP APART	KEEP APART
4.2 Spontaneously combustible			Segregate from	Segregate from	Segregate from	Segregate from
4.3 Dangerous when wet			Segregate from	Separation may not be necessary	KEEP APART	Segregate from
Oxidising substances						
5.1 Oxidising substances	5		Segregate from	Separation may not be necessary	Separation may not be necessary	Segregate from
5.2 Organic peroxides			ISOLATE	Segregate from	Segregate from	ISOLATE
Toxic substances	6		KEEP APART	Separation may not be necessary	Separation may not be necessary	KEEP APART
Corrosive substances	8		KEEP APART	KEEP APART	KEEP APART	KEEP APART

Segregate from

These combinations should not be kept in the same building compartment or outdoor storage compound. Compartment walls should be impermeable, of at least 30 minutes fire resistance and sufficiently durable to

withstand normal wear and tear. Brick or concrete construction is recommended. An alternative is to provide separate outdoor storage compounds with an adequate space between them.

Separation may not be necessary

Separation may not be necessary, but consult suppliers about requirements for individual substances. In particular, note that some types of chemicals within the same class, particularly Class 8 corrosives, may react violently, generate a lot of heat if mixed or evolve toxic fumes.

ISOLATE

This is used for organic peroxides, for which dedicated buildings are recommended. Alternatively, some peroxides may be stored outside in fire-resisting secure cabinets. In either case, adequate separation from other buildings and boundaries is required.

The segregation advice shown in the following table does not include chemical incompatibilities. In some cases, different compatible substances in the table may react together. Then the employers should also apply the material safety data sheets and other suitable sources for reactivity data for determining if storing them together is safe or not.

Table 29: Segregation in Warehousing(HSG71, 2009)

4			5		6	8
						
Segregate from	Segregate from	Segregate from	Segregate from	ISOLATE	KEEP APART	KEEP APART
Separation may not be necessary	Segregate from	Separation may not be necessary	Separation may not be necessary	Segregate from	Separation may not be necessary	KEEP APART
KEEP APART	Segregate from	KEEP APART	Separation may not be necessary	Segregate from	Separation may not be necessary	KEEP APART
KEEP APART	Segregate from	Segregate from	Segregate from	ISOLATE	KEEP APART	KEEP APART
	KEEP APART	Segregate from	Segregate from	Segregate from	KEEP APART	Separation may not be necessary
KEEP APART		KEEP APART	Segregate from	ISOLATE	KEEP APART	KEEP APART
Segregate from	KEEP APART		KEEP APART	Segregate from	Separation may not be necessary	Separation may not be necessary
Segregate from	Segregate from	KEEP APART		Segregate from	KEEP APART	KEEP APART
Segregate from	ISOLATE	Segregate from	Segregate from		KEEP APART	KEEP APART
KEEP APART	KEEP APART	Separation may not be necessary	KEEP APART	KEEP APART		Separation may not be necessary
Separation may not be necessary	KEEP APART	Separation may not be necessary	KEEP APART	KEEP APART	Separation may not be necessary	

KEEP APART
 Separate packages by at least 3 m in the storeroom or storage area outdoors. Materials in non-combustible packaging that are not dangerous substances and that present a low fire hazard may be stored in the separation area. This standard of separation should be regarded as a minimum between substances known to react together readily, if that reaction would increase the danger of an escalating incident.


 The lower standard refers to the outside storage of gas cylinders. Where non-liquefied flammable gases are concerned, the 3 m separation distance may be reduced to 1 m.

Where a particular material has the properties of more than one class, the classification giving the more onerous segregation should be used.

This particularly applies to many corrosive substances in Class 8, which can react together to produce heat or toxic gases. Such as:

- Acids/sulphides – generate hydrogen sulphide
- Acids/hypochlorites – generate chlorine gas;
- Acids/alkalis – generate heat; and
- Acids/cyanides – generate hydrogen cyanide gas;

Generally, segregation of acids provides to be sure that incompatible substances should not be stored together. This reduces the possible incompatibility problems because at least two packages should damage to react. When two compatible components are solids, the reaction occurs more slowly.

There has been no general advice about segregation of miscellaneous dangerous substances placed in Class 9 and other dangerous materials in the Carriage Regulations because they have various properties in them. For these kind of substances, you should take help from the suppliers.

4.7.2. Storage Location

While a dangerous substance is considered to locate in a new warehouse, then to be able to prevent any kind of risk for neighboring populations and property, a risk assessment should be done. Some groups of the population have priority on others. These are children in schools, residents of retirement houses and patients in the hospital.

- Use and storage of cellular plastics
- Storage of Full and Empty LPG Cylinders and Cartridges
- Energetic and spontaneous combustible substances(fuel oil, paint, kerosene, magnesium, cesium, aluminium powder, plastic dust, coal, powdered metal etc.)
- The storage of flammable liquids in containers
- Storage and handling of industrial nitrocellulose

Rather than the Building Regulations, these will be required greater. In every situation, the bigger separation distance should be followed.

4.7.3. Access

A warehouse storage compounds can be designed in many various design and location style. However, the access of the storage should be suitable for various day-to-day operations. The Building Regulations provides the applicable standards in construction of new buildings.

In case of emergency, access of the storage is so important. The access of the storage and boundry fencing around it should be opened and enough for entry of firefighting equipment by the local Fire and Rescue Service in immediate cases. There should be more access than one to the storage area because in the case of incident, one of these accesses can cancel. If the conditions on site are jammed, it is needed to be considered traffic movement schemes, e.g. speed restrictions and one-way systems.

It is obviously seen that, in the incident the access of the Fire and Rescue Service is vital, so at all times accesses of the storage should be available. At the same time, parking or access of unauthorized vehicles must be controlled so that the Fire and Rescue Service's access does not become unavailable.

Besides the importance of access to the storage or the warehouse, the escapes routes are so vital in an emergency such as fire. Unfortunately, the escape routes are considered as a part of general fire precautions under the Regulatory Reform – Fire Safety. For more details, the rescue authorities and the responsables of local fire should be consulted because they enforce the regulations.

4.7.4. Handling and Transport

Containers should be stacked to ensure safety in the storage during the facility operations. With stack design, the possible leaks from a container should be seen and removed easily and it should allow dealing with them appropriately. For 200 liters metal or this kind of containers, the recommended stacking is being under two high and if possible on pallets. Drums should be stacked with chocks to prevent them from moving. As for compress gas cylinders, they should be stored as horizontally and ensured not be topple. Also liquefied petroleum gas (LPG) and acetylene should prevent toppling. Placing the containers in front of them should not close the means of escape or ventilation openings. Stacks should be at least 0.5 m below electric lights.

For transport and handling, the most appropriate and suitable equipment should be used so that the safety can be provided. This equipment are chosen for the type of packages and their storage types. In narrow aisle areas, the specialist forklift trucks are the most appropriate and they requires more training. If the arrangement is not provided during the movement of the packages, then it is possible to occur accidents or damage packages or spillage of the contents. While handling operations, palletized goods should be endured to prevent any accident caused by their movement.

Vehicles loaded with packaged dangerous good should be parked in a safe area while loading and unloading. There should be a part in the risk assessment, which shows the possibility of a collision can cause a spillage of such goods.

4.7.5. Operations

During dispensing, processing, mixing or other activities, which create spills, separate areas should be used rather than the store. These areas should be designed for reducing spills and dangerous releases. The maximum loading in the racks should not be overfilled.

The order of the storage of the racks should be done as some considerations. Empty racks should be lined from the bottom to up so that avoiding generating unstable stacks. The other significant matter about this issue is the level of the racks e.g. the racks should be sorted according to their hazard possibility and it should be considered that which substance can leak onto the lower level rack.

In some warehouses, there is no rack system and goods are stored in block stacks. In this stores, to limit the intensity of the fire depends on the stack sizes. Of course, a maximum size and height for stacks should be followed as standards show. Height is also important for stacks because when it is too high, the lower layers can be overloaded and their stability can deform and endanger.

4.7.6. Security

The duty of physical control measures is to minimize the explosion or fire risk. These only can be defeated with tampering and trespassing. Unauthorized people are not be able to enter the storage area during working hours. This can be too dangerous. To provide this security, you can keep the storage locked and the key of this room should only be in authorized people.

The standard of security required depends mainly on the results of a major fire. Security patrols and intruder alarms, etc. might be considered as appropriate, but other simple precautions such as maintaining fences(made according to general fire precautions) and external walls should not be forgotten. If there is any missing construction panels, sheets or broken windows, then they should be immediately repaired. These openings allow unauthorized people to enter the store in case of fire and even fire can started from these holes. Empty drums or pallet stacks in the position of opposite the building might help unauthorized access and for an arsonist it can also be as the fuel source.

When an explosive environment and air condition exists, all ignition sources should be kept under control regularly. This is another part of risk assessment. Although there are many source of ignition, some of them are as follows:

- Smoking and smokers' materials;
- Electrical supplies and equipment;
- Maintenance work, especially hot work;
- Hot surface ignition sources such as storage which is close to hot pipes or light fittings;
- Arson;
- LPG-fuelled shrink-wrapping machines;
- Heating systems incorporating open flames
- Static electricity;
- Warehouse vehicles, and battery charging facilities;
- radio frequency energy sources, such as mobile phones;
- Spontaneous combustion, such as rags or paper, which are contaminated with oil or paint, they will not be properly disposed of.

All storage areas should have fixed or portable, correctly installed, maintained and designed electrical equipment according to “The Electricity at Work Regulation”. For installation, testing to control the risk of fire, electric shock, periodic inspection, guidance for the appropriate design and fixed installations, there is standardization.

Installing a main switch which can be accessed from outside is a good practice for new facilities. In addition, there should be distribution boards located in a fire resting room of the main store entrance.

The electrical installation inside the storage such as lightning, it should be ensured that it is correctly located (e.g. it is away from easily ignitable materials), suitable for intended usage, and necessary preventative maintenance carried out. There should not be power cables around any area, in the case of any leaks by corrosive substance they can be damaged and attacked mechanically.

The classification of zones and the risk assessment of the hazardous areas are identified with “The ATE (of EU)” and “DSEAR (of UK)” and similar regulations. With these regulations, the proper installation and usage of electrical equipment can be provided in hazardous areas. To be able to keep the source of ignition under the control, some special precautions are determined with these standards on installation, construction and use of electrical equipment. These standards also include advices on installing, selecting and maintaining equipment.

The usage of unauthorized electrical equipment such as heaters, radios or kettles is recommended to control.

It is carefully cared that any kind of flammable sediment should be cleaned to touch the heating system. AZDN and some certain solid substances have safe temperatures in the storage above the heat they will decompose and they generally ends with catastrophic results. After the safe storage temperature is determined, there should not be keep any heated surface above this temperature to provide the safety.

Vehicles which are operating in the storage areas or buildings of hazardous substances can be fulfilled the appropriate standards so that any kind of explosive atmospheres to create ignition can be prevented.

The parking of vehicles filled with LPG or petrol should not be allowed in the storage area outside working hours. Recharging batteries generates hydrogen, a flammable gas. When the situation the electrical powered vehicles should charge like forklift trucks, it should be done in a bay not in the storage area and there should be a good ventilation during recharging.

Radio frequency power emerged from radio transmission masts or CB systems and mobile phones are the potential source of ignition. It should be assessed the risk created by the structure on the business and the appropriate actions should be taken to eliminate or control the risk.

Another part of risk assessment is IBC's the risk ignition emerged from static electricity. The use of insulating plastic might led to an increased incidence of static build up through handling and liquid movement

Many cases of fire take place while repairing and activities and sometimes as a result of them. According to "health and safety law", safe conditions should be provided for work equipment. The ones, who should carry out maintenance and inspections, should be only authorized and qualified personnel.

4.7.7. Aerosols

Aerosols are in inventory of some chemical warehouses. As a propellant liquefied flammable gas, generally LPG or dimethyl ether should be used in aerosols. This is a part of risk assessment because aerosols have potential risks with this feature.

Packages of aerosols have usually marks according to "UN 1950 Limited Quantity packages". These packaged aerosols should be controlled before receiving into the warehouse so that whether the contents of the packages are damaged or not can be decided. These controls can be done with gas perceiving detectors or by visual inspection in the vehicles they are transported to be send to the warehouse. This inspection can help to catch wet packets, smells of cloudy wrapping.

Generally, while fork-lift truck operations, an incident occurs to react the content of aerosols and causes fires. After a collision, drooped pallets or loose cans, these cans can take damage, and then when a forklift truck ignites the material coming out of the damaged can, a destructive fire may start. Because of that one of the primary causes for fire in chemical warehouses is forklift trucks, these vehicles should be selected carefully not to cause a fire of aerosols. Where the hazardous goods and aerosols are stored in high quantities, AC motors and enclosed contactors are the appropriate vehicles for the operation.

In the condition of overheating, aerosols might rupture. Therefore, it is dangerous to keep them near heating pipes, under direct sunlight or in hot air vents. Repacking works such as shrink-wrapping pallets or groups of aerosols should not be done inside of the warehouse.

The warehouses, which can have highly flammable liquids and intense heating to cause an external fire, are not suitable for storing aerosols.

The effect of ignited aerosols will be a severe fire. Firefighting becomes difficult and fire can spread widely if aerosols are ruptured. Reducing these risks, steel mesh barriers and racks of pallets, which contain aerosols, can be used. Another precaution is to restrict the quantity of stored aerosols in all fire-resisting compartments.

Where there are possibilities, keeping aerosols separated or segregated from other materials by a firewall is recommended. With this barrier, two functions can be provided in chemical warehouses: Firstly, it prevents fire emerged by aerosols to spread to other flammable hazardous goods; and secondly, it reduces the possibility to spread of a fire emerged by other hazardous goods to aerosols stored in the same storage.

4.7.8. Intermediate Bulk Containers (IBCs)

IBCs are designed only for transportation purposes. However, in recent times, IBCs are started to use for storing liquids especially flammable liquids so a lot of chemical warehouses started to have IBCs daily.

Of course, some risks because of the use of IBCs for storage emerged, as well:

- In case of fire, IBCs are apt to failure at the valves or anywhere else. As a result of it, the liquid in them leaks and increases the fire. This fire creates an escalation. This fire grows in minutes and there are incidents, which caused to lose a whole warehouse with this kind of fire.
- When IBCs are not used only for their purpose; transportation, but for long-term storage, they can be degraded. Therefore, some leaks can appear and they can contact with any ignition source, this will create a fire at the end. Many mechanisms such as, stacking with no reference to load bearing certification or ability, weathering, using with incompatible substances or etc. can lead IBC to a failure. To be able to reduce this risk an inspection procedure should be applied in all sites and when it is found any poor

condition, then those IBCs should be moved out of the facility. By the way, ADR prepared a specific inspection regime for IBCs using for their real purpose, transport.

- Generally, IBCs are made of plastic materials that are cost-effective. These plastic materials are not conductive to electricity. When these containers are filled with non-conducting flammable materials and then they are moved the surface of the containers, an electrostatic charge will emerge. This charge can easily take a path to earth or decay in time. If this earth path is worked on, an electric shock can be created when it touches to IBC. In case of this kind of charge, even a small flammable liquid leaks can easily ignite and an uncontrollable fire occurs (Safety.BLR Nov.19,2011>Nonconductive flammable liquids:bonding and grounding may not be enough to prevent a disaster).

While a specific assessment is applied in IBCs using for the storage, these issues should be addressed (to comply with ATEX-DSEAR and the Management Regulations).

4.7.9. Storage of Hazardous Waste

The storage of hazardous waste should be in compliance with “the Waste Framework Directive, the Hazardous Directive” and for many cases “the Integrated Pollution Prevention and Control (IPPC) Directive”.

The employers should know what waste containers contain before they are received in to the warehouse. The labels on the containers should be placed correctly and appropriately according to their contents. To make an appropriate separation or segregation in the storage, their suitable storage conditions and integrity should be known correctly.

4.7.10. Building Constructions

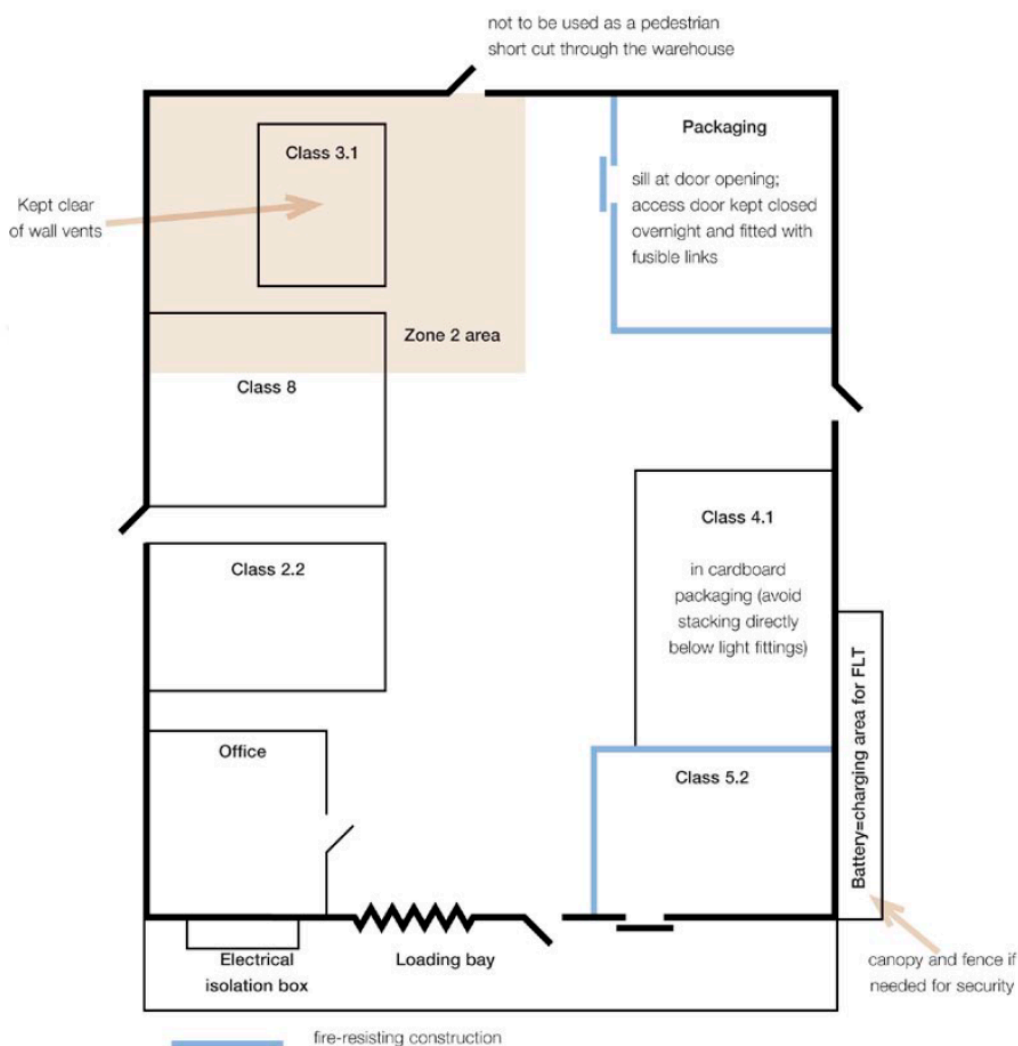
The controls of the outdoor storage areas and buildings for dangerous substances should be under building and planning legislation.

The standards specified by the Regulation are compartment sizes, fire resistance, means of escape and assistance to the Fire and Rescue Service.

The materials, which are used in the construction a building for dangerous substances, should preferably be non-combustible. The duty of the fire resisting walls to keep an external fire grown deliberately away from the dangerous substances. As a part of risk assessment, combustible materials should be used. Sometimes, buildings can be prone to take lightning and this can cause a fire. In this buildings, there should be a protection

system against the lightning. More guidance on the assessment of lightning risk and measures to reduce it are given in “IEC EN 62305:2006 Standards Protection” against lightning.

Table 30: Dangerous Goods Warehouse Layout(HSG 71, 2009)



The main aim of fire resisting structure is to prevent the fire spread, and any kind of escalation caused by this fire, or the protect the means of escape. This is a requirement determined by “the Regulatory Reform (Fire Safety)”. The legislation shows how to act in a case of local fire and the duties of the rescue authorities. These can advise on general fire precautions. There are standards for fire resistance in building regulations, which have certain structures. There might be other requirements for fire protection, suppression system, fire compartmentation and separation requested by the insurers.

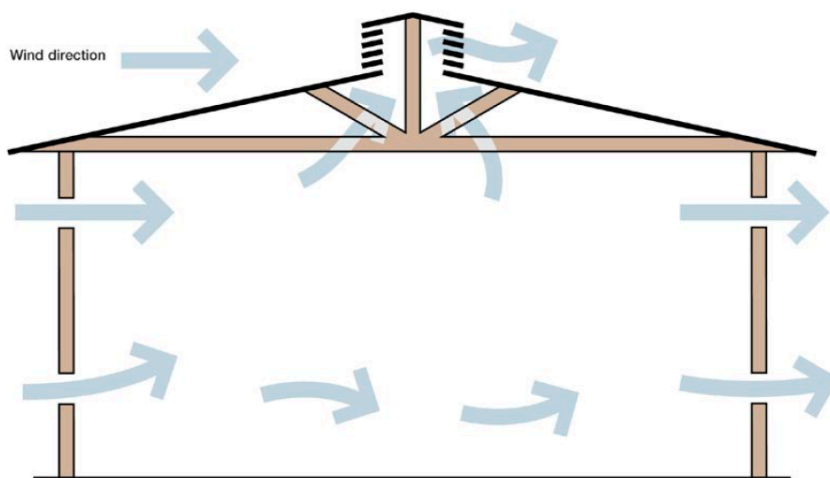
While a storage building is designed, the layout of storage within the warehouse has to be considered. There might be an inbuilt store besides the main warehouse in some warehouses. These inbuilt stores might be used for storing hazardous substances such as aerosols, gases and flammable liquids, peroxides. In this case, the store must have a fire resisting structure.

To have an access from the outside of the main store to the interior is better. In this way, it can ensure that the fire resistance between the main store and the interior store is not jeopardised by any access doors being permanently left open. If there is link with the fire alarm on the access door of the interior store, it is better. When the alarm gets activated, then the system should close the fire access doors. At the end of the each working day, the internal fire doors should be closed manually rather than trusting the automatic closure system.

When a leak of gases or flammable liquids appears, the concentrations of these flammable vapours are important source of danger. A good, regular ventilation can prevent this. (Figure 30). The basic way of providing good ventilation is placed permanent and fixed openings such as louvers or air bricks on external walls at both low and high levels. Where there are only opening on two walls then a wind-forced, cross flow can emerge. Also, the high and low level opening will proved air circulation by thermal currents. During working hours, to ventilate the accesses of the vehicles might be sufficient. However, the risk assessment recommends a ventilation system out of working days.

In large buildings there should be mechanical ventilation system to be able to provide sufficient air movement. When this system is necessary, a constant operation is better. To detect a failure of air circulation system, an airflow monitoring system should be used. These devices should be installed in the ventilation ductwork (such as a flow switch or differential pressure switch) and linked to an alarm. Measurements might measures any sort of air change in the building.

Table 31: Dangerous Goods Warehouse Ventilation(HSG 71, 2009)



During planning a warehouse, the properties in neighbor have to be considered. If there is necessity to build additional firewalls, segregation by distance or other safety features, they have to be evaluated. Thus, the risk caused by the site's activities can be reduced for neighboring properties.

4.7.11. Design and Construction of Packaging and Containers

The integrity of packaging and containers is the main production precautions against any risk emerging from the dangerous substances, if they are not stored in bulk or tanks. Because of the fact that there may always be some leaks or escapes from individual packages or breaks, puncture, the appropriate arrangements should be applied for these packages.

194 According to Both “CHIP and the Carriage Regulations” the safety of chemical packages should be ensured by suppliers, manufacturers and distributors.

Each container's designing and construction should be in compliance with the suitable standards for safety purposes. For containers, the appropriate standard is UN performance-tested type. A UN-approved container can be identified by referencing the UN mark as specified in ADR. These containers are better for storage.

When there is corrosion possibility, the containers should be prevented from it by painting or protected against degradation arise by light with suitable shading. Beside, the materials of the container are important. It should not be made of any compatible material, which it

can react when contacting the chemical or physical substances they contain. This is to ensure any leakage caused by the contamination does not occur.

Before reusing of the containers, they should be inspected carefully against any damage, which they can interact when they are filled again with chemicals or other wastes. Generally, problems emerge from corrosion, which occurs around the base seams of drums or damaged linings to drums.

4.7.12. Spillage control

If an industrial building occurs, it should have some procedures for spillage control. In the storage area, to use means of control for spillage and to prevent uncontrolled liquid spreading with these means are important. These means make some control measurements possible. The spillages can be cleaned in suitable conditions by using sealing putties, booms, dry sand, absorbent granules. Then a registered waste contractor can remove contaminated materials appropriately and safely. The clean, spare and empty drums or bags should be used for this purpose. There are proprietary salvage drums, which are known at the same time as over pack drums to be used for holding leaking drums or such. After using a salvage drum or an over bag, they should be labelled according to their purpose and contents.

4.7.13. Control of Spillages In Outdoor Storage Areas

As for the outdoor storage areas, low bund or sill are suitable to install to contain spillages. This should surround a volume which must be at least 110% of the capacity of the largest container in the bund. Against the possibility of any leaks from the containers can drop onto the safe contained place, the storage floor should be sloped slightly. In addition, a valve-controlled conduit or interceptor pit can be used to retain on site, depending on the hazardous material in the store. There should be a fireproof jointing material in containment system.

Buildings and storage should be constructed by using resistant and compatible floors with the content of the store. For example, many acids flow in concrete floors, solvents flow in bitumen floors, and impregnated timber floors by flammable liquids or oxidising agents such as peroxides increase fire risk. Preventing leaks or releasing them from containers can be provided with sloping floor structure. However, this kind of floor are not

useful for the warehouses, which are designed with racking system because if the floor slopes, the item on the rack will be compromised. Another way to contain leaks is to provide a sill across the opening door. These sills are generally about 150 mm high. As another requirement can be ramps for wheeled trolleys, forklift trucks etc. The walls which goes up to the height of the sill should be constructed as impervious and consistent with the stored materials. When the building's drains link to the site drainage systems, there should be need some additional containments.

While spillage and containment control, the existing of any fire suppression should be taken account. The reason of that is water floated in such a system can spread some materials, which are lighter than water. Thus, this system and the spillage control should be compatible. If there is no appropriate arrangement for drainage or sills at the door opening, then internal fire doors are not enough to avoid spread of fire from an expanding liquid pool.

These requirements are different than firefighting water run off containment because the latter might need to avoid the release of materials from the store to the environment in case of an incident. This kind of run off can be considered as water from both manual firefighting and installed system. When foam and fire suppression systems are discharged, they might be a hazard for the environment and then containment will need to be allowed for.

The precautions to control or reduce the fire and explosion risks mean to control health risks at the area. However, some other precautions and measures are required to protect human health besides the other precautions. These additional steps may be the coalescences of vapours or dusts which can damage health of human beings. COSHH is an application and according to it all employers are responsible for preventing and controlling potential exposure to harmful substances – a guidance exist in “Control of Substances Hazardous to Health (Fifth Edition): The Control of Substances Hazardous to Health Regulations 2002 (as amended): Approved Code of Practice and guidance.”⁴⁰

4.7.14. Health Precaution

The owners of the warehouses, which store hazardous substances, should work in safe system whiling coping with spillages. There are several control measures. The measurement should be done according to Material safety date which shows how to

approach and deal with the spillages subject to the action. It is an obligation to have this data for each substances on the warehouse.

During the cleaning of spillages, the procedure of the site has to be applied and materials should be disposed in this way to keep the area safe. The goggles, gloves and protective gear should be used while working to protect skin or eye from any contact. Clean up operation may require a appropriate respiratory protection. When new substance received to the site, the personal who has protective equipment for these substances has to deal with them.

Personal Protective Equipment 214 (PPE) shall not be used for the place of other equipment to be used for other risk controls. This equipment should be the last resort for handling with hazardous substances to make them in safe and health. That is way, before the using PPE, other methods should be applied to control exposure. Of course, there might be other situation required some necessary protective equipment.

PPE includes the following:

Overalls, gloves, helmets, waterproof equipment, safety footwear as protective clothes and ear protectors and eye protectors as protective equipment.

While selecting, which PPE should be used in the activity, the nature of the hazardous substances in the warehouse and the type of the work has to be taken into consideration.

‘CE’ marks should be on the PPE materials using on site and it should be comply with “Personal Protective Equipment Regulations 2002 (89/686/EEC.PPE directive)”.

4.7.15. Hazardous Area Classification

According to the Regulation 7 of DSEAR, the employers should apply a risk assessment in their activities with dangerous substances and then they need to eliminate the risks to reduce them. Vapours, dusts, mist and gases create explosive atmospheres. Where there are such elements in a warehouse in enough quantity to create an explosive condition, then some precautions should be taken to protect people under predictable process such as burst or leaking container. In addition, a classification for hazardous area should be done. These classifications identify the types of control over the ignition sources in the storage area.

The classification of hazardous areas and places is done according to the potential occurrence of the explosive atmosphere with their duration and frequency. This means it is

a frequency-based assessment. It gives estimations about the frequency of the occurrence of the atmosphere and its duration. The results of the control measurements and ignition should be operated safely and they need to be in compliance with the DSEAR regulation and the risk assessment.

International standard “BS EN 60079-1043” explains the basic principles of area classification for gases and vapours and “BS EN 50281:200244” for dusts. The DSEAR also contain guidance on this issue.

Because of there are a lot of product movement in large warehouses, a risk assessment arranged spesificly for them has to be made to measure the frequency, duration, size of any potential explosive release.

4.7.16. Emergency Arrangements

As a basis of the risk assessment, employers should always have an emergency arrangement to be able to provide safety of the people on their site and minimize to effect of any kind of incidents then bring the situation to its normal stability. The first requirement, which should be in the emergency arrangement, is to be able to evacuate people to a safe place in case of emergency.

At the same time, a designed training and instruction is need to be available for the employers. Besides that they need to know when there can be necessity of external emergency support, they need to know how to act in case of an emergency according to employees’ emergency arrangement. The arrangement should be revise periodically and if there are any changes in the work place such as the quantity or content of dangerous substances, then the necessary formation on the arrangement should be done immediately.

4.7.17. General Fire Precautions

When a fire started, everybody must be in hurry and try to reach a safe place. The concept of ‘general fire precautions’ means structural features and equipment to achieve this. Such as:

- Firefighting equipment;
- Escape routes to fire exits;
- Sprinklers or other appropriate media
- Fixed installations such as water or foam

- A system of giving warning in the event of fire;
- An efficient arrangement for warning
- Rescue service in case of the fire;
- And sufficient management procedures, which make these features available and maintained, and this procedure should provide an efficient training to use all of them.

To be able to complete a risk assessment according to regulations of the “the Regulatory by Communities (CFPA-Confederation of Fire protection agency, ATEX-Appareils destines utilizes an ATmospheres EXplosives) and Local Government”, the precaution, which should be taken, needs to be considered.

During the times when people are on site such as out of working day or anywhere in the warehouses that there is no people, a fire cannot be seen. This will be a vital risk for the people because even fire is not seen the smoke emerged from it can carry toxic materials and people can breathe it unknowingly. This can be prevented by early fire detection. This can be done by a automatically alarmed fire detector which warns the site immediately. This device has a feature to alert the Fire and Rescue Service and the surroundings, as well. There is the description and advice of the suitable equipment for is in BS 5839.

In the storage area, a sufficient number of fire equipment should be exist. The primary feature of them is to handle with the incipient fires because this kind of fires do not contain any dangerous substance. By using this equipment, people can escape and the risk is reduced. The people who have trained on it should use the fire extinguishers. When there is a dangerous substance such as aerosols in a fire, then fighting against it cannot work. However, if a fire starting in a packaging or a waste bin can be tackled with the equipment and a big fire can be prevented like this. The locations of the extinguishers should be in the escape routes because if people move more than 30 mt to reach the extinguishers, this will be dangerous. This should be places with signs showing them. The signs should comply with “Health and Safety (Safety Signs and Signals) Regulations 92/58/EEC EU-OSHA.” The equipment should comply with the standards.

4.7.18. Fire Protection

Compartmentation is one of the measures in which the dangerous substances are keeps in fire resistant enclosure. Such measures are important to limit the effect of the fire and to

restrict its damage at least to a specific area. The notional period of the fire resistance determines the duration of the protection. The necessary period of it should be predetermined. the anticipated fire load and duration, and the time for the Fire and Rescue Service to arrive and start tackling the fire are the several factors of the determination of the duration.

4.7.19. Fire Suppression System

Automatic fire suppression systems are important to reduce the risks because they tackle a fire immediately when it is detected.

Especially in the warehouses where the contents of the stores change frequently and other places which have a fire suppression system, to ensure the sufficiency of the system for the contents is important. Automatic sprinkler installation is the most preferred system because it uses as the extinguishing medium. However, it should be known by the employer that water is not suitable for extinguishing medium in every case of fire. Sometimes fire can get worse by it.

The two basic type of the sprinkler installation is like that:

Sealed sprinkler-head system: there is a seal on each sprinkler head. It is temperature-sensitive. In the case of fire these are heated and then start the operation. The sealed sprinkler head system is good for the materials which absorb water. At the same time, restricting water entry into the fire area reduces the damage in store because of the rain. Also, the size of the containment system is essential for preventing and minimizing firewater run-off is minimised.

Open deluge system: these are generally takes place near the fire detectors. When it works the system immediately starts to discharge water over the area. This helps to cool all materials in fire or ear the fire. This system is mostly preferred in the stores where flammable liquids are kept because their extinguishing is too difficult after ignition.

Flammable liquids are immiscible in water so the fire with these materials cannot be tackled by only water. Even in some incidents, water causes spread of the fire. Then a foam with sprinkler system will work more effectively in this kind of fire. However, if the flammable liquids are on high racks in plastic containers, foam either may not be sufficient.

Generally, recirculating firewater is not recommended because sometime when it contaminates with flammable liquids, the fire may get worse.

While installing automatic fire suppression system, the standards lead by ISO-DIS 6182/ BS 5306-2.NFPA-13 etc. should be followed. Of course, the classifications in these standards have to be taken into consideration. 'Oil and flammable liquid hazard' are the classification which used for palletized stocks in plastic containers of flammable liquids, but the classification 'flammable liquids in combustible containers' is not suitable for them. All system to use should be properly serviced and maintained.

4.7.20. Smoke Control System

Keeping smoke under control by discharging it out of building as soon as a fire starts is important. Thus, the means of escape will be protected and the risk of fire spread will be reduced. At the same time, this helps the Fire and Rescue Service in their operations.

The purpose-designed smoke system is ideal to be useful for both buildings and stored materials. natural ventilation which is used with opening vents or with a powered exhaust system operating at a specified temperature are two types of smoke control system.

Glass roof lights are made of materials which have low melting levels. This makes them easily shattered in case of fire and so they are effective in smoke control. However, when they drop on a plastic material in the building, they become a source of ignition and can affect the workings of sprinkler heads. At the same time, it is impossible that they help in the early stage of the fire as a purpose-designed system.

It is significant that the smoke control system should start its operation after fire detection or fire suppression system. It means that these systems should not wait for smoke arise into the area. While both a smoke control system and fire suppression system will be used together, a competent fire protection engineer should be assigned for this because installation of both system together is complex.

4.7.21. Emergency Procedures

The emergency procedure should be started at the earliest point of any incident so that the impact on people, environment and premises can be reduced to the lowest level. To deal with the emergency, a well-planned procedure is vital. All possible incidents should be considered and the followings should be taken into the consideration:

- The nature and quantities of the stored dangerous substances;
- The location of the facility and its design;
- The people, both on site and off site, who might be affected; and
- Predictable environmental effects

The duty of the Fire and Rescue Service is to tackle fires in every stage. This includes adaptation to the means of access to properties and the layout, the utility of water supplies. To support the works of the local rescue and fire authorities, the employers should follow these:

- The provision and maintenance of suitable access for firefighting personnel and their vehicles;
- The provision of a convenient fire main and hydrant.

When the spread of the fire to other parts in or off the site is predictable, the only consideration of the employers should be how to reduce the risks for people out there.

For the necessary precautions which should be taken in the case of fire, the owners/employers should consult to the local fire and rescue authority. This should be preplanned. The service will take responsibility of the operation to stop the fire. Therefore, it is important that they need to know the equipment for firefighting on the site before. Even the procedure agrees that the firefighting service can take help from the ones on site if there is nobody exposed to risk in the handover. Any descendent duty of the works fire team should be in harmony with the “Fire and Rescue Service” and detailed information should be in the emergency procedures.

4.7.22. Control of Off-Site Risks

One of the highly polluting factor is firewater run-off. It can be considered as the biggest strain on normal drainage facilities. In the case of a pollution because of a firewater run-off (it should be a part of risk assessment), it should be consulted with the Environment Institutions and local fire and rescue authority.

4.7.23. Information, Instruction and Training

Where there is no sufficient training, supervision and operation procedures, there will be many serious incident. The failure of these qualities is considered as the root reason of many accidents. Thus, when the employees are wanted to be involved in operations with

maximum health and safety contribution, they need to be trained well with proper arrangements. This arrangement should be more than an ordinary training, but also it should be supported with supervision to ensure a completed using of skills and knowledge on the subject.

Employers may apply some regulation placed in the Carriage Regulations-ADR to assign an advisor to comply with Instructions to initiate the emergency procedure when the nature of the activity is suitable.



CHAPTER 6

5. AN APPLICATION OF DANGEROUS GOODS LOGISTICS WAREHOUSES

5.1. BASICS OF ANALYTICAL HIERARCHY PROCESS (AHP) METHODOLOGY'S

AHP is a method for ranking decision alternatives and selecting the best one when the decision maker has multiple criteria (Taylor, 2004) The AHP enables the decision-makers to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in a systematic manner under multiple criteria environment . (Cheng et al, 1999). In the literature; AHP, has been widely used in solving many decision making problems (Kurttila et al., 2000; Kangas et al., 2001, Pesonen et al., 2001; Kajanusa et al., 2004; Arslan., Turan, 2009; Kandakoğlu et al., 2009; Dinçer., Görener, 2011; Lee., Walsh, 2011).

There are two fundamental approaches to solving problems: the deductive approach and the inductive approach.

Basically, the deductive approach focuses on the parts whereas the systems approach concentrates on the workings of the whole.

The AHP combines these two approaches into one integrated, logic framework. The Analytic Hierarchy Process (AHP) was developed by Thomas L. Saaty. (Saaty, T.L., The Analytic Hierarchy Process, New York: McGraw-Hill, 1980) The AHP is designed to solve complex problems involving multiple criteria.

An advantage of the AHP is that it is designed to handle situations in which the subjective judgments of individuals constitute an important part of the decision process.

Basically the AHP is a method of

- (1) Breaking down a complex, unstructured situation into its component parts;
- (2) Arranging these parts, or variables into a hierarchic order;

(3) Assigning numerical values to subjective judgments on the relative importance of each variable; and

(4) Synthesizing the judgments to determine which variables have the highest priority and should be acted upon to influence the outcome of the situation.

The process requires the decision maker to provide judgments about the relative importance of each criterion and then specify a preference for each decision alternative on each criterion.

The output of the AHP is a prioritized ranking indicating the overall preference for each of the decision alternatives.

Major Steps of AHP Analysis

1) To develop a graphical representation of the problem in terms of the overall goal, the criteria, and the decision alternatives. (i.e., the hierarchy of the problem)

2) To specify his/her judgments about the relative importance of each criterion in terms of its contribution to the achievement of the overall goal.

3) To indicate a preference or priority for each decision alternative in terms of how it contributes to each criterion.

4) Given the information on relative importance and preferences, a mathematical process is used to synthesize the information (including consistency checking) and provide a priority ranking of all alternatives in terms of their overall preference.

In AHP, preferences between alternatives are determined by making pairwise comparisons. In a pairwise comparison, the decision maker examines two alternatives by considering one criterion and indicates a preference. These comparisons are made using a preference scale, which assigns numerical values to different levels of preference (Taha, 2003). The standard preference scale used for AHP is 1-9 scale, which lies between “equal importances” to “extreme importance” where sometimes different evaluation scales can be used such as 1 to 5. In the pairwise comparison matrix, the value 9 indicates that one factor is extremely more important than the other, and the value $1/9$ indicates that one factor is extremely less important than the other, and the value 1 indicates equal importance (Sarkis., Talluri, 2004)

Table 32: Pairwise Comparison Scale (Saaty, 1996;)

The Fundamental Scale for Pairwise Comparisons		
Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2, 1.3, etc. can be used for elements that are very close in importance.		

Research and experience have confirmed the nine-unit scale as a reasonable basis for discriminating between the preferences for two items.

Even numbers (2, 4, 6, 8) are intermediate values for the scale.

A value of 1 is reserved for the case where the two items are judged to be equally preferred.

The procedure to estimate the relative priority for each decision alternative in terms of the criterion is referred to as synthesization. Once the matrix of pairwise comparisons has been developed, priority of each of the elements (criterion) being compared can be calculated.

The exact mathematical procedure required to perform synthesization involves the computation of eigenvalues and eigenvectors,

The following three-step procedure provides a good approximation of the synthesized priorities.

Step 1: Sum the values in each column of the pairwise comparison matrix.

Step 2: Divide each element in the pairwise matrix by its column total.

The resulting matrix is referred to as the normalized pairwise comparison matrix.

Step 3: Compute the average of the elements in each row of the normalized matrix.

These averages provide an estimate of the relative priorities of the elements being compared. The values in the normalized pairwise comparison matrix are converted to decimal form. The result is usually represented as the (relative) priority vector.

An important consideration in terms of the quality of the ultimate decision relates to the consistency of judgments that the decision maker demonstrated during the series of pairwise comparisons.

To handle the consistency question, the AHP provides a method for measuring the degree of consistency among the pairwise judgments provided by the decision maker. If the degree of consistency is acceptable, the decision process can continue.

If the degree of consistency is unacceptable, the pairwise comparison judgments should be reconsidered and possibly revised before proceeding with the analysis.

The AHP provides a measure of the consistency of pairwise comparison judgments by computing a consistency ratio. The ratio is designed in such a way that values of the ratio exceeding 0.10 are indicative of inconsistent judgments.

5.1.1. Estimating Consistency ratio

Step 1: Multiply each value in the first column of the pairwise comparison matrix by the relative priority of the first item considered. Same procedures for other items. Sum the values across the rows to obtain a vector of values labelled “weighted sum.”

Step 2: The elements of the vector of weighted sums obtained in Step 1 by the Divide e corresponding priority value

Step 3: Compute the average of the values computed in step 2. This average is denoted as

$$\frac{1}{n}$$

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

Step 4: Compute the consistency index (CI):

$$CR = \frac{CI}{RI}$$

Step 5: Compute the consistency ratio (CR):

Step 5: Compute the consistency ratio (CR):

Where RI is the random index, which is the consistency index of a randomly generated pairwise comparison matrix. It can be shown that RI depends on the number of elements being compared and takes on the following values.

Random index (RI) is the consistency index of a randomly generated pairwise comparison matrix.

Table 33: Random Index Table

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

What is the benefit of AHP Usage as a method, why and where is it used academically and in business area.

Analytic Hierarchy Process (AHP) is a type of multi-criteria assessment (MCA) technique for analysing complex decisions.

In a world whose complexity is rapidly growing, making the best decisions becomes an increasingly demanding task for managers of companies, governmental agencies and many other decision and policy makers. In recent years, this has gone arm-in-arm with the growth of decision analytics methodologies.

Namely, decision makers are more reluctant to make gut decisions based of feelings and hunches, and instead prefer to use analytic and quantitative tools, and base and analyze their decisions on a solid ground. Many methods stemming from applied mathematics and

operations research have proved useful to help decision makers making informed decisions, and among these methods there are also those requiring, as inputs, subjective judgments from a decision maker or an expert. It is in this context that the Analytic Hierarchy Process (AHP) becomes a useful tool for analyzing decisions.

As long as the AHP is used as a technology for aiding decisions, it seems that its study belongs to decision analysis. On the other hand, to justify its connection with operations research, without going too far, we can refer to some definitions reported by Saaty, the main developer of the AHP, in one of the first graduate textbooks in operations research (Saaty, T.L, 1988). In his book “Mathematical Methods of Operational Research”, curious and thought-provoking definitions can be found: Operations research was defined as “quantitative common sense”.

On the other hand, operations research can be described as: The application of scientific and especially mathematical methods to the study and analysis of problems involving complex systems.

Hence, it is straightforward to conclude that the study of the AHP belongs to operations research too. Within operations research, two different types of studies appeared. The classical operations research, more mathematically oriented, which studies the modeling and solution of structured problems can be called ‘hard’ operations research.

Perhaps the fact that the AHP mostly deals with subjective judgments and intangible attributes gave the false idea that it did not belong to ‘hard’ operations research, but rather to its ‘soft’ side. However, in recent discussions;(Mingers, J.: Soft OR comes of age—but not everywhere (2011) the tools or the role of the AHP has been revisited and now it seems clearer that it has been a matter of study for ‘hard’ operations research.

Therefore it is applied in a wide variety of fields (mainly engineering, business strategic, education, management, quality assessment, healthcare industries).

Because Supply chain is an Engineering and on the other side an important business Management process, we can see AHP methodology mostly chosen in Supply Chain and warehousing and Supplier Management area.

Besides, If the Supply Chain and Management is a matter of concern, risk is a very important factor to consider.

Risk is an inherent activity and it occurs because we can never predict explicitly that what will happen tomorrow or in the near future. This uncertainty creates a gap between what really happens and what a firm has planned for and consequently causes losses due to the sequence of causal events or failures. However, as the risk can create troubles for a big loss, therefore industries, people have to evaluate the potential for such a sequence of causal events or failures. A crucial element of the risk management process is the identification and assessment of risk (Tapiero, 2007; Vilko., Hallikas, 2012).

Organisations have been steadily broadening their approach to risk management since the mid twentieth century – initially focusing on insurance management, then expanding to financial, safety and public relations issues, and finally, companywide and supply chain issues (Norrman., Lindroth 2004).

This is due to the frequent disruptions a supply chain encounters on a regular basis. Svensson (2000) defined supply chain disruptions as unplanned events that may occur in the supply chain, which might affect the normal or expected flow of materials and components.

Disruptions not only halt supply chain operations, without preparation and precautions it takes time for the affected system to recover (Hendricks., Singhal 2005), (Sheffi., Rice 2005). All this has made managing supply chain risks a challenge that it was never before. Whereas in the past, supply chain managers were mainly concerned with reducing cost, reducing purchase price variance and managing inventory, today supply continuity is the single biggest business driver and Warehouses are one of the main drivers among Supply chain systems.

Therefore AHP and risk has been used in Supply chain processes in different areas. The below examples can be given as AHP methodology used articles. Some of them used only AHP methodology. Some of them integrated with some other methodologies such as FMEA , Topsis ,

Fish bone analysis, GIS etc.

Multi attribute evaluation and selection of sites for agricultural product warehouses based on an Analytic hierarchy process.(J.L.Garcia et al.2013) A methodological approach oriented to evaluate

optimal locations of new agri-food warehouses. Three different areas in Mexico evaluated and AHP has been applied .

Evaluation of suppliers in the process of buying and supplying using AHP.(AShahraki et al, 2012)

Choosing the best choices in every decision needs analyzing some factors. As a result, organizations are faced with multi- criteria decision issues. This paper shows how to use analytical hierarchy in power industry and in the field of plant's boilers of heat recovery in a special manner.

Project risk assessment using the Analytic Hierarchy Process.(M.Mustafa.,J.Bahar 1991)

A case study of risks optimization using AHP Method.(S.Sharma., R.Pratap, 2013) The main motive of this paper is risk identification and determining risk optimization, which are more severe for the Company. The vital motive of this analysis to review the literature in the field of various risk factors for supply chains to understand current practices and to help Industry to sustain its continue. An Analytical Hierarchy Processing (AHP) method with enhanced Consistency to rank risk factor for suppliers is created for getting risks optimization requirement.

Developing a risk assessment index for hazardous material transportation. (Ö.Bali., K.Göztepe, 2014)

To ensure safe transport, reducing risks in hazardous materials transportation (HAZMAT) has a great importance. For this purpose, in the first phase, the study experts opinions in HAZMAT is taken to determine factors to be considered for risk assessment in HAZMAT. In the second phase the determined factors are categorized and the hierarchical structure of them put forward In the third stage, the factors are weighted using Analytic Hierarchy Process (AHP) according to experts opinions.

Safety risk assessment using AHP during planning and budgeting of construction projects. (S.Aminbakhsh., M.Gündüz, 2013) Health and safety risks are among the most significant risks in construction projects since the construction is characterized by a relatively high injury and death rate compared to other industries. In this paper a safety risk

assessment framework is presented based on the theory of cost of safety (COS) model and the Analytic Hierarchy process(AHP)

A decision support system for supplier selection and order allocation in stochastic, multi stakeholder and multicriteria environments.(J.Scott et al.2014) As firms continue to seek competitive advantage through supply chain design and operations they aim to create optimized supply chains. This calls for on one hand consideration of multiple conflicting criteria and on the other hand consideration of uncertainties of demand and supply. This paper This paper proposes an integrated method for dealing with such problems using a combined Analytic Hierarchy Process–Quality Function Deployment (AHP–QFD)

Risk evaluation of warehouse operations by using FMEA and AHP approaches under fuzzy environment.(M.Nazam et al. 2015) In this study, the effects of supply chain operation is investigated and supply chain risks on supply chain performance. Operationally, warehouse processes contain various risks which lead to a poor supply chain performance. Risk analysis in warehouse operations is a challenging task to enhance both the supply chain efficiency and the customer satisfaction. In this context, failure mode and effects analysis, (FMEA) allowing a group of experts to use linguistic variables for identifying three risk factors namely; severity (S), occurrence (O), and detection (D), is considered for FMEA by applying fuzzy technique for order performance by similarity to ideal solution (TOPSIS) integrated with analytical hierarchy process (AHP) in the food retail chain.

Application of FMEA and AHP in Lean Maintenance .(M.Shahrabi., A.A.Shojeai, 2014) Lean maintenance is the application of lean methods in maintenance. Application of these principles in activities, leads to cost reduction, higher quality, decreasing the downtime of machineries, enhancing reliability and finally efficiency, performance and more benefit. In this context, a case study has been performed using AHP and FMEA in one of the largest and oldest finery stations of the world. Expert Choice software has been used for the computation and sensitivity analysis.

Integration of the fish bone diagram, brainstorming and AHP method for problem solving and decision making.(A.A.Yazdani., R.T.Maghaddam, 2012) By selecting a proper method in a brainstorming meeting, the effective factors in this regard are identified. Furthermore, by using a fish bone (or cause-and-effect) diagram, the cause-and-effect

relationships become apparent. By using the analytical hierarchy process analysis the priority for the possible solutions is determined.

Integrated Risk assessment of Hazardous Chemical Installations using GIS and AHP Integrated Risk Assessment, (Q.Zhao., J.Guo; 2008) This paper aims to develop and implement a simple and easy-used method to major industrial chemical hazard risk assessment. Firstly, multi-criteria decision-making technique (the Analytic Hierarchy Process) is presented, for the hazard assessment of the substances and installations. The spatial data such as water distribution, roads, fire forces, medical forces, density of population, economic situation, etc of the surroundings of the hazardous chemical installations are input into a Geographical Information System, (GIS program), it is easy to assess the risk of hazardous chemical installations. Besides, this method has been put into practice in the case of the emergency management agency of a Chinese city .

Moreover, the Analytic Hierarchy Process (AHPs) has been used in various settings to make decisions.

- In public administration there have been many applications.
 - The state of North Carolina used it to develop evaluation criteria and assign ratings to vendors, leading to the selection of a best-value vendor acceptable to the decision makers.
 - The Nuclear Regulatory Commission (NRC) of the US with so many competing requirements for their information technology projects used it to allocate all of a \$100 million + portfolio. Using the AHP not only helped allocate NRC's IT resources, but also reduced the amount of decision time from 15 to 20 meetings down to just a few.
 - The Department of Defence in the US uses it frequently and extensively to allocate their resources to their diverse activities.
 - The General Services Administration (GSA) of the USA used AHP to support their annual information Technology Council (ITC) and Council of Controllers (COC) meeting to prioritise their major Information technology initiatives. They used the process to refine their analytical framework, prioritise their criteria and then rate each IT initiative against them. The result was the first-ever GSA-wide prioritisation of major IT initiatives, which included a benefit-cost analysis and a benefit-risk analysis.

- In (2001), it was used to determine the best relocation site for the earthquake devastated Turkish city Adapazari.

- British Airways used it in 1998 to choose the entertainment system vendor for its entire fleet of airplanes.

- The process was applied to the US versus China conflict in the intellectual property rights battle of 1995 over Chinese individuals copying music, video and software tapes and CD's. An AHP analysis involving three hierarchies for Decision making with the AHP 97 benefits, costs and risks showed that it was much better for the US not to sanction China.

- Xerox Corporation has used the AHP to allocate close to a billion dollars to its research projects.

- In 1999, the Ford Motor Company used the AHP to establish priorities for criteria that improve customer satisfaction. Ford gave Expert Choice Inc, an Award for Excellence for helping them achieve greater success with its clients.

- In 1986 the Institute of Strategic Studies in Pretoria, a government-backed organisation, used the AHP to analyse the conflict in South Africa and recommended actions ranging from the release of Nelson Mandela to the removal of apartheid and the granting of full citizenship and equal rights to

the black majority. All of these recommended actions were quickly implemented.

- The AHP has been used in student admissions, military personnel promotions and hiring decisions.

- In sports, it was used in 1995 to predict which football team would go to the Super bowl and win (correct outcome) . The AHP was applied in baseball to analyse which Padres players should be retained.

T.L Saaty 2008 (Decision making with the analytic hierarchy process)

- IBM used the process in 1991 in designing its successful mid-range AS 400 computer. IBM won the prestigious Malcolm Baldrige award for Excellence for that effort.

5.2. APPLICATION OF METHODOLOGY

5.2.1. Appearance of Hazardous Substances Warehouse in Turkey

The thesis topic is, how the dangerous goods warehouses in Turkey should be evaluated in terms of risk . It determines how an appropriate dangerous goods warehouse can be selected, keeping certain criterias into consideration and carrying out a risk analysis.

Therefore, firstly a field study has been done about the risks of hazardous materials warehouses, which operate in Turkish logistics sector.

Logistic warehouses can be of various kinds, small and large in our country. It is pretty difficult to make an inventory about the numbers, locations and sizes of the warehouses in Turkey.

As indicated in 2006 - 14 No Turkish Logistics Sector Infrastructure Report of Istanbul Chamber of Commerce, it is understood that the storage sector is in need of improvement. According to the report, Capacity utilization of business premises seems to be at a level below 30%, In recent years, institutional sector-based specialized warehousing activities have gained momentum and It can be said that the need for dangerous warehouses has come to the forefront in these applications.

Storage of hazardous materials is subject to certain legal requirements for our country's legislation Since the ADR Convention has recently been introduced and the infrastructures for compliance with the legal regulations related to the international norms of dangerous goods storage are in the development stage, the number of sample applications in the hazardous material warehouses is limited. .

Moreover, it is also true that many small-scale enterprises operate without providing the necessary legal conditions for the storage of dangerous goods.

The fact that a significant part of our country's industry and commerce is concentrated in and around Istanbul, therefore, shows that dangerous material storages is also concentrated high in this region.

For this reason, in order to determine the risk factors between the enterprises having legal conditions in our work, a limited number of institutional firms which have hazardous

substance storage with sample applications having legal working permits in and around Istanbul with a closed area of at least 4000 m² have been taken.

5.2.2. Research method

Quantitative research methods have been used to analyse the risk of hazardous substances in our country. In the first stage of the field research, source survey was made, sector reports of the logistics sector, domestic and overseas printed publications, scientific researches were examined and basic data on field methodology of field studies were obtained.

Within this context, approaches to categorize the risks associated with the storage of hazardous substances and to assess the risks are set forth

In these approaches, it has been observed that the risk analysis is made in 6 different ways in general, as indicated in the literature review. Those are;

- Path analysis / Cause analysis
- Consequence analysis
- Event tree analysis
- Fault tree analysis
- AHP Analysis

When each of these risk analysis methods is examined, adequate availability of healthy data outside the AHP for fieldwork is unlikely to be used in our research.

For this reason, the AHP analysis method was selected and a questionnaire was applied to the managers of institutional storage companies with international hazardous substances standards on the grading and categorization of risks.

5.2.3. Preparation of Data Sets for AHP method

In order to prepare the datasets that can analyze the risks in the fieldwork, questionnaires based on numerical data have been applied to competent persons who are working as managers or in key duties in the dangerous goods warehouses due to the special needs of the subject.

In the selection of hazardous material storage, institutional warehouses with operational permission and having a certain physical size were selected as target application areas

In the preliminary survey conducted, it is revealed that the concentration of such warehouses in İstanbul and its surroundings, which are concentrated in the industrial area, reveals the need to be geographically limited to this region.

5.2.4. Creating the Sample

It seems to be impossible to conduct a survey on all dangerous goods warehouses in terms of both time and cost. For this reason, sampling is needed.

The results of the study have to reach the right information and to generalize the obtained information, and the necessity of representing the correct cluster as the sample of the survey conducted in the field application. The ability to form the right conglomerate is a quality that can provide generalization in the analysis of the risks associated with dangerous substance warehouses. In the survey study, institutional warehouses were taken into consideration as a sample in the selection of hazardous substance warehouses.

However, the sample has been limited to hazardous warehouse operations that are capable of carrying out risk analysis of hazardous materials in our country and bearing the requirements of the ADR Convention on the Transport of International Hazardous Substances, which our country also accepts (including warehousing because of the scope of loading and unloading processes) and this type of institutions has been included in the scope of research.

5.2.5. Survey Applications

It has been required to answer questionnaires prepared by interviewer by selecting competent firms that has expertise in the field to test the adequacy of the questionnaire about the risks in the warehouse to the dangerous goods warehouse managers and key personnel determined according to the sampling.

Those competent firms are 13 institutional and the most important firms in terms of hazardous goods storage in Turkey. One of them has got warehouses, which has been built and organised, with high standards. This situation even gives them being a good, qualified example as a dangerous goods warehouse in terms of Risk Management. Another warehouse is one of the very important essence and scents warehouse in Turkey and among region countries. Because of the flammable and Inflammable substance content, it helps to create a good database again in terms of Risk Management. The other warehouses

that we have examined in the scope of our study are 3PL warehouses. Those warehouses general-purpose warehouses and dangerous goods warehouses, which provide import, export, distribution, warehousing and custom bounded warehousing services.

When we look at the overview of the institutional warehouses in Turkey, they are multipurpose and they service to different customers with different items. We see that the warehouses we have taken as samples are also multipurpose commercial warehouses except one.

Historically, the existence of private, commercial facilities where hazardous materials are stored specifically based on the last 10-15 years. In the last few years we see that high-standard warehouses have begun to emerge although they are very few in numbers. One of the main reasons for this is ADR legislation has begun to be implemented. Another reason is that environmental sensitivity is beginning to increase. Many harmonization laws have been enacted in the years after 2000, especially when the European Union harmonization laws have accelerated. Those set of laws has been effective in determining warehouse standards and increasing audit operations.

Our target group is therefore such institutions, who has got knowledge about last improvements, pioneer in the implementation of laws, open to development and can be shown as an example to other medium/small sized institutions.

A separate interview form has been prepared in order to give the final form of the questionnaire in these interviewed companies. According to the comments and evaluations obtained after the questionnaire test, the questionnaire was revised and the final version of the questionnaire was given.

Questionnaire applications of PhD study in selected institutional warehouses were completed within six months at the first months of 2017, following the completion of the thesis literature study and the theoretical infrastructure.

Questionnaire application In the storage of hazardous materials, 13 qualified companies with qualified personnel, physical and technical sub-structures were identified in our country and an average of 2 to 5 managerial survey questions were asked to be answered in each business.

Survey studies were conducted in different ways among selected companies. In Turkey's two major business that we have seen critical for the storage of dangerous goods, where the application of the latest developments is made and strictly followed, expert opinion survey was conducted personally and the case studies have been observed. Those were 3 PL companies. In other one business, which is a drug and paint company, the survey answers have been taken with e-mail communicating through telephone and e-mail.

In other organizations, expert opinions were requested with the prepared forms through a mediator expert from relevant institutions. The number of responding organizations has been limited in the first instance. Despite repeated requests to organizations, difficulties have arisen in getting returns. Returns have been completed with the mentioned mediator expert after few trials. One of the survey companies were state institution, the other one is a fragrance company and the rest were 3 PL companies.

The names of the respondents and the respondents in the survey were kept confidential in the context of the confidentiality principle in the sector and the principle of confidentiality of risks against non-sharing of other businesses.

5.2.6. Criteria determination and Survey Questionnaire design

In AHP criteria selection, the mostly used technics are; the surveys with the target group, the meetings, exchange of ideas with the experts.

In individual AHP studies, generally surveys with the target group are preferred. For example in 2007 Tüzemen and Özdağoglu made a research about the determination of the criterias, which phd students take into consideration when they select their lifefriend. Another AHP research has been made by G.İşıklar Alptekin., G.Büyüközkan to evaluate mobile phone alternatives. In both multicriteria decision making studies, the surveys with the target group has been conducted in order to find the right criterias and It was logical in such subjective decision making studies to ask the target group to understand their decision criterias.

In other AHP studies specifically in corporate domain, although the above technics might be used,

Some others like brainstorming, fish bone analysis, what if analysis, root cause analysis, SWOT analysis can be preferred. Few examples can be seen in previous AHP articles section. see (Yazdani., Magghdam, 2012)

5.3. Evaluations of Risk Factors Encountered in Turkey's Storages Areas

In our study, we preferred both experts in dangerous goods area and the literature and regulations.

When preparing the questionnaire, the system of CEFIC (The European Chemical Industry Council) SQAS (Safety, quality Assessment for Sustainability: is a system of uniform third party assessments to evaluate the performance of Logistic service providers and chemical distributors; SQAS assessments cover quality, safety, security, environment and corporate social responsibility. The SQAS assessment reports allow chemical companies to evaluate their Logistics service providers according to their own standarts and requirements) has been investigated and the basic logic has been evaluated.

Table 34: Evaluation of Risk Factors Encountered in The Storages Areas of Turkey

Warehouse construction/Layout	Material	Management	Human factor	Environment
• Fire detection/ warning systems • Fire protection equipment(water) • Fire protection equipment(Foam) • Emergency escape signs • Emergency escape lighting • Firewater drainage system • Fire resisting seperation • Ventilation • Fire doors,fastenings • Fire fighting equipments • Electrical exproof installation	• Amount of stored material • Content of material • Placement of material • Packaging type of material • Packaging amount of material	• Safe working procedures • Standarts,quality management systems • training education and certification • emergency response plans • safe manning levels • authority,inspections ,control • Safe working items(PPE)	• Skills • Experience • Level of education/training • Fatigue • intentional factors	• Equipment maintenance • Workspace conditions (noise,slippery surfaces) • weather conditions • Mechanical failure • Location of warehouse • Arson • Regulations

The reason why the regulations and SQAS has been selected in our study; because there are many quantitative and qualitative work since years in international area and although SQAS is not a very well known and used accredited auditor in Turkey, it is mostly preferred supply chain auditor abroad and companies let their firm to be audited with such companies for their safety.

Table 35: Main Criterias of the Survey

Warehouse Consructions / Layout	Material	Management	Human Factor	Enviroment
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If we shall explain the main criterias; what are they in details, why are they important, what could be the reason for them to be selected, the followings might be the brief descriptions of them.

The regulations in Transport, Warehousing, Work and workers Safety in Europe, in US and other developed countries has been prepared and revised for long years and still active and improvements are made according to the current conditions. Therefore it contains years of experience in practice. With the help of those years of experience, an assessment system has been created by Chemical Industry council and member countries. This is called as SQAS. Safety&Quality Assessment for Sustainability.

Table 36: Warehouse Construction / Layout: Sub Criterias

Warehouse construction/Layout
• Fire detection/ warning systems • Fire protection equipment(water) • Fire protection equipment(Foam) • Emergency escape signs • Emergency escape lighting • Firewater drainage system • Fire resisting seperation • Ventilation • Fire doors,fastenings • Fire fighting equipments • Electrical exproof installation

And besides SQAS evaluation, the risks of the dangerous goods warehouses has been evaluated also with the selected warehouse managers / experts .and it has come out that the

risks might be classified in 5 main group and above mentioned criterias has been created according to this information.

The main criterias what has been agreed with participants are:

Warehouse Layout, Material, Management, Human factor and Environment (Table 1)

Beside the main criterias 32 different sub criterias have been created. 8 of them belong to the sub criteria of Warehouse Layout/construction:

5.3.1.1. Main criteria---Warehouse Layout

The business of a company depends upon the efficiency of manufacturing, supply chain and marketing and commercials. Supply chain efficiency depends on the effectiveness of logistics which includes warehouse operations. Warehouse operations can be effective provided warehouse design, layout, infrastructure, processes, staff and safety norms, transportation are appropriate to the requirements and also safe.

Warehouses are facilities that provide a proper environment for the purpose of storing goods and materials that require protection from the elements. Warehouses must be designed to accommodate the loads of the materials to be stored, the associated handling equipment, the receiving and shipping operations and associated trucking, and the needs of the operating personnel. The design of the warehouse space should be planned to best accommodate business service requirements and the products to be stored/handled.

Special-designed warehouses meeting strict requirements can also provide liquid storage (fuel and nonpropellants), flammable and combustible storage, radioactive material storage, hazardous chemical storage etc.

Hazardous chemicals improperly stored and improperly handled in the warehouse, can cause fire or explosion resulting in injury of personnel at site, as well as the neighboring areas and loss of property inside the warehouse and outside. An understanding of hazards and associated risks will help in selecting better control measures. The potential safety and health and environmental impacts can be prevented by implementing control measures in

the early design stage. When talk about the design stage, the Layout , Infrastructure is the most important stage in order to prevent possible dangers.

Although it was very difficult to find special designed hazardous goods warehouses from the beginning of the construction process in Turkey, most of the pre-built warehouses were being made available for storage of hazardous materials. If the products to be stored consist of dangerous substances in a mixed nature , then the design, layout process has to be even more carefully planned compared to one or two types of hazardous materials stored warehouses. The number of warehouses planned and built for this purpose is not enough to pass hand fingers quantity. Therefore it is a very important field to be thoroughly studied and developed and therefore has been chosen as a important risk area by the participants too.

Under the main criteria; Warehouse Layout/ construction, there are the following sub criterias

5.3.1.1.1. Fire-dust detection/warning systems

A fire alarm system is intended to enable a fire to be detected at a sufficiently early stage so that people who are at risk can be made safe either by escaping from the fire, or by the fire being extinguished (also to prevent extensive property damage). Neither of these measures can be used until people are made aware of fire.

The effectiveness of the fire detection and alarm system depends on the stage of the fire at which it is operated. In order for all the occupants to escape without too much difficulty, an early alarm should operate before the escape routes becomes smoke logged to such an extent as will cause occupants to have difficulty finding their way out of the building. It protects by:

- a. Detecting a fire at an early stage
- b. Alerting and evacuating occupants
- c. Notifying the relevant personnel
- d. Activating auxiliary functions e.g. smoke controls; lift homing etc / identifying and guiding fire fighters.

An alarm system is generally made up of: (M.D.Goh., E.M.Kwek, 2008)

Smoke / Heat Smoke / Heat Detectors (Detectors (Fire Detectors Fire Detectors))

Alarm Panels (Alarm Panels (Control and Indicating Equipment Control and Indicating Equipment))

Alarm Bells (Alarm Bells (Fire Alarm Devices Fire Alarm Devices))

Manual Call Points Manual Call Points

DECAM Panel (DECAM Panel (Fire Services Fire Services Signalling Transmitter Transmitter)

DECAM Station (DECAM Station (Alarm Monitoring Station Alarm Monitoring Station))

Extinguishing Panels (Extinguishing Panels (Control for automatic fire protection equipment Control for automatic fire protection equipment))

Gas / Sprinkler (Gas / Sprinkler (Automatic fire protection equipment Automatic fire protection equipment))

Charger/Battery (Charger/Battery (Power Supply Equipment Power Supply Equipment)

As it can be seen if the detection system is an advanced system, then there could be a connection system sprinkler system or with here mentioned name fire protection system.

According to NFPA 45²⁴; for Relatively small structure & low fire risk, the Manual fire alarm with DECAMS system is suitable and this type of system is named as K1 system.

Other more advanced systems are respectively: Automatic surveillance Automatic fire detection with DECAMS system is named as K2 system.

Automatic fire suppression system Automatic sprinkler (CP52) with DECAMS system

Automatic extinguishing system (foam system) Automatic foam sprinkler with DECAMS system

A complete understanding of the hazards requires an assessment of the container and packaging systems and storage arrangements and then the decision of suitable system for fire detection, protection has to be given by Management.

²⁴ Web.https://www.scdf.gov.sg/.../fire.../Appendix_B.pdf

5.3.1.1.2. Fire protection-sprinkler (water/foam)

As mentioned above, according to need it can be selected, and preferably due to the high hazard probability in dangerous goods warehouse, an advanced system, together with detection system should be preferred.

5.3.1.1.3. Emergency Escape Signs/Lighting

Escape route is a route designated for escape to a place of safety in the event of an emergency. Emergency escape route lighting; Areas of higher risk (fork lift routes next to footpaths, areas used by external drivers) might require maintained emergency lighting. Emergency escape lighting system provides to minimise panic and ensure there is sufficient illumination to allow the occupants of warehouse to reach a place where an escape route can be identified.

5.3.1.1.4. Firewater Drainage System

Water is the most widely used medium for fighting fires. It is not only extinguishes flames but also takes heat from the fire which helps reduce the risk of radiated heat, structural damage and reignition. Large volumes of water are frequently used in fire fighting and, although some will turn to steam in the heat, much will fall to the ground and drain away from the site of the fire. If hazardous chemicals are involved, foam might be used to fight a fire rather than water but there may still be a need for water to cool other property or plant nearby, to reduce the risk of it becoming involved in the fire.

Water or foam used to fight fires at premises where chemicals are used or stored can become contaminated with the chemicals and become hazardous itself. (For example firewater run-off from a fire in Basle, 1986, resulted in major pollution of the river Rhine, extending many kilometres downstream and lasting many years.²⁵(HSE,EH 70, 1995)

Advice on the containment systems and the fire-fighting arrangements in general should be obtained from the Fire Authority. In discussing these matters, the flammability of the building structure and contents as well as any fire detection/suppression system has to be taken into consideration. A small fire may require only a few tens of cubic metres of water whereas a large fire may require in excess of several thousand cubic metres of water.

²⁵ HSE, EH 70 Fire Water Drainage System 1995 Pg:4

Bunds are sensible precaution to store environmentally hazardous chemicals in warehouses as the simplest solution.

5.3.1.1.5. Fire Resisting Separation / Doors

Sub-dividing it into a number of discrete compartments can restrict the spread of fire in a burning building. In many chemical warehouses, different types of materials are stored in distinct areas within a compartment, either separated by distance from other storage, or segregated by non fire-rated partition walls. Such segregation and separation may be of benefit in preventing or delaying fire spread until arrival of the fire brigade.

Fire door assemblies generally consist of the fire door, the frame and the door hardware. Fire doors can be classified by an alphabetical designation (identifying the opening that is protected), an hourly designation (identifying the fire resistance rating), or a combination of the two. Building codes and NFPA 80 generally specify fire doors by their fire protection rating rather than the opening classification. (NFPA, 1995)

5.3.1.1.6. Ventilation

All areas where flammable liquids are handled should be adequately ventilated to dilute any released vapours to a safe level. The ventilation should be sufficient to dilute the amount of vapour released to well below its flammable limit, and below the relevant occupational exposure limit. In some cases, good natural ventilation positioned predominantly at low level plus some at high level may be enough, but in others, mechanical ventilation and/or local exhaust ventilation would be needed.

5.3.1.1.7. Fire Fighting Equipments

The primary purpose of fire extinguishers is to tackle incipient fires to prevent them becoming larger, or to aid an escape. The extinguishers should be appropriate to the nature of the potential fire.

For: wood, paper and cloth, use a water, foam or multi-purpose dry powder extinguisher;

Flammable liquids, use a dry powder or foam extinguisher; and

Electrical items, use a carbon dioxide (CO₂) or dry powder extinguisher.

Extinguishers should conform to a recognised standard, such as BS EN 3–7: 2004. It is also important that there is an appropriate scheme to ensure they are regularly checked and properly maintained. (HSG 168, 2010)

5.3.1.1.8. Electrical Installation

Electrical installations must be designed and constructed so as not to present a fire or explosion hazard; persons must be adequately protected against the risk of accidents caused by direct or indirect contact. Electrical installations and protection devices must be appropriate to the voltage, external conditions and the competence of persons with access to parts of the installation. The lamps and electrical installations must be designed in such way that during the storage operation no damage can be caused in any kind. The lighting (lamps) of the warehouse must be above the traffic ways and must be at least 0.5 meters above the goods. The lamps must be of such kind and distance that they don't heat the goods. 1989/654/EG Annex I + II No. 3 1989/654/EG Annex I + II No. 8 is the EU standards about electrical parts. ATEX regulation should be followed and complete or some electrical connections should be ex proof.

Under the second main criteria Warehouse material, 5 different sub criterias have been generated. These are: Amount of material(in the Warehouse)

The amount of dangerous materials is very important in terms of describing risk. As this is the reality, the control of Major Accident Hazards regulation in 2015 publish a category table and in those table the establishments divided into two categories as upper tier and lower tier establishments and the warehouses of dangerous goods substances are included in lower tier establishments. If the tonnages of certain materials, which is described in Regulation 34, schedule 1 /Categories of dangerous goods substances and their tonnages, passes the mentioned quantity, then the hazard mitigation Process are required. There is also the same regulation in Turkey within the framework of compliance laws. But it is very newly adapted and it seems the implementation process will take time.

Under the second main criteria; Material, there are the following sub criterias;

5.3.1.2. Main Criteria: Material

Hazardous materials can be found in a warehouse. These materials can be either raw materials or finished goods depending on the nature of the company's products or if the

mentioned firm is a 3 PL company, then it is a commercial activity. However, a hazardous material is one that is capable of producing harmful physical effects such as a fire, sudden release of pressure and explosion or acute health effects, such as burns, convulsions and chronic effects such as organ damage and cancers.

Therefore the knowledge about the stored materials is very important. Because the effects of each type of material might be different also depending on the quantity stored, the content of the material, packaging of the material or packaging amount of the material and also placement of the material. Different substances create very different risks and it is important that the standards adopted at the warehouse are based on an understanding of the physical and chemical properties of the substances concerned and the potential reactions between substances.

Table 37: Material: Sub Criterias

Material
• Amount of stored material • Content of material • Placement of material • Packaging type of material • Packaging amount of material

The overall quantities of the substances to be stored and the maximum size of individual packages can change the steps to be taken for the assessment. If a hazardous material put in a plastic packaging of 5 lt, and if a damage occur, the spillage might be very small quantity and not very seriously hazardous. But if the same material put in a container of 1000 litre or a 5000 tank, and if a spillage occurs, then the damage, threat of those packaging can be much serious or worse. If this material is corrosive material, the effects could be more harmful for the environment, racks, floor etc. If this material is an organic peroxide or toxic type of product, then the effects could be more harmful for the people around. Therefore the second important criteria have been chosen as “Material” by the participants.

5.3.1.2.1. Content of Material / Placement of Material

When putting in place the segregation scheme it is important to identify all the hazard properties of a chemical. Many chemicals have multiple hazards and a decision must be made as to which storage location within the warehouse or drum store is the most appropriate for each individual chemical.

Normally the storage area will be determined by the more hazardous property of the chemical and having assessed the consequences in the event of an accident in the storage area. For example if a chemical is both flammable and corrosive it would be appropriate for the chemical to be stored with other flammables. However if a chemical is both flammable and very toxic then other factors need to be considered before selecting the appropriate storage area, such as the physical properties of the chemical and the quantity being stored. If the chemical emits very toxic gases or vapours then the chemical may need to be isolated within the flammable storage area. There will always be some chemicals that will not fit neatly in one category or another, but with a proper identification of the chemical hazards and assessment of consequences of an accident release using the information available in the SDS, most chemicals should be assigned to appropriate storage areas. See segregation Table.

Besides, if the substance is harmful, workers might be exposed. By: breathing in gases, fumes mist or dust? / Contact with the skin? /swallowing? / Contact with the eyes? /skin puncture? Both factors are assessed for risk according to their content, according to their position.

5.3.1.2.2. Packaging Type of Material

The basic role of packaging in any industrial organization:

- To protect a product from damage or contamination by microorganisms and air, moisture and toxins.
- To keep the product together, to contain it (i.e. So that it does not spill).
- To identify the product.
- Protection during Transport and ease of Transport.
- Stacking and Storage.

Once dangerous goods have been classified correctly, table A of ADR regulation allows all the details of permitted packaging to be accessed. Columns 8 to 14 show what sort of packaging is allowed and directs the to the details.

Example:

UN No 1263 Paint product in PG I (first entry)

Column 8 shows that it may be packed according to the instruction P001. In turn, top of column 8 directs you to para 4.1.4, which gives the details of what P001 allows. A wide range of packaging types is given.

It can also be seen that different requirements apply according to Packing group (PG). In this example, if drums are chosen as the (single) packaging, there are ten types available, all limited to 250 litres.

Similarly reading from columns 10 to 14 shows what tank methods are available and by reference to the relevant parts of ADR, complete details may be found.

That process may be adopted for all substances; they do allow the packer to see exactly what is and what is not permitted. The DGSA should advise the packer in this matter. 26

5.3.1.2.3. Packaging Amount of Material

As the dangerous goods packaging grows, so does its risk, depending on the content. Therefore in any risk assessment studies firstly the tanks, (for ex. 5000 kg) then the containers (for ex. 1000 kg) then the drums, (for ex. 200 kg) then the smaller packaging (for ex. 20 kg / 5 kg) can be shown risky, respectively.

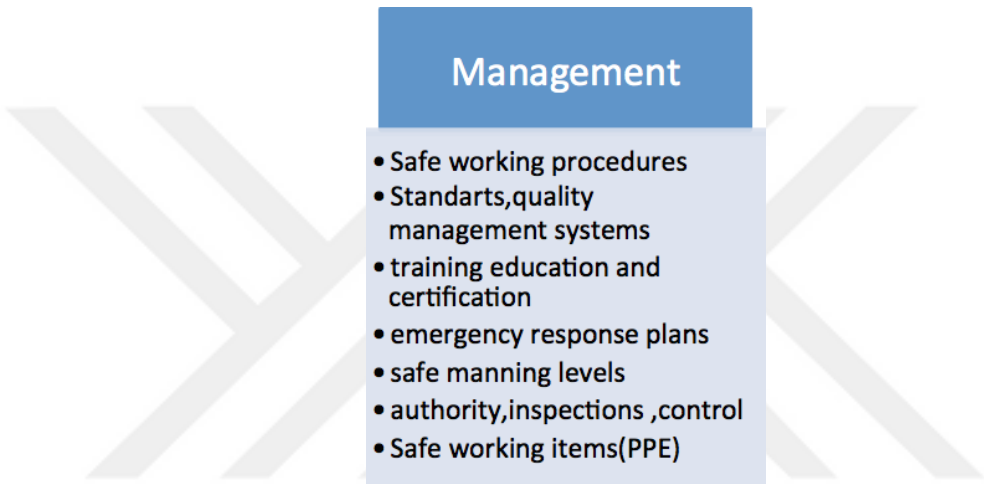
5.3.1.3. Main criteria: Management

The warehouse is one of the strongest assets of an institution and to lead that Institution Management skills and methods and operation is very important. Maximize effective use of space, maximize effective use of equipment, maximize effective use of labour, maximize accessibility of all items, maximize protection of all items, maximize effective use of Information, maximize the protection of company's assets, minimise goods handling, minimize the company's operating costs are the responsibility of a warehouse

²⁶ Web. www.hse.gov.uk/cdg/manual/packaging.htm ADR Packaging Regulation

Manager and additionally if this warehouse is a dangerous goods warehouse, then the warehouse Management has to succeed about minimising the risks in the warehouse and warehouse personnel. In order to do this, the needed working procedures have to be created and applied in each level of responsibility. For example forklift operator, loader, receiver, supervisor, Area Manager etc. Quality Management systems could be a good guidance and should be thoroughly examined and the suitable parts of the system has to be applied to company's procedures.

Table 38: Management: Sub Criterias



Total Quality Management (TQM) is an approach that seeks to improve quality and performance, which will meet or exceed customer expectations. This can be achieved by integrating all quality-related functions and processes throughout the company and thus the warehouse. TQM help companies minimize waste and reduce the chance of errors in order to do things better, faster, and be more responsive to customers' changing needs. Strategy, data, and effective communications help to integrate quality throughout the organization. Emphasis is on continuous improvement.

Quality management often is associated with the Japanese concept of poka-yoke or “mistake proofing. If the Management of the Company and the warehouse is aware of TQM and follower and practitioner of this system, it gives a good opportunity for the quality of processes and operation of the warehouse. Standards are also guidance systems to be used in coordination with the quality management system. For example NFPA (US National Fire Protection association) standards are mostly used standards especially for

Fire protection systems. ISO Standards, EU Standards for different materials could be used regionally for our country. The Australian, New Zealand, Canada and Asian Standards are also valid for other region countries.

Under the third main criteria Warehouse Management, 7 sub criterias have been created. We can name them as follows:

5.3.1.3.1. Safe Working Procedures

Only appropriate and instructed employees who carry out work in accordance with operating instructions and regulations may be employed in the warehouse. The employees are under obligation to notify the warehouse management immediately about any occurrences such as damaged packaging, leakages, and accidents.

5.3.1.4. Standards, Quality Management Systems

A core definition of total quality management (TQM) describes a management approach to long-term success through customer satisfaction. In a TQM effort, all members of an organization participate in improving processes, products, services, and the culture in which they work. The Warehouse Management can reduce risks and improve processes by adding warehouse personnel to the process.

A quality standard is a detail of the requirements, specifications, the various guidelines and characteristics to be able to meet its quality by the product in order to meet the purpose of the product, process or the service. ISO international standards are the most widely accepted set of quality standards adopted by majority of firms across countries. In case if a company fails to meet its quality standard, it may end up losing the trust of the customer and thus its market share.

Standards are one of the mostly used factors decreasing the risks together with Quality Management.

5.3.1.4.1. Training, Education and Certification

Two classes of training necessary to ensure competence have been established, mandatory General SHE (Safety, Health, Environment) training and job or hazard specific SHE training.

Job or hazard specific training is determined by the role or duties an individual undertakes within the Management. The identification of the need for such training is the responsibility of line management based upon their understanding of the hazards faced. To facilitate the identification of hazard specific training each SHE code defines the training necessary to undertake work where a specific hazard exists. For ex. all the workers in Warehouse should be educated periodically about the contents and the hazards and mitigation measures of the materials. MSDS training is one of those specific trainings.

5.3.1.4.2. Emergency Response Plans

The main focus of the assessment (plan) is that an internal emergency plan has been prepared that is proportionate to the possible major accident scenarios for the establishment concerned and for which the necessary measures have been taken to limit their consequences for human health and the environment. Initiating emergency procedures at the earliest stage of an incident can significantly reduce the impact on people, premises and the environment. A procedure for dealing with emergencies is needed to develop. Consideration needs to be given to the range of possible events, taking into account the following:

The nature and quantities of the dangerous substances stored;

The location of the storage facility and its design;

The people, both on site and off site, who may be affected; and

Possible environmental impacts in consultation with the local fire and rescue authority, that precaution are needed; the extent will depend on the nature of the site.

5.3.1.4.3. Safe Manning Levels

The term ‘safe manning levels’ refers to having the right people in the right place at the right time. It is not just a matter of having enough staff, but also ensuring that they have suitable knowledge, skill and experience to operate safely.

5.3.1.4.4. Authority, Inspection, Control

Management or an independent auditor might do the mentioned control and inspection. Audit is the structured process of collecting independent information on the efficiency, effectiveness and reliability of the total health and safety management system and drawing

up plans for corrective action. The adequacy of the system can be assessed against a relevant ‘standard’. Audits should be conducted periodically.

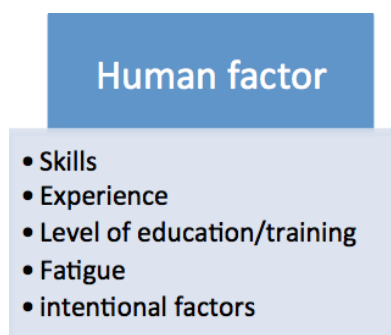
5.3.1.4.5. Safe working items (PPE)

Personal protective equipments as body protection must always be used if the dangers of injury and health hazards cannot be eliminated or not adequately eliminated through technical or organisational safety measures. The protective equipments (depending on requirements according to the results of the risk assessment: safety gloves, safety shoes, safety helmet, safety goggles, face protection mask, protective clothing, respiratory protective devices etc.) must be suitable for leaking chemicals and work to be carried out and must be placed at the disposal of the respective employees. Employees must wear provided protective equipment as instructed; compliance is to be monitored by supervisors.

5.3.1.5. Main Criteria: Human Factor

There is an increasing emphasis on the importance of managing human factors – how interact the people, the job and the organisation as a whole to achieve improved safety and business performance in the chemical industries, thus warehouse, is an important task to be evaluated.

Table 39: Human Factor; Sub Criterias



A simple way to view human factors is to think about three aspects: the job, the individual and the organisation and how they impact on people’s health and safety-related behaviour.

Tasks should be designed in accordance with ergonomic principles to take into account limitations and strengths in human performance. Matching the job to the person will ensure

that they are not overloaded and that the most effective contribution to the business results. Mismatches between job requirements and people's capabilities provide the potential for human error.

People bring to their job personal attitudes, skills, habits and personalities which can be strengths or weaknesses depending on the task demands. Individual characteristics influence behaviour in complex and significant ways. Their effects on task performance may be negative and may not always be mitigated by job design. Some characteristics such as personality are fixed and cannot be changed. Others, such as skills and attitudes, may be changed or enhanced.

Organisational factors have the greatest influence on individual and group behaviour, yet they are often overlooked during the design of work and during investigation of accidents and incidents. Organisations need to establish their own positive health and safety culture.

How a better understanding of how to manage human factors can drive safety standards and overall business performance, therefore, in order to be successful and respectful to personnel, Management can benefit from psychologists and chartered ergonomics and human factors specialists. So they can better

- understand what human factors is and how it affects human performance, health and safety
- understand how human factors needs to be managed within an organisation, including the scope and involvement of different parties
- develop knowledge about specific topic areas related to major accidents and how to reduce the related risks
- understand and gain practical use of common tools and techniques used within human factors
- understand how to apply certain human factors tools

Since human failures are responsible for up to 80% of all types of accident and figure in almost every major accident it is important to reduce those failures as much as possible.²⁷

²⁷ web.www.hse.gov.uk/comah/index.htmT

Applying human factors methods helps to reduce accidents. Companies, Management should do as much as they can to prevent everyday accidents and injuries - for example slips, trips and falls. But, particularly concerned matter is, preventing major hazard accidents: those that could injure a large number of people, on and off the site.

As this factor in the end seems to be the last point creating an accident or incident, many accidents are blamed on the actions or omissions of an individual who was directly involved in operational or maintenance work, (Although these are usually rooted deeper in the organisation's design, management and decision-making functions) this criteria has been selected as one of the main criterias.

Other 5 sub criterias belong to main criteria Warehouse Human factor. Human factor criterias can be listed as follows:

5.3.1.5.1. Skills

The main descriptions about skill can be summarized as follows.

I. Basic skills: Basic numeracy and literacy / Verbal communication / Ability to receive downward communication/Ability to follow instructions / Learning to learn / Planning and organising

II. Interpersonal and intrapersonal skills: Upward problem – solving / Interpersonal skills, including listening skills/Self-awareness/Team-working / Meeting management / Coaching / Thinking innovatively and creatively / Decision-making with an awareness of consequences.

III. Conceptual and more complex behavioural skills: Managing conflict/Leadership – including motivation, delegation and empowerment/Conceptual thinking skills.

The personnel, who owns above-mentioned skills are evaluated and assigned according to specific job suitability.

5.3.1.5.2. Experience

Familiarity with a skill or field of knowledge acquired over months or years of actual practice and which, presumably, has resulted in superior understanding or mastery.

5.3.1.5.3. Level of Education/Training²⁸

First it has to be decided what training the organisation needs. The skills and knowledge needed for people to do their job properly and in a safe and healthy way, has to be identified. These have to be compared against people's current skills and knowledge and identify the gaps. Awareness training needs for everyone, including directors, managers and supervisors has to be considered.

- New recruits need basic induction training into how to work safely, including arrangements for first aid, fire and evacuation;
- People changing jobs or taking on extra responsibilities need to know about any new implications;
- Young employees are particularly in need of training a particular attention has to be given to them. New, inexperienced and young employees should be adequately supervised;
- Some people's skills may need updating by refresher training.

The methods have to be chosen at the same time.

- Giving information or instruction
- Coaching or on-the-job training;
- Training in the 'classroom';
- Open and distance learning;
- In groups or individually; a
- Computer-based or interactive learning.

5.3.1.5.4. Fatigue

Fatigue does not have a neat scientific definition but it can be described to feel tired and not to be able to perform work productively. Particularly, a tired person will be less vigilant, will have less effort to process information, will have slower response times, and will be less interested in working when compared to a person who is not tired. Events that cause fatigue can be specified as follows .

²⁸ web.www.hse.gov.uk/pubns/indg345.pdf training pg:4-6

- sleeping in poor conditions, that has been interrupted many times
- having to work at the time of what is called low point of day; for example, very early hours in the morning
- Long working hours, specifically around 14 to 16 hours.
- badly planned shift work
- Insufficient breaks during the working day

Management should improve the above conditions to avoid risk.

5.3.1.5.5. Intentional Factors

Intentional Hazard can be described as source of harm, duress, or difficulty created by a deliberate action or a planned course of action.

Safety training will often only focus on educating its employees to understand the primary hazard areas, the safe working practices and the rules they are expected to comply with, but surely it must look deeper than this and consider the underlying factors of what the triggers are to cause accidents despite the adequate mandatory control measures that are put in place. Maybe a comprehensive training approach should not be limited to only recognising human attitudes and perceptions, but include trainees self-assessing and recognising their own reactive behaviour in different operational situations.

All in all, it should therefore be taken more seriously that the human attitude accounts for a considerably high percentage of the root cause of incidents in the workplace and organisations should consider building this subject more into their training strategy

5.3.1.6. Main Criteria: Environment

The environmental issue referred to in this heading should be understood as factors that can create risks in and out of the warehouse.

This is the last criteria and sub criterias are generated under the main criteria Environment.. They are created as 7 different elements. They are:

- Equipment maintenance
- Workspace conditions
- Weather conditions

- Mechanical failure
- Location of warehouse
- Arson
- Regulations

Table 40: Enviroment; Sub Criterias

Environment
• Equipment maintenance • Workspace conditions (noise,slippery surfaces) • weather conditions • Mechanical failure • Location of warehouse • Arson • Regulations

5.3.1.6.1. Maintenance

Clean-up and regular maintenance is important for keeping equipment in good working order. The equipments, machinery such as air gun, air compressor, ladders, loading platforms or any other equipment related with the company's work area , should be maintained but this maintenance has to be safe specifically if this is done in a dangerous goods warehouse.

This Maintenance should provide appropriate personal protective equipment to staff and ensure use while operating equipment;

A hearing conservation program is required when exposure to equipment noise is equal to or greater than the action level of an 8-hour time-weighted average of 85 dB.

Adequate **air flow** shall be provided in work areas to lessen potential exposures to vapors or gases emitted from equipment and specifically prevent those gases from the stored products not to mix very dangerous substances.

5.3.1.6.2. Slips

Slips happen where there is too little friction or traction between the footwear and the walking surface. Common causes of slips are:

- Wet or oily surfaces
- Occasional spills
- Weather hazards
- Loose, unanchored rugs or mats
- Flooring or other walking surfaces that do not have same degree of traction in all areas

In Canada over 42,000 workers get injured annually due to fall accidents. This number represents about 17% of the "time-loss injuries" that were accepted by workers' compensation boards or commissions across Canada (based on statistics from Association of Workers' Compensation Boards of Canada, 2011). Statistics show that the majority (66%) of falls happen on the same level resulting from slips and trips. The remaining 34% are falls from a height. (Falls from an elevation, such as falls from ladders, roofs, down stairs or from jumping to a lower level, etc.)

Trips happen when the foot collides (strikes, hits) an object causing the person to lose the balance and, eventually fall. Common causes of tripping are:

- Obstructed view
- Poor lighting
- Clutter in the way
- Uncovered cables
- Bottom drawers not being closed
- Uneven (steps, thresholds) walking surfaces.

5.3.1.6.3. Mechanical failures

The mechanical failures in the warehouse could be any Warehouse Equipment Failures such as control panels, motor starters, Forklifts, cranes etc.

Whether these mechanical devices are small appliances, high-capacity cranes or somewhere in between, they are often subject to unforeseen incidents or failures of some sort. These failures or incidents could stem from a faulty design, manufacturing defect or

an error in operating practices. In order to bring such incidents to satisfactory resolution, a complete investigation by highly trained experts must be conducted to determine what happened and why.

When talking about the location of the warehouse, establishing the logistics and picking operations in the immediate vicinity in order to optimise transport distances and processes might be thought. This is right when the subject is the optimisation of supply chain process but when the subject is the risk, then the location is important whether there is only industrial institutions in the near area or is it located near living area, schools or hospitals etc.

Condensation can occur on ceilings, walls, floors and beddings for many reasons. For example, in buildings with a heavy structure and that use natural ventilation, a sudden change of weather with warm, moist ambient air may induce condensation when the surface temperature is lower than the dew-point temperature of the moist incoming air (Niu, 2001) Therefore the weather changes should be taken into consideration when installing ventilation or when constructing the building as a warehouse.

5.3.1.6.4. Arson

Arson is defined as the wilful and malicious burning or charring of property. The crime of intentionally starting a fire in order to damage or destroy something, especially a building. When this property which the person intends to give harm, damage and cause fire, is a property, in which dangerous goods stored, the result would be much serious than an ordinary warehouse due to its content. Arson is a real, substantial problem and risk on all sites, particularly where there are trespassers. Measures should be in place to prevent unauthorised access; Care is needed to ensure that no gaps develop in the fencing/hoarding around the site. Therefore preventing procedures should be much strictly prepared and followed.

5.3.1.6.5. Regulations

Regulations what is mentioned here, are the laws and notifications about the hazardous materials, which has been published by the related Ministries such as Industry and

Environment Ministry, Ministry of Labour, Ministry of Transportation and Communication. Other domestic regulations are in Management section.

Due to the above-mentioned different reasons, the last main criteria have been selected as Environment.

5.4. AHP SURVEY MEASUREMENT SCALE

After preparing the main criterias and sub criterias and completion of survey, getting the results from related experts, the next step is evaluation of the results.. According to AHP analysis, main criterias have been compared in pairs to assess their relative preference with respect to each of the elements at the next higher level. The numbers have been filled in the pairwise comparison matrix as per the following numbers in the scale table

Result of the Survey, the appearance of the pairwise comparison matrix is as follows.

Table 41: Main criteria -pairwise comparison matrix / Normalised matrix

Main Criterias / Dangerous goods warehousing risk analysis					
Pairwise Comparison Matrix					
	Warehouse construc	Material	Management	Human factor	Environment
Warehouse construction	1	5	4	5	7
Material	1/5	1	1/2	1	4
Management	1/4	2	1	4	5
Human factor	1/5	1	1/4	1	4
Environment	1/7	1/4	1/5	1/4	1
Column totals	1,7929	9,2500	5,9500	11,2500	21,0000
	Cw (Normalised)				
1	0,557768924	0,540540541	0,672268908	0,444444444	0,333333333
2	0,111553785	0,108108108	0,084033613	0,088888889	0,19047619
3	0,139442231	0,216216216	0,168067227	0,355555556	0,238095238
4	0,111553785	0,108108108	0,042016807	0,088888889	0,19047619
5	0,079681275	0,027027027	0,033613445	0,022222222	0,047619048

Step 1: The values in each column has been summed up of the pairwise comparison matrix.

Step 2: Each element in the pairwise matrix has been divided by its column total. The resulting matrix is referred to as the normalized pairwise comparison matrix.

Step 3: Calculates the average of the items on each line of the normalized matrix . These averages provide an estimate of the relative priorities of the compared elements . The values in the normalized pairwise comparison matrix are converted to decimal form as per

above example for main criteria's. The same procedure has been applied for all other sub criteria's respectively as shown below.

Table 42: Sub Criteria Warehouse Layout Pairwise Comparison Matrix/Normalised Matrix

Sub Criteria / Warehouse construction - Layout								
Pairwise Comparison Matrix								
	Fire detection/warn	Fire protection(W)	Emergency escape	Firewater drainag	Fire resisting sepe	Ventilation	Fire fighting equip	Electrical installati
Fire detection/warning systems	1	5	5	7	3	3	5	1
Fire protection(Water/Foam)	1/5	1	5	7	3	3	4	2
Emergency escape signs-lighting	1/5	1/5	1	3	1/3	1/3	1	1/7
Firewater drainage system	1/7	1/7	1/3	1	1/5	1/5	1/4	1/5
Fire resisting seperation/doors	1/3	1/3	3	5	1	1	2	1/2
Ventilation	1/3	1/3	3	5	1	1	3	1/3
Fire fighting equipments	1/5	1/4	1	4	1/2	1/3	1	1/5
Electrical installation	1	1/2	7	5	2	3	5	1
Column totals	3,4095	7,7595	25,3333	37,0000	11,0333	11,8667	21,2500	5,3762
	Cw (Normalised)							
1	0,293296089	0,644369438	0,197368421	0,189189189	0,271903323	0,252808989	0,235294118	0,186005314
2	0,058659218	0,128873888	0,197368421	0,189189189	0,271903323	0,252808989	0,188235294	0,372010629
3	0,058659218	0,025774778	0,039473684	0,081081081	0,030211148	0,028089888	0,047058824	0,026572188
4	0,041899441	0,018410555	0,013157895	0,027027027	0,018126888	0,016853933	0,011764706	0,037201063
5	0,097765363	0,042957963	0,118421053	0,135135135	0,090634441	0,084269663	0,094117647	0,093002657
6	0,097765363	0,042957963	0,118421053	0,135135135	0,090634441	0,084269663	0,141176471	0,062001771
7	0,058659218	0,032218472	0,039473684	0,108108108	0,045317221	0,028089888	0,047058824	0,037201063
8	0,293296089	0,064436944	0,276315789	0,135135135	0,181268882	0,252808989	0,235294118	0,186005314

Table 43: Sub criteria Warehouse Material pairwise comparison matrix/Normalised matrix

Sub Criteria / Dangerous goods warehousing Materials					
Pairwise Comparison Matrix					
	Amount of stored m	Content of materi	Placement of mati	Packaging type of	Packaging amount
Amount of stored material	1	3	3	6	5
Content of material	1/3	1	1	3	3
Placement of material	1/3	1	1	5	5
Packaging type of material	1/6	1/3	1/5	1	1
Packaging amount of material	1/5	1/3	1/5	1	1
Column totals	2,0333	5,6667	5,4000	16,0000	15,0000
	Cw (Normalised)				
1	0,491803279	0,529411765	0,555555556	0,375	0,333333333
2	0,163934426	0,176470588	0,185185185	0,1875	0,2
3	0,163934426	0,176470588	0,185185185	0,3125	0,333333333
4	0,081967213	0,058823529	0,037037037	0,0625	0,066666667
5	0,098360656	0,058823529	0,037037037	0,0625	0,066666667

Table 44: Subcriteria Warehouse Management pairwise comparison matrix / Normalised matrix

Sub Criterias / Dangerous goods warehousing Management							
Pairwise Comparison Matrix							
	Safe working proced	Standarts,quality i	Training educatio	Emergency respon	Safe manning leve	Authority,inspecti	Safe working item
Safe working procedures	1	1	1	3	3	3	5
Standarts,quality man.systems	1	1	1	5	3	3	3
Training education and certification	1	1	1	5	4	3	3
Emergency response plans	1/3	1/5	1/5	1	1	1/3	1
Safe manning levels	1/3	1/3	1/4	1	1	1	3
Authority,inspections,control	1/3	1/3	1/3	3	1	1	3
Safe working items(PPE)	1/5	1/3	1/3	1	1/3	1/3	1
Column totals	4,2000	4,2000	4,1167	19,0000	13,3333	11,6667	19,0000
	Cw (Normalised)						
1	0,238095238	0,238095238	0,24291498	0,157894737	0,225	0,257142857	0,263157895
2	0,238095238	0,238095238	0,24291498	0,263157895	0,225	0,257142857	0,157894737
3	0,238095238	0,238095238	0,24291498	0,263157895	0,3	0,257142857	0,157894737
4	0,079365079	0,047619048	0,048582996	0,052631579	0,075	0,028571429	0,052631579
5	0,079365079	0,079365079	0,060728745	0,052631579	0,075	0,085714286	0,157894737
6	0,079365079	0,079365079	0,08097166	0,157894737	0,075	0,085714286	0,157894737
7	0,047619048	0,079365079	0,08097166	0,052631579	0,025	0,028571429	0,052631579

Table 45: Sub criteria Human factor pairwise comparison matrix / Normalised matrix

Sub Criterias / Dangerous goods warehousing human factor					
Pairwise Comparison Matrix					
	Skills	Experience	Level of education	Fatigue	Intentional factors
Skills	1	1/4	1/4	1/5	3
Experience	4	1	1	1	3
Level of education/training	4	1	1	1/2	3
Fatigue	5	1	2	1	5
Intentional factors	1/3	1/3	1/3	1/5	1
Column totals	14,3333	3,5833	4,5833	2,9000	15,0000
	Cw (Normalised)				
1	0,069767442	0,069767442	0,054545455	0,068965517	0,2
2	0,279069767	0,279069767	0,218181818	0,344827586	0,2
3	0,279069767	0,279069767	0,218181818	0,172413793	0,2
4	0,348837209	0,279069767	0,436363636	0,344827586	0,333333333
5	0,023255814	0,093023256	0,072727273	0,068965517	0,066666667

Table 46: Sub criteria Environment pairwise comparison matrix/Normalised matrix

Sub Criterias / Dangerous goods warehousing Environment							
Pairwise Comparison Matrix							
	Equipment mainten	Workspace conditi	weather condition	Mechanical failure	Location of wareh	Arson	Regulations
Equipment maintenance	1	1/3	4	1/3	1/3	1	1/3
Workspace conditions	3	1	5	1/2	5	4	1
weather conditions	1/4	1/5	1	1/5	1/3	1	1/3
Mechanical failure	3	2	5	1	3	5	3
Location of warehouse	3	1/5	3	1/3	1	3	1/3
Arson	1	1/4	1	1/5	1/3	1	1/4
Regulations	3	1	3	1/3	3	4	1
Column totals	14,2500	4,9833	22,0000	2,9000	13,0000	19,0000	6,2500
	Cw (Normalised)						
1	0,070175439	0,066889632	0,181818182	0,114942529	0,025641026	0,052631579	0,053333333
2	0,210526316	0,200668896	0,227272727	0,172413793	0,384615385	0,210526316	0,16
3	0,01754386	0,040133779	0,045454545	0,068965517	0,025641026	0,052631579	0,053333333
4	0,210526316	0,401337793	0,227272727	0,344827586	0,230769231	0,263157895	0,48
5	0,210526316	0,040133779	0,136363636	0,114942529	0,076923077	0,157894737	0,053333333
6	0,070175439	0,050167224	0,045454545	0,068965517	0,025641026	0,052631579	0,04
7	0,210526316	0,200668896	0,136363636	0,114942529	0,230769231	0,210526316	0,16

After creating the pairwise comparison matrix and normalisation of this matrix, the next step was to estimate the Consistency ratio, which was below % 10 for each calculation thus for each criterias.

Step 1: The priority vector has been created taking the average values of the normalized matrix.

Step 2: Each value in the first column of the pairwise comparison matrix has been multiplied by the relative priority of the first item considered. Same procedures for other items. The values across the rows has been summed up to obtain a vector of values labelled 'weighted sum'

Step 3: The elements of the vector of weighted sums obtained in Step 1 have been divided by the corresponding priority value.

Step 4: The average of the values have been computed which was done lastly in step 2.

All results of each criterion have been calculated as follows respectively starting with main criterias.

Table 10: Main Criterias Consistency Calculation

Main Criterias Consistency calculation						
	Priority vector	Principal eigenvalue	Randomness Index	Lambda		
Warehouse construction	0,51	0,9138	0,58	>3	CI	5,42 0,1055
Material	0,117	1,0787	0,9	>4	CI/RI	0,0942 >Consistency>OK
Management	0,223	1,3297	1,12	>5	RI	
Human factor	0,108	1,2173	1,24	>6		
Environment	0,042	0,8827	1,32	>7		

Table 47: Warehouse Layout Consistency Calculation

Warehouse Layout consistency calculation

	Priority vector	Principal eigenvalue
Fire detection/warning systems	0,284	0,9676
Fire protection(Water/Foam)	0,207	1,6092
Emergency escape signs-lighting	0,042	1,067
Firewater drainage system	0,023	0,853
Fire resisting seperation/doors	0,095	1,0431
Ventilation	0,097	1,1457
Fire fighting equipments	0,05	1,0522
Electrical installation	0,203	1,0917

Lambda	8,8294
CI	0,1185
CI/RI	0,084 >Consistency>OK
8> RI	1,41

Table 48: Warehouse Material Consistency Calculation

Warehouse Material consistency calculation

	Priority vector	Principal eigenvalue
Amount of stored material	0,457	0,9293
Content of material	0,183	1,0348
Placement of material	0,234	1,2652
Packaging type of material	0,061	0,9824
Packaging amount of material	0,065	0,9702

Lambda	5,1818
CI	0,0455
CI/RI	0,0406 >Consistency>OK
RI	1,12

Table 49: Warehouse Management Consistency Calculation

Warehouse Management consistency calculation

	Priority vector	Principal eigenvalue
Safe working procedures	0,232	0,9734
Standarts,quality man.systems	0,232	0,9734
Training education and certification	0,242	0,9982
Emergency response plans	0,055	1,0434
Safe manning levels	0,084	1,1251
Authority,inspections,control	0,102	1,1937
Safe working items(PPE)	0,052	0,9956

Lambda	7,3027
CI	0,0505
CI/RI	0,0382 >Consistency>OK
RI	1,32

Table 50: Human Factor Consistency Check Calculation**Human factor consistency calculation**

	Priority vector	Principal eigenvalue
Skills	0,093	1,3274
Experience	0,264	0,9468
Level of education/training	0,23	1,053
Fatigue	0,348	1,011
Intentional factors	0,065	0,974

Lambda	5,3118
CI	0,078
CI/RI	0,07 >Consistency>OK
RI	1,12

Table 51: Environment Consistency Check Calculation**Environment consistency check calculation**

	Priority vector	Principal eigenvalue
Equipment maintenance	0,081	1,1511
Workspace conditions	0,224	1,1149
weather conditions	0,043	0,9545
Mechanical failure	0,308	0,894
Location of warehouse	0,113	1,467
Arson	0,05	0,958
Regulations	0,181	1,128

Lambda	7,6684
CI	0,1114
CI/RI	0,0844 >Consistency>OK
RI	1,32

Because all the consistencies were within the required limit, which is below 0,10; the rankings of all criterias as per their importance level has come out. Firstly as per classification domestically, per criteria, and then globally for all criterias together.

The findings from evaluating the main criteria are as follows:

- 1) Firstly, the Warehouse infrastructure is significantly more weighted than the other three factors. This is ,with a weight of around 50 % compared to other factors.
- 2) The second priority has been given to the Management with around 20 %.
- 3) The difference between the third and fourth factors is only about 1 % . The third factor comes with 12 % as of Material. The fourth is Human factor with around 11 %.
- 4)The last factor seems to be the Environment with around 4 %.

When we come to the sub-criteria, the first place among the factors , which is within warehouse infrastructure, is fire and dust detection systems. This criterion, which is 14,5% ahead of 32 criteria, has 28,4% points among only warehouse infrastructure criteria.

Table 52: Importance level / Rankings altogether

Comparison of global and local importance levels				
Main criterias	Weights	Sub Criterias	Local weights	Global weights
Warehouse construction	51,0%	Fire detection/warning systems	28,4%	14,5%
Material	11,7%	Fire protection(Water/Foam)	20,7%	10,6%
Management	22,3%	Electrical installation	20,2%	10,3%
Human factor	10,8%	Training education and certification	24,2%	5,4%
Environment	4,2%	Amount of stored material	45,7%	5,3%
		Safe working procedures	23,2%	5,2%
		Standarts,quality man.systems	23,2%	5,2%
		Ventilation	9,7%	4,9%
		Fire resisting seperation/doors	9,5%	4,8%
		Fatigue	34,8%	3,8%
		Experience	26,4%	2,9%
		Placement of material	23,4%	2,7%
		Fire fighting equipments	5,0%	2,6%
		Level of education/training	23,0%	2,5%
		Authority inspection,control	10,2%	2,3%
		Emergency escape signs-lighting	4,2%	2,1%
		Content of material	18,3%	2,1%
		Safe manning levels	8,4%	1,9%
		Mechanical failure	30,8%	1,3%
		Firewater drainage system	2,3%	1,2%
		Emergency response plans	5,5%	1,2%
		Safe working items	5,3%	1,2%
		Skills	9,3%	1,0%
		Workspace conditions	22,4%	0,9%
		Packaging amount of material	6,5%	0,8%
		Regulations	18,1%	0,8%
		Packaging type of material	6,1%	0,7%
		Intentional factors	6,5%	0,7%
		Location of warehouse	11,3%	0,5%
		Equipment maintenance	8,1%	0,3%
		Weather conditions	4,3%	0,2%
		Arson	5,0%	0,2%

The second criterion in the warehouse design was also placed as second in the whole criterion and the group in the total. In whole criterion, fire protection-sprinkler system was scored as second with 10.6% of all criteria and 20.7% in its own group.

The third criterion is again from the first group: Electrical installation. The result of this criterion is nearly the same with the second one. The difference is less than 1 %.Among

whole criterion It has been 3rd with % 20,2 within it's own group, among whole criterias % 10,3.

The percentages of the next six criteria were close to each other and were around 5%

The last two criterion are again from the same group: Warehouse infrastructure. Ventilation with % 4,9 and Fire resisting separation with % 4,8. Their share in their group is: % 9,7 and % 5 %.

One of the higher four criteria's group is material with 5,3 % and the other three are from the management group. As of the second group, Management is putting 3 criterias for the first time. 4th, 6th and 7th

With global percentages % 5,4, % 5,2, % 5,2. An important point to note here is that the 3 criteria that score around 5% on global basis, has got around 23% when talking about their own group. Their percentages in their own group respectively are: 24,2 %, 23,2 % and 23,2 %.

The next 5 criterias are around % 3 and 2 of them from the first group-Infrastructure; the other three are from another group, human factor. The percentage of this group, which first time enters the evaluation are 3.8%, 2.9% and 2.5% globally and their subjects are respectively: Fatigue, Experience and Level of education/training. In their own group, Fatigue gets the score of % 34,8 and other criterias % 26,4 and % 23.

The other 4 criterias get the percentage around 2 % with two of them from group Management, one from Layout, one from Material. In their group, Content of material gets % 18,3 ; Authority, inspection and control; % 10,2; Safe manning levels; % 8,4; Emergency escape signs-lighting: % 4,2.

The other 14 criterias have a global percentage of around 1.3 percent and below, with higher percentages in their own groups.

Storing a certain amount of hazardous material poses serious risks not only to the workers in the warehouse but also to the persons near the warehouse and the environment.

The accidents that cause the most important concern are those involving fire. Such fires, workers, emergency services and the public are exposed to the threat of heat, harmful smoke and fumes, flying missiles. Fires can also cause materials to spread over a larger area through smoke and damage water and the environment to fight fire.

Since the most significant hazard in a warehouse is the fire hazard, workers must determine which ignition sources, including electrostatic charges, can cause a potential fire, energetic chemical decomposition, explosion, or the like.. At a minimum, the following energy forms should be included when evaluating potential ignition sources.

(a) Heat; (b) electrical; (c) mechanical; (d) chemical.

Possible sources of ignition include:

(a) heat energy, eg: ■ heating installations; ■ internal combustion engines; ■ open fire and flame; ■ hot surfaces; ■ smoking; ■ hot work, including welding spatter, laser or other intense radiation sources;

(b) electrical energy, eg: ■ electrical lighting devices such as lamps; ■ electromagnetic radiation; ■ radio frequency sources; ■ short circuit; ■ electrical arc; ■ earth fault; ■ conductor fault; ■ lightning strike; ■ discharges of static electricity; ■ loose contact; ■ excessive temperature rise due to overload; ■ induction heating; ■ resistive heating; ■ connection to inappropriate electrical supply;

(c) mechanical energy, eg: ■ friction (eg overheating); ■ ultrasonic; ■ impact; ■ grinding; ■ compression (including adiabatic compression and shock waves);

(d) chemical energy (refer to SDS/technical information sheets or data), eg: ■ self-heating; ■ impact- and heat-sensitive materials (eg pyrophoric substances);

■ reactions between dissimilar metals (eg thermite reaction sparks); ■ runaway exothermic reaction.

Where there is potential for an explosion, the scale of effects and the extent of harm will depend on: the substance, the amount involved and how quickly it can be absorbed. The building configuration of warehouse or obstacles will have an effect on the burn rate.

Because the internal buildings infrastructure and specially the fire detector system can mitigate the effects of a possible fire the most important criteria seems to be this system and our criteria expert assessment showed the same result too.

The second most important group Management's location is logical because it is the practitioner of the other criterias and therefore important than the other 3 factors.

A checklist has been developed to assist warehouse management and employees in developing a more detailed view of at risk points and is included in the supplement starting from the main criterias.



5.5. CHECK LIST

Environment

QUESTIONS	YES	NO
Are work surfaces kept dry or appropriate means taken to assure the surfaces are slip-resistant?	☐	☐
Are sufficient emergency exits provided?	☐	☐
Do these conform to local safety requirements?	☐	☐
Are all work areas properly illuminated?	☐	☐
Are all spilled materials or liquids cleaned up immediately?	☐	☐

Is combustible scrap, debris and waste stored safely and removed from the worksite promptly?	☐	☐
Is product stored at a safe distance from light fittings, electrical equipments?	☐	☐
Are pits and floor openings covered or otherwise guarded?	☐	☐
Is employee exposure to welding fumes controlled by ventilation, use of respirators, exposure time, or other means?	☐	☐
Is employee exposure to chemicals in the workplace kept within acceptable levels?	☐	☐
Are spray painting operations done in spray rooms or booths equipped with an appropriate exhaust system?	☐	☐
If forklifts and other vehicles are used in buildings or other enclosed areas are the carbon monoxide levels kept below maximum acceptable concentration?	☐	☐

Has there been a determination that noise levels in the facilities are steps being taken to use engineering controls to reduce excessive noise levels?	☐	☐
Where heat is a problem, have all fixed work areas been provided with spot cooling or air conditioning?	☐	☐
Are employees working on streets and roadways where they are exposed to the hazards of traffic, required to wear bright coloured(traffic orange/ yellow)warning vest?	☐	☐
Is equipments producing ultra violet radiation properly shielded?	☐	☐
Is product stored at a safe distance from ancillary operations such as shrink wrapping using open flames, refilling, repacking, equipments maintenance or are those done in a segregated room?	☐	☐
Does the warehouse have adequate precautions against arson and burglary?	☐	☐

If the warehouse is heated, is the heating source located away from the storage area and is direct heating of products avoided.?	☐	☐
If any product is stored outside the warehouse; are conditions satisfactory regarding security?	☐	☐
Weather protection?	☐	☐
Access for fire fighting?	☐	☐

Warehouse Construction/Layout

QUESTIONS	YES	NO
Does the warehouse fulfil requirements regarding construction materials?	☐	☐
Floor surface?	☐	☐
Internal firebreak walls?	☐	☐
Roof covering and ventilation?	☐	☐
Heat and smoke release?(for ex:AS/ISO 9705; ISO 5660 Fire test for heat and smoke release rates)	☐	☐
Drainage?	☐	☐
Local fire regulations?	☐	☐
Is the warehouse fitted with a lightning conductor?	☐	☐
If any office or amenity accommodation exists in the warehouse structure.	☐	☐

Is it adequately segregated from the store?	☐	☐
Has it an exit other than through the warehouse?	☐	☐
Is the warehouse bunding at least 20 cm in height?	☐	☐
What additional system for containment of fire fighting water exists?	☐	☐
None?	☐	☐
Underground retention pit?	☐	☐
External containment wall?	☐	☐

Other? Describe	☐	☐
Is the containment capacity is sufficient to contain the expected volume of fire fighting water?	☐	☐
Is the firewater drainage system approved by the Environment Ministry?	☐	☐
Does the warehouse have automatic protection such as sprinklers or smoke detectors ?	☐	☐
Do you have a fire alarm system and is it certified as required?	☐	☐
Is the fire extinguishing system was designed with appropriate materials such as foam, water, taking into account the contents of the warehouse products?	☐	☐
If you have interior standpipes and valves, are they inspected regularly?	☐	☐
If you have outside fire hydrants, are they flushed at least once a year on a routine preventive maintenance schedule?	☐	☐
Are fire doors and shutters in good operating condition?	☐	☐

Are fire door and shutters unobstructed and protected against obstructions , including their counterweights?	☐	☐
Are automatic sprinkler system water control valves, air and water pressures checked weekly/ periodically as required?	☐	☐
Are sprinkler heads protected by metal guards, when exposed to physical damage?	☐	☐
Are portable fire extinguishers provided in adequate number and type?	☐	☐
Are fire extinguisher mounted in readily accessible locations and fully charged?	☐	☐
Are all extinguishers serviced, maintained and tagged at intervals not to exceed one year?	☐	☐

When electrical equipment or lines are to be serviced , maintained or adjusted , are necessary switches opened, locked-out, and tagged whenever possible?	☐	☐
Are portable electrical tools and equipment grounded or of the double insulated type?	☐	☐
Are electrical appliances such as vacuum cleaners, polishers, vending machines grounded?	☐	☐
Is the electrical system was designed as exproof?	☐	☐

Are extinguisher free from obstructions or blockage?	☐	☐
Does the number and type of fire extinguishers, hydrants and hose-lines satisfy requirements ?	☐	☐
Is a record maintained of required monthly checks of extinguishers?	☐	☐
Are fire alarms automatically linked with the fire brigade?	☐	☐
What is response time?	☐	☐
Is there a plan to deal with emergencies?	☐	☐
Has this been agreed with the local fire-brigade?	☐	☐
Is there a fireplan showing positions of all fire fighting equipments?	☐	☐
Are personnel trained in firefighting?	☐	☐
Is there a fire drill regularly practised in cooperation with the local fire-brigade?	☐	☐
Are your workplace electricians familiar with International/national standards, safety orders?	☐	☐

Do extension cords being used have a grounding conductor?	☐	☐
Are all temporary circuits protected by suitable disconnecting switches or plug connectors at the junction with permanent wiring?	☐	☐
Are all cord , cable and raceway connections intact and secure and are clamps and other securing means securely held in place?	☐	☐
In wet or damp locations, are electrical tools and equipments appropriate for the use or location or otherwise protected?	☐	☐
Is the location of electrical power lines and cables(overhead, underground underfloor, other side of walls) determined before digging, drilling or similar work is begun?(Is there a electrical drawing plan)	☐	☐
Are all disconnecting switches and circuit breakers labeled to indicate their use or equipment served?	☐	☐
Do all interior wiring systems include provisions for grounding metal parts of electrical raceways, equipments and enclosures?	☐	☐
Are all electrical raceways and enclosures securely fastened in place?	☐	☐
Are all parts of electrical circuits and equipments guarded against accidental contact by approved cabinets or enclosures?	☐	☐
Is sufficient access and working space provided and maintained about all electrical equipments to permit ready and safe operations and maintenance?	☐	☐
Are all unused openings (including conduit knockouts) in electrical enclosures and fittings closed with appropriate covers or plates?	☐	☐

Is low voltage protection provided in the control device of motors driving machines or equipments, which could cause probably injury from advertent starting?	☐	☐
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Is all portable electrical equipment used inside confined spaces either grounded and insulated or equipped with ground fault protection?	☐	☐
Are all exits marked with an exit sign and illuminated by a reliable light source?	☐	☐
Are the directions to exits, when not immediately apparent, marked with visible signs?	☐	☐
Are doors, passageways or stairways , that are neither exits nor access to exits and which could be mistaken for exits, appropriately marked "NOT AN EXIT" "TO BASEMENT" "STOREROOM" and the like?	☐	☐
Are there sufficient exits to permit prompt escape in case of emergency?	☐	☐
Are aisles and walkways marked as appropriate and always kept clear?	☐	☐
Are doors that are required to serve as exits designed and constructed so that the way of exit travel is obvious and direct?	☐	☐
Are exit doors side hinged?	☐	☐
Where panic hardware is installed on a required exit door, will it allow the door to open by applying a force of appr. 7 kg or less in the direction of exit traffic?	☐	☐
Are standard guardrails provided wherever aisle or walkway surfaces are elevated more than 76 cm above any adjacent floor or the ground?	☐	☐
Are toxic, organic peroxides , flammables separated from other products by floor walls or rooms?	☐	☐
Are all warehouse products containing inert , toxic, flammable , corrosive etc materials racking or placing design done according to segregation and separation table (regulation).	☐	☐

Materials

Are hazardous substances identified which may cause harm by inhalation, ingestion, skin absorption or contact?	☐	☐
Are approved containers and tanks and drums and all ~~packaging used~~ for the storage and handling of flammable and combustible liquids?	☐	☐
Do storage rooms for flammable and combustible liquids have explosion-proof lights?	☐	☐
Do storage rooms for flammable and combustible liquids have mechanical or gravity ventilation?	☐	☐
Are all solvent, flammable liquid and other hazard wastes kept in fire-resistant covered and/or suitable containers until they are removed from the worksite?	☐	☐
Is vacuuming used whenever possible rather than blowing or sweeping combustible dust?	☐	☐
Are safety cans used for dispensing flammable or combustible liquids at a point of use?	☐	☐
Have standard operating procedures been established and are they being followed when cleaning up chemicals? Where needed for emergency use, are respirators stored in a convenient, clean and sanitary ~~location~~ ?	☐	☐
Are all spills of flammable or combustible liquids cleaned up promptly? Are all containers, such as drums and storage tanks labeled as to their contents e.g "caustic"	☐	☐
Are eye wash fountains and safety showers provided in areas where corrosive chemicals are handled?	☐	☐

Is personal protective equipments provided, used and maintained whenever necessary?	☐	☐
Are the respirators OSHA approved and are they regularly inspected and cleaned, sanitized and maintained?	☐	☐
Are you familiar with the threshold limit values or permissible Exposure Limits of airborne contaminants and physical agents used in the workplace?	☐	☐
Is each container,drum,bottle etc for a hazardous substance labeled with product identity and hazard warning?	☐	☐
Is there a Material Safety data sheet(MSDS)readily available for each hazardous substance used?	☐	☐
Is there a list and/or table about the physical and health hazards of substances in the work area, how to detect their presence,and protective measures to be used?	☐	☐
Are cylinders legibly marked to clearly identify the gas contained?	☐	☐
Are compressed gas cylinders stored in areas which are protected from external heat sources such as flame impingement, intense radiant heat, electric arcs or high temperature lines?	☐	☐
Are cylinders stored or transported in a manner to prevent them creating a hazard by tipping, falling or rolling or will not be damaged by passing or falling objects or by unauthorised persons?	☐	☐
Are all valve protectors placed on cylinders and all valves closed off before a cylinder is moved,when the cylinder is empty, and the completion of each job?	☐	☐
Are low pressure cylinders checked periodically for corrosion, general distortion , cracks or any other defect ?	☐	☐

Warehouse Management / Human Factor

Is there a defined management structure with clear areas of responsibility?	☐	☐
Do these responsibilities include: receipt and dispatch of goods?	☐	☐
Occupational health and safety?	☐	☐
Industrial hygiene and safety?	☐	☐
Maintaining suitable storage conditions?	☐	☐
Security?	☐	☐
Protection and environment?	☐	☐
Emergency procedure plans?	☐	☐
Does the warehouse have adequate precautions against arson and burglary?		
Are all the staff adequately trained concerning?		
Knowledge of product hazards?	☐	☐
Safe operating procedures?(for ex. Is the prohibition of smoking rigidly enforced in the warehouse?)	☐	☐
Emergency procedures?	☐	☐

Is a supervisor present during receipt and dispatch of all goods to check documents, package and integrity etc?	☐	☐
Is there an assigned safety standby employee whose responsibility sound an alarm if necessary and render assistance?	☐	☐
Are there trained personnel in First aid and Cardiopulmonary resuscitation available?	☐	☐
Are employees instructed in proper first aid and other emergency procedures?	☐	☐
Are Material safety data sheets(MSDS) for all products available?	☐	☐
Is an outline of the storage plan of the materials in each warehouse kept up to date?	☐	☐
Are forklift trucks operating in warehouses with flammable goods properly protected from generating sparks?	☐	☐
Does product segregation or seperation within the premises satisfy requirements?	☐	☐
Are passage ways clearly marked and accessible?	☐	☐
Are block arrangement for block storage comply with recommendations?	☐	☐
Are inspection aisles kept free?	☐	☐
Are stock records kept up to date?	☐	☐
Does this guarantee knowledge of the quantity and location of the goods at any time?	☐	☐
Are all exits kept free of obstructions?	☐	☐

Are the requirements on use and charging of forklift trucks satisfied?	☐	☐
Are standards of hygiene and housekeeping adequate?	☐	☐
Is personal protective equipments provided, used and maintained wherever required	☐	☐
Are these routinely worn when handling products?	☐	☐
Does protective equipments exists on the premises for handling spills?	☐	☐
Are adequate first aid materials and facilities provided and are staff familiar with their use?	☐	☐
Is there an agreed procedure for dealing with spillages?	☐	☐
Are spilled dry products removed by vacuum cleaner?	☐	☐
Is absorbent material available?	☐	☐
Waste disposal, Are wastes disposed of in a safe manner?	☐	☐
Have the methods of disposal been approved by the authorities?	☐	☐
Are grinders,saws and similar equipments provided with appropriate safety guards?	☐	☐
Are power operated tools checked regularly for deterioration or damage?	☐	☐

Is the reuse of emptied containers satisfactorily prevented?	☐	☐
Is there adequate supervision to ensure that employees are following safe machine operating procedures?	☐	☐
Is equipments and machinery securely placed to prevent any movement that could result injury?	☐	☐

Is there a power shut off switch within reach of the operator's position at each machine?	☐	☐
Are all emergency stops red?	☐	☐
Are employees physical capacities assessed before being assigned to jobs requiring heavy work?	☐	☐
Are employees working on streets and roadways where they are exposed to the hazards of traffic ,required to wear bright coloured(traffic orange/yellow) warning vest?	☐	☐
Are employees aware of hazards involved with the various chemicals which they are involved and training is given periodically?(how to use labelling system, MSDS, its content,explanation of "right to know")	☐	☐
Do you have a fire prevention plan?	☐	☐
Have you established practices and procedures to control potential fire hazards and ignition sources?	☐	☐
Is maintenance of automatic sprinkler system assigned to responsible persons or to a sprinkler contractor?	☐	☐
Are employees periodically instructed in the use of extinguishers and fire protection procedures?	☐	☐
Have standard operating procedures been established and are they being followed when cleaning up chemical spills?	☐	☐

Is there a check up procedure for warehouse personnel taking their blood	☐	☐
complain about skin dryness, irritation, sensitization, other factors of discomfort?	☐	☐
Is exposed wiring and cords with frayed or deteriorated insulation repaired or replaced promptly?	☐	☐
Are Osha security procedures and related standards are taken into account for warehouse personnel?	☐	☐
Is the periodic audits carried out by warehouse assigned personnel 3rd party audit firms?	☐	☐
is it done at least once a year?	☐	☐

CHAPTER 7

6. RESULTS AND EVALUATION

6.1. FINDINGS FROM STUDY

The purpose of writing this thesis is to prioritize the risks that may arise in the dangerous substance warehouses as it was mentioned earlier and to rank them according to their importance, to guide the warehouse managers during the warehouse management, to provide some predictability of the risks and to ensure that they can be reduced and managed beforehand.

Thus contributing to good governance practices, leading individual firms to create their own specific systems and practices.

Therefore, the risk issue has been briefly reviewed like the following steps and tried to elaborate it in order to form a basis for my study.

In risk analysis, screening techniques range from simple checklists to risk-based or result-based screens that take both frequency and consequences and generate a numeric or categorical score, where data availability is limited or impractical (such as examining a large number of different movements), screening analysis is most appropriate.

Qualitative or semi-quantitative risk estimates generally include experience, judgment, good practices, training, procedures, audit and maintenance, codes and standards, past performance, etc. and it can be used as a method during either in transportation or in fixed installations such as warehouses.

In the quantitative risk method, and also in some qualitative and semi-quantitative methods, the following method is generally followed. The scope is determined. After defining the scope, quantitative study can be done in various ways such as examining the event, selecting the event, estimating the consequences, estimating likelihood, estimating risk.

Risk analysis scope definition transforms user requirements into operational goals. Risk measures and forms of risk presentation are selected to complete a study for risk analysis. A working depth is then selected based on the specific targets identified and available resources. If there is a need for specific research (such as for example additional event tree

analysis) and there is no problem in reaching the destination, the study ends with the definition of specific information.

Initiated event to describe and investigate accident-based incidents is usually done by way of historical data. To investigate non-accident incidents is done by methods such as hazard identification techniques.

Case study is the identification and tabulation of all events regardless of the event of importance or initiation. The review may be closely related to the current evidence.

Event Selection is the process by which one or more important events are selected to represent all identified events, event results are defined, and event output cases are developed.

Consequence Estimation is the methodology used to determine the potential for damage or injury from certain events. A single event (eg, a breakdown of a pressurized liquid tank) can result in many different event results [eg. Steam Cloud Burst (VCE), Boiling Liquid Magnifier Steam Burst (BLEVE), burning]. These results are analyzed using source and distribution models.

Likelihood Estimation is a methodology used to estimate the frequency or probability of an event. Estimates can be obtained from failure sequence models, such as fault trees and event trees, or past event data, on failure frequencies from specific failure models.

The Risk Estimate combines the results of all selected events and their possible consequences to provide a risk measure. The risks of all selected events are estimated and collected separately to give a general risk measure.

Use of Risk Estimates is the process by which the results of a risk analysis are used to make decisions either by relative ranking of risk mitigation strategies or by comparison with specific risk targets. This step is actually a process from risk analysis to risk assessment.

When all the above mentioned risk analysis steps and literature have been examined, the research subject has been selected as; so far in Turkey which types of accident and have happened and what was the reason of those accidents and triggered event of them.

At the same time, it was thought that it could be easy to find the data needed for this issue and it has been focused on the accidents occurred during the transport of dangerous goods

in Turkey. However, because ADR legislation has recently been implemented in Turkey and Hazardous Materials Consulting has been newly established and therefore DGSA s could not give, install the needed, compulsory and sufficient and satisfactory hazard Information into the Department of Transportation System. There was only a year that a very small number of accident had been just installed into data system. This would result in the failure of the part of the Likelihood estimation that has been mentioned briefly above, and afterwards it would not be possible to investigate the possibility of predicting likelihood by using the event tree or the fault tree method.

After trials in the Ministry of Transport without success, another trial to get data from Istanbul Fire Department did not work either. The fire data, neither about the dangerous chemicals carried by a moving vehicle nor about a warehouse, in which the dangerous goods stored, could be reached..

Therefore, it has emerged that a study about the fires and reasons of the fires can not be succeeded yet in Turkey, although many countries all over the world frequently use their national datas to reveal the causes of fires. This matter could be mentioned firstly as a gap, that needs to be developed urgently. However, within a few years, the accident data collected by the Ministry of Transport would accumulate enough to be opened to researchers and academicians, and authorities would be able to lead in the direction of our shortcomings and the issues that need to be corrected.

On the issue of information access problem in the firebrigade; If the subject is a system problem, it is important that the firefighters computer systems are organized in such a way that the details of the fire, the root causes and the information can be reached easily, and when it is completed, the contribution will be high for academicians , researchers.

Therefore the research has been transformed from transport risk analysis to dangerous goods storage risk analysis. First of all, as mentioned above, the extent, the scope of the risk had to be determined.

For this reason, opinions from experienced logistics experts / managers / authorities has been received as well as literature searching has been done and Information from the legal documents, regulations were found about the dangers, hazards, which could lead risks in the storage. Thus the main and subcriterias have been defined.

As of the methodology, AHP method was used, with this way, both qualitative and quantitative methods were utilized. At the same time, because many firms use checklists in accordance with the needs and objectives of the company and for their staff, it is easy to understand and use; the control lists were prepared based on subcriteria. As a result, a second method to be described qualitatively contributed to the research.

Two Hypothesis had been identified.

H1: When the risk factor in a warehouse is evaluated, the infrastructure is more important than Management.

H2: When the risk factor in a warehouse is evaluated, the Management is more important than Material.

The variables mentioned at the beginning of the study and the hypotheses drawn by these variables were rated according to the AHP methodology in the application part of the study.

According to the AHP results, it is understood that the most important risk issue is the infrastructure as a result of the risk grading. Other risk issues are respectively Management, Material, Human factor and Environment according to their importance.

Details of the sub-criterias are given in the application section.

While the criteria were set in the study, many Informations, regulations, documents have been investigated about storage, which have been prepared and evaluated by many committees and institutions, and one of the most satisfactory ones was seen and used as SQAS.

Today, the European Chemical Industries mostly use 3PL companies for the storage, loading, unloading and transport of finished chemical products, raw materials and intermediate materials. The companies that undertakes the logistics services of chemicals have to give assurance to the company that they do logistics activities for the safe and high quality operation of the employees and for protection of the environment. In the past, this assurance was provided through periodical inspections of logistics service providers of chemical companies. However, since this method was implemented in a piecewise approach, it resulted in a large number of high cost and ineffective inspection programs for both parties.

Triple Responsibility, or responsible care is the commitment of the world chemical industry to maintain continuous improvement in its health, safety and environmental performance and open communication on its activities.. The Triple Responsibility movement, which came into light in Canada in 1984 and in 1985 in the same country, spread throughout the world, first in America (1988) and later in Europe (1989). National chemical industry associations are responsible for effective implementation of the Triple Responsibility in their respective countries. The responsible Care in Turkey is carried out by Chemical Manufacturers Association (TKSD).²⁹ Since 1993, it has been implemented under the coordination of TKSD. CEFIC has created the Intervention of Chemical Transport Emergency (ICE) program, which aims to increase the safety performance of storage, loading / unloading and transport of intended chemicals. The key element of the ICE program is to develop several Safety and Quality Assessment Systems (SQAS) for different modes of transport and/or logistics operations.

Safety Quality Assessment for Sustainability (SQAS) can assess the quality, safety and environmental management of logistics service providers in a standardized manner. Both independent assessors and standard assessment questionnaires are used to perform auditing. This has prevented the chemical companies from performing multiple audits and at the same time ensuring that each of the audited firms has easily tracked how they have progressed.

As a result of the SQAS evaluation made by an independent person, no certificate is given for the audited firm but a report based on the facts emerges. The chemical manufacturer undertaking the hazardous substance logistics services as a third party service, will assess the content of this report according to their needs.

Although SQAS can not guarantee the quality and safety of the service provided by the supplier (3PL), it provides a mechanism to evaluate the continuous development of the 3PL. The system generates the necessary feedback to the 3PL company for the weak and strong points resulting from the inspection. In addition, the weak points that need to be strengthened after the outcomes are evaluated by the chemical producer enterprises are strengthened by forming a solution partnership with the 3PL. It constantly improves and develops. In order to prevent possible accidents; SQAS was developed.

²⁹ web.www.tksd.org.tr/rc.html

While SQAS is working on auditing by considering the standards from one side of the picture, the other side of the picture shows some organizations, which do not prefer to receive services from this accredited organization. Even if there are some organizations, that do not prefer to get this service, they have to follow the accrediting standards when they build up the infrastructure of their warehouse and during their operational activities.

It is very important to follow both the legal and voluntary systems that exist in human health, environment, quality and safety issues, and there are the following main institutions in this subject.

Risk management tools; Law and Voluntary Management Systems

- ISO 9001 International Organisation for Standardisation. Quality Management systems
- OHSAS 18001 Occupational Health and Safety Management Systems
- ISO 14001 Environmental Management Systems
- Responsible care. Human Health, Environment, Quality and safety
- EMAS Eco-Management and Audit scheme
- SA 8000 Social Accountability standard
- ILO-OSH 2001 Guidelines on Occupational Safety and Health management systems
- BS 8800 Guide to Occupational Health and Safety Management Systems
- SIGMA Project – Sustainability - Integrated Guidelines for Management

Globalizing commercial and industrial relations require certain levels of standardization, especially in terms of quality, occupational health and safety and environmental protection

The Triple Responsibility program also utilizes the necessary parts of all the standards and conducts the system at the same time with the following management rules:

Occupational Health and Safety • Environmental Management System • Distribution • Communication - Community Consciousness-Emergency • Process Safety • Product Responsibility (TKSD, 2010)

The European Chemical Transport Association (ECTA) has announced that it will continue to work in the hazardous materials logistics sector within the 2012 Triple Responsibility Plan to minimize the risk and to carry out the necessary work for environmentally sensitive

logistics operations. As of January 1, 2010; 35 companies were involved in the Triple Responsibility Project. In 2018, this number increased to 104 companies.

At the moment, 3 Turkish companies are seen as ECTA members as of February 2018.³⁰ Two of them are having services about tanker filling, transfer and cleaning in the warehouse. The other is a company that provides services on packaged dangerous chemicals storage. This organization is one of the rare ones in its subject and opened the first the appropriate warehouse organization in Turkey and develops itself in this regard continuously.. But Turkey also has much more hazardous materials storage service providing organizations.

The increase of the membership of ECTA will contribute to the logistics sector. Because the ECTA membership certificate can be obtained after certain criteria are met and after continuous improvement.

However, firms do not prefer to allocate a certain budget in case of auditing this accredited institution. The cost price balance should be revised when the risk cost factor is taken into account and it is necessary to operate the general rules, regulations, penalties and supervision mechanisms.

In the research, it has emerged that the regulations, rules, laws, management systems, and education have been subject to different definitions under the heading Management and Environment and under the heading Human factor, and it has generally been emphasized and importance has been given.

In the survey, after the result of creating and ranking of the main and sub sub-criteria, the warehouse infrastructure as of the main criteria, has been ranked at the top of the statistic, as determined by hypothesis too. Apart from the ones that are evaluated individually in the research section, my general criteria evaluation which may contribute to the research result, in terms of our country's reality, are as follows:

The main criterias are ranked firstly with infrastructure, then management, afterwards product, then human factor and the latest, environment. When we look at the sub-factors that are the content of the main factors, it seemed generally reasonable, but the "rules,

³⁰ web.<https://www.ecta.com/Responsible-Care>

regulations" section under the environmental heading did not get enough attention, which can be described actually the first point of departure for all companies.

Regulations, Legislations, Circulars under the laws of Turkey, especially in the framework of European harmonization laws and Integration, is introduced as it should be, but the main deficiency is experienced during implementation and supervision of these enacted regulations.

Regulations about hazardous substances in Turkey;

Regulation on the classification, labeling and packaging of materials and mixtures. (11.12.2013/28848)

Regulation on the protection of buildings from fire (19.12.2007/26735)

Regulation on the transport of dangerous goods by road (24.10.2013/28801)

Regulation on Health and Safety when working with chemical substances (12.08.2013/28733)

Regulation on the inventory and control of chemicals (23.05.2010/27539)

Regulation on the control of major industrial accidents (18.08.2010/27676)

Metropolitan Municipality, Regulation on the storage and inspection of flammable, combustible, chemical materials (28.11.1997/10418)

Regulation on safety data sheets for harmful substances and mixtures (13.12.2014/29204)

Regulation on Hazardous Chemicals (20.04.2001/24379)

Regulation on the prevention of major industrial accidents and reduction of their effects (30.12.2013/28867)

The Regulation on the Prevention of Major Industrial Accidents may be made for larger industrial plants, but it may also apply to businesses that have a certain tonnage and store certain materials, and in this Regulation, it is firstly necessary to report business scope products together with the tonnages of them. At the same time, it was also requested the Regulation to conduct quantitative risk assessment from the companies. It is expected that risk assessment will be made with various scenarios and the Ministry of Environment will

be informed and the risk determined according to this scenario will be reduced to a lower level.

In this regard, it is especially important to follow the enterprises that store the products that fall under the dangerous articles of many companies.

Controls should be made both during loading, unloading and transport and in the warehouse, while the products are stationary, and the controls should be a standard, a scenario, a way to be followed. For example, if the vehicle carrying dangerous goods is on the road or in a warehouse inspection, how and by whom the inspection will be carried out, what is the most important part to be inspected in the vehicle during the inspection, etc. is not clear totally. The ADR has not been clear since the application date or the person, who should be supervised and audited is not fully acquainted with the subject. Education is also important in this regard. A sufficient number of people must be trained and supervised during transportation and at the warehouse, and the penalties must be deterrent.

Another important issue regarding laws and regulations is the coordination of permits, authorizations and licensing organizations with each other. Provincial Directorates and Directorates of Organized Industrial Zone in the Industrial Zone are authorized in the case of a license for a warehouse. However, the Directorate requires the approval of the firefighter in the process of issuing the license and after the approval of the firebrigade, the warehouse license is granted. However, before the license is issued, the firefighter must take the individual contents and tonnage of the products to be stocked in that warehouse and plan accordingly. Like in an industrial firm, product types, possible tonnages are requested in the capacity report, it is necessary to ask this kind of information before a license is issued by the firebrigade also for a warehouse. However, such an operation is not carried out today.

So, in fact, the proper implementation of the regulations is to prevent or minimize the risk before it occurs.

Fire detection, fire protection and electrical system designation, all of which constitute the infrastructure in the first three ranks, also means reducing the high risk situation by operating it immediately before or just at the beginning of the risk situation occurs. These are investments made, in order to avoid high risk such as death or injury.

Topics such as education, standards, safety procedures that the administration needs to organize also emphasize the importance of education and it makes sense to rank them first as important issues.

The drainage system, which is important for the environment, could have been only located in the middle of the rankings. Perhaps it would be in much more front row rankings in other countries, but it is known that there are gaps in practice and that many wastes are disposed of illegally, although the laws are actually quite strict.

The Cefic initiative continues through the chemical logistics department and its 2020 vision is determined as follows.

- 1) Encourage and guide transition from alternative modes of transport to sustainable, green modes of transport.
- 2) To continually improve logistics security by contributing to the capabilities of European chemical companies and logistics service providers.
- 3) Develop supply chain organization and processes / supply chain collaboration

It is believed that one of the main themes in the coming years will be security, risk mitigation, with the statement of CEFIC "to continuously improve logistics security by contributing to the capabilities of logistics service providers" in the second article. This issue has to be taken into consideration in our country by being organized by the Chemical Industrialists' Association or by another organization.

Logistic enterprises in our country need top boards and / or organizations that form, build systems like SQAS. These senior bodies should advise on projects related companies such as research and development projects, to implement systems such as SQAS or similar systems. These senior bodies should provide various trainings and organize international events for the respective businesses. Thus, systems such as SQAS or similar systems can be developed.

When all the criteria are taken into account, the following must be done in order to minimize the risks during the storage of hazardous substances. The first and most important criteria according to the research was shown as **Infrastructure**. Therefore ;

- It is necessary for the competent authorities to inspect the warehouse infrastructure most strictly and not to issue licenses for those that are not suitable, when a warehouse

requires a working license as a dangerous goods warehouse or even when the warehouse is in operation.

- **The Regulations** issue has been discussed at the beginning of this part together with the legislations, regulations of Turkey's dangerous goods warehousing and Transport. In light of these explanations, the following items can be summarized as suggestions on regulations
- The system created by the European Chemicals Industry Association (CEFIC) and evaluated the suppliers under the heading of SQAS and European experts according to process modules are evaluating responsible care standards. Turkey is required to train auditors and experts to make an assessment of SQAS and HSE-S standards.
- In Turkey, necessary legal arrangements should be made suitable to world standards conforming to the system of evaluation and auditing system "Responsible Care".
- The quantity of enterprises, which has got highest rated score in modules transportation, storage and washing facilities, railway transportation, logistics operations station of SQAS system; a common evaluation system for European chemical industry, must be increased across Turkey.
- Any entity that makes dangerous substance logistics should make its own statistical data system and make it necessary to share the information contained in this system with the relevant organizations and the necessary legal regulations should be made in accordance with the world standards.

Outside the criterias design and infrastructure, laws, regulations and legislations set by the legislator., all other criterias are directly and indirectly related to the Management thus human resource. The correct operation of the applications in the warehouse is carried out by the human resource, Management. Some of the subcriterias in the environment section are the same. Suggestions for correct implementation of these criterias in **Management, Human factor, Environment** can also be summarized as follows.

- The trainings to be provided to the employees have a critical precaution in terms of preventing the accidents with a predictive approach. For this reason, the continuity of the education given at each level should be taken as basis.

- It has to be ensured that all personnel are aware of the protection of health and the environment, providing necessary trainings to the relevant personnel and ensuring the continuity of these trainings. The continuous training and evaluation system needs to be integrated into the entire operation to remove the accidents, to make safe projects, and to reduce environmental impact.
- Practical activities should be carried out to increase quality and productivity in education and convert theoretical knowledge into practice.
- It is very important that all the training that will be given would be presented turning education into a popular activity by transforming them into a game in order to break down the resistance of the education.
- The elimination of problems such as injuries or illnesses that may arise from the activities of the businesses of hazardous materials logistics should be made a business policy.
- Excellent responsible care performance requires full commitment of employees at all levels. For this reason, all employees of the enterprises and suppliers should not compromise on this subject.
- In order to achieve these conditions, it is very important that the companies who will do business with the enterprises that are engaged in dangerous goods logistics should be going through the prequalification procedure and the company should work with successful companies.
- Meetings should be held regularly with companies with pre-qualification. By sharing the experiences gained at these meetings, it is necessary to evaluate the works and deficiencies. The proposed solution should be passed on in order to remove the problems
- The logistics operators should establish a quality control team for the continuity of the system.
- If the branches of the enterprises are spread throughout the country, the quality control team should periodically conduct inspections at other branches as well.
- Supervisory reports should be presented to the Management for eliminating deficiencies resulting from the control and strengthening weaknesses

- In order to increase the performance, the audits should be carried out frequently and the necessary corrective and preventive activities should be applied according to the results obtained in the audit.
- Quality control teams should be trained periodically to be effective in controls and inspections.
- The danger to the environment and human health should always be determined in advance and the necessary precautions must be taken. For example; **Materials** to be stored in the depot should be separated and placed as shown in REACH, COMAH, ADR regulations In order to reduce the risk .
- In order to prevent the reoccurrence of accidents and to improve performance, it is necessary to prepare reports on all incidents and accidents, including insecure situation, insecure behaviour and lightweight accidents.
- Economic and efficient use of natural resources and energy resources should be encouraged
- The work should be encouraged to comply with local and international laws, regulations and standards.
- It is necessary for all employees to adopt and enforce all work to ensure that it is not as urgent and important as to be done without taking the necessary safety precautions and without ensuring safe working conditions.
- ISO 9001 Quality, ISO 14001 Environment, OHSAS 18001 Occupational Health and Safety Management Systems, SQAS type requirements should be applied in accordance with our country's legal regulations.
- With the principle that work accidents and occupational diseases are preventable, the hazards has to be removed that may affect the health of employees and, if not possible, to establish, operate and develop control systems that will minimize the effects by evaluating the risks.
- Control systems should be established, operated, developed and transformed into company policy to prevent or minimize the effects of environmental pollution by identifying and evaluating the factors that may lead to pollution.

- The resulting wastes should be controlled at their source. In situations where waste generation is not avoided, this formation should be kept at a minimum and reuse of waste should be ensured by recycling.
- Non-recyclable wastes should be disposed of in accordance with the laws.
- It should be essential to reduce the impacts of the activities such as environmental and health effects carried out by the use of waste materials, emissions, and energy more effectively.
- The occurrence of possible emergencies should be avoided. It should be prepared to minimize the risks and impacts of emergencies and be informed of effective communication systems.
- During the logistics process, safe and world-class, standardized equipment must be used and control and calibration of equipments has to be made periodically.
- An effective Management System adopted at every stage of the company's organization must be applied with determination. For example, total quality management or petroleum stations: HSE-S
- It should be worked with companies that are striving to adopt similar policies.
- Health, Safety, Environment and Security issues should be supported by all kinds of cooperation in the sector.
- During the logistics process, technical safety should be applied at the highest standards
- The most important social and economic goal of logistics enterprises should be to ensure that people and the environment, , are not damaged in any way joining to systems like triple responsible care.
- The quality of the services provided at all times should be questioned and improvements should be made to the service quality.
- Evaluating the proposals of customers, employees, competitors, non-governmental organizations and government bodies will help the company to develop it s system .
- Emphasis should be placed on the co-operation of business partners, suppliers, competitors and supervisory bodies to raise industry standards.

- It is extremely important that unbiased, positive and negative aspects of performance, such as SQAS, are reported and transparency of this process is also important.
- Those who contribute to the improvement of the performance of the SQAS outside and inside the institution should be rewarded and the continuity of this process must be ensured.
- It is necessary to put measurable objectives and work with the power of the business to achieve these goals.
- Downstream communication (from the suppliers) and upward communication (from the customers to the suppliers) must be provided in the supply chain to prevent hazardous material accidents.

As a result, In the big picture, when considering applications, overall rules of law, legislations, regulations throughout Turkey, The Chemical Manufacturers Association, or the top board required to be created with a different structure, should share the statistical information relating to hazardous substances and logistics in Turkey with the relevant institutions. Performed statistical studies, will provide benefits to measure the performance of logistic service providers in Turkey and on the plans foreseen to be made in this area.

With the work done in the enterprises, the service quality of the enterprises will increase day by day and the substantial amount of money connected with accidents and accidents will also decrease. After 2006, the accident and statistical benefit ratio of environmental factors in common ECTA members is very good and it should be delivered to all logistics companies in Turkey, this has to be the most important target . Since 2000, lost time injuries of ECTA members has decreased by % 43; since 2006, chemical related transport injuries has decreased by % 36; again since 2006, greenhouse gas emissions has decreased by % 34. These positive changes, that have only taken place in the past decade, are actually a very high rate for countries, which have been carrying dangerous substances, storing them and making and improving their law constantly for almost 60 years. Normally in Turkey because we are in a much less developed environment, positive reflection of the

rate of development will be much more. This also is an opportunity for Turkey's rapid development and change

Thus, the disasters that may occur will be reduced to the minimum, and human health and the environment will be minimally affected in the negative direction.

6.2. GENERAL EVALUATION OF STUDY RESULTS

The grading of the risks of hazardous substance warehouses is guided by the AHP methodology as described in the application section. The risk rating is based on the data obtained from the questionnaire followed by selected institutional warehouses.

Expert opinions participating in the warehouse surveys have provided input for AHP methodology based on the order they have performed, taking into account the hazards they have experienced in their own warehouses.

The AHP results also contribute to the reduction of the risks due to the factors to be taken against the possible hazards that may arise in the dangerous substance warehouses which is called as Corrective preventive actions.(CPA)

In this respect, it is understood that at the beginning of the most important outputs of the thesis, is to show, which subjects are mainly responsible for the CPA activities.

As a further study, a quantitative model can be suggested. After the warehouse risks are identified and sorted, It is possible to determine the weights of the risks with a quantitative model . For example, in technical cases, such as on the operation of the systems in the warehouse infrastructure or on the operation of the equipment, a “Failure mode and effect analysis” may be performed. Or “human reliability analysis” could be made for human related parts, “Management and Human factor”.

ATTACHMENT

(Questionnaire - Risk analysis of dangerous goods in a warehouse)

Main Criterias																a.avera
How important is the warehouse infrastructure, compared to the materials stored in the Warehouse?	3	5	5	5	5	3	5	3	3	3	5	5	5	9	64	4,6
How important is the warehouse infrastructure, compared to the Management in the Warehouse?	3	5	3	3	3	5	3	3	5	3	5	5	3	7	56	4,0
How important is the warehouse infrastructure compared to employee factor in Warehouse?	5	5	5	5	5	5	5	5	5	3	5	5	5	7	70	5,0
How important is the Warehouse infrastructure compared to the warehouse environment?	7	7	5	7	5	7	7	7	7	5	7	7	7	1	86	6,1
How important is warehouse materials compared to employee factor in Warehouse?	-3	-3	-3	1	1	-3	1	-3	-3	1	-5	-3	-3	-3	-28	-2,0
How important is the Warehouse infrastructure compared to employee factor in Warehouse ?	1	1	1	1	1	1	3	1	1	5	0	1	1	0	19	1,3
How important is the storage material compared to the warehouse environment?	3	5	5	5	3	5	5	5	5	3	3	3	5	7	62	4,4
How important is warehouse management compared to employee factor in Warehouse?	5	3	3	3	5	3	3	3	7	5	5	5	3	3	56	4,0
How important is warehouse management compared to Warehouse environment ?	5	3	5	7	5	5	3	5	3	5	3	5	5	7	66	4,7

how important is the warehouse employee factor compared to the Warehouse environment?	3	5	5	3	3	3	3	3	5	3	3	3	3	7	52	3,7
Sub criteria evaluation >Warehouse infrastructure	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
How important is the fire detection-warning system compared to fire protection equipment	5	3	3	5	5	5	5	5	7	7	5	7	5	7	74	5,3
How important is the fire detection-warning system compared to the emergency exit signs / lighting?	5	5	5	5	5	5	5	5	5	5	5	5	5	5	70	5,0
How important is the fire detection-warning system compared to the fire water drainage system?	7	7	7	5	7	5	5	7	7	5	5	7	7	9	90	6,4
How important is the fire detection-warning system compared to the fire resistant wall, seperation / doors?	5	3	3	3	3	3	3	3	3	3	3	5	3	1	44	3,1
How important is the fire detection-warning system compared to the ventilation system?	3	3	3	3	3	3	5	5	3	3	3	3	3	1	44	3,1
How important is the fire detection-warning system compared to fire fighting equipment?	5	5	5	5	3	5	5	5	5	5	5	5	5	7	70	5,0
How important is the fire detection-warning system compared to ex proof electrical connections?	1	1	1	1	1	1	1	7	1	1	1	1	1	1	20	1,4
How important is the fire protection equipment compared to emergency exit signs / lighting?	5	5	5	5	3	5	5	3	5	5	5	5	5	1	62	4,4
How important is the fire protection equipment compared to the fire water drainage system?	7	7	7	7	5	5	7	5	7	7	7	7	7	5	90	6,4

How important is the fire protection equipment compared to fire resistant walls, compartments / doors?	3	5	3	3	3	7	3	1	3	3	3	3	3	1	44	3,1
How important is the fire protection equipment compared to the ventilation?	3	3	3	3	3	3	3	5	3	3	3	3	3	1	42	3,0
How important is the fire protection equipment compared to the fire fighting equipment?	3	3	5	5	5	3	5	5	5	5	7	3	5	3	62	4,4
How important is the fire protection equipment compared to ex proof electrical connections?	1	5	1	1	1	5	1	3	1	1	1	3	1	0	25	1,8
How important is the emergency exit marking / lighting compared to the fire water drainage system?	3	3	3	3	3	1	3	3	3	3	3	1	3	5	40	2,9
How important is emergency exit marking / lighting compared to a fire resistant wall, compartment / doors?	-3	-3	-3	-3	-3	-3	-3	1	-3	-3	-3	-3	-3	-3	-38	-2,7
How important is emergency exit marking / lighting compared to the ventilation system?	1	-3	-3	-3	-3	-3	-3	-5	-3	-3	-3	3	-3	-3	-34	-2,4
How important is emergency exit marking compared to fire fighting equipment?	1	1	1	1	1	1	1	1	1	1	1	1	1	3	16	1,1
How important is emergency exit marking compared to ex proof connections?	-7	-7	-7	-7	-7	-7	-7	-7	-5	-5	-7	-7	-7	-5	-92	-6,6
How important is the fire drainage systems compared to the fire resistant wall, compartment/doors?	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-70	-5,0
How important is the fire drainage systems compared to the ventilation?	-3	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-3	-5	-5	-66	-4,7
How important is fire drainage systems compared to fire fighting equipment?	-7	-3	-3	-3	-3	-3	-5	-3	-3	-3	-5	-7	-3	-3	-54	-3,9
How important is the fire drainage systems compared to ex proof electrical	1	-5	-7	-7	-5	-7	-5	-7	-7	-7	-7	1	-7	-5	-74	-5,3

connections?																
How important is the fire-resistant wall,compartment/doors compared to ventilation?	3	1	1	1	1	1	1	1	1	1	1	3	1	1	18	1,3
How important is the fire-resistant wall,compartment/doors compared to the partition, fire fighting equipment?	-3	3	3	3	3	3	3	3	3	3	3	-3	3	5	32	2,3
How important is the fire-resistant wall,compartment,doors compared to ex proof electrical connection?	3	-3	-3	1	-3	-3	-3	-3	-3	-3	-3	3	-3	-3	-26	-1,9
How important is ventilation compared to fire fighting equipment?	1	3	3	3	3	3	3	3	3	3	3	1	3	-3	32	2,3
How important is ventilation compared to ex proof electrical connection?	-3	-3	-3	-3	1	-3	-3	-3	-3	-3	-3	-3	-3	-3	-38	-2,7
How important is the fire fighting equipment compared to the ex proof electrical connection?	-3	-5	-5	-5	-3	-5	-3	-7	-5	-5	-5	1	-5	-5	-60	-4,3
Sub criteria evaluation>Material	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
How important is the stored amount of materials compared to the content of the materials?	3	3	3	3	3	3	3	3	3	3	3	3	3	-3	36	2,6
How important is the stored amount of material compared to the location of the stored materials?	3	3	3	3	3	3	3	3	3	3	3	3	3	-3	36	2,6
How important is the stored amount of materials compared to the packaging type of the materials?	5	7	7	7	7	7	5	7	5	7	7	5	7	-3	80	5,7

How important is the stored amount of materials compared to the amount of packaging material?	5	5	5	5	5	5	7	5	5	5	5	5	5	1	68	4,9
How important is the content of the stored materials compared to the location of the stored material	1	1	1	1	1	1	1	1	1	3	1	3	1	1	18	1,3
How important is the content of the stored materials compared to the packaging type of the material?	3	3	3	3	3	3	3	3	3	3	3	3	3	3	42	3,0
How important is the content of the stored materials compared to the amount of packaging?	3	3	3	3	3	3	3	3	3	3	3	5	3	3	44	3,1
How important is the placement of the stored materials compared to the packaging type of the materials?	5	5	5	5	3	5	5	5	5	5	5	5	5	5	68	4,9
How important is the placement of the stored materials compared to the packaging amount of the materials?	5	3	5	5	3	5	3	3	5	5	5	5	5	7	64	4,6
How important is the packaging type of the stored materials compared to the packaging quantity?	3	1	1	1	1	1	1	3	1	3	3	3	1	-3	20	1,4
Sub criteria evaluation>Management	1	2	3	5	5	6	7	8	9	10	11	12	13	14		
How important is safe working procedures compared to standards, quality management systems, procedures?	1	1	1	5	1	1	1	1	1	1	1	3	1	-3	16	1,1
How important is the safe working procedures compared to training, information and certification?	1	1	3	5	1	1	1	1	1	3	1	1	1	-5	16	1,1
How important is safe working procedures compared to contingency plans?	3	3	3	3	3	1	3	1	3	3	3	3	3	1	36	2,6

How important is safe working procedures compared to safe manning levels?	1	3	3	3	1	3	1	3	3	3	3	1	3	1	32	2,3
How important is the safe working procedures compared to competence, control and control?	3	3	3	3	3	3	3	3	1	3	3	3	3	-3	34	2,4
How important is safe working procedures compared to safe working equipment?	5	5	5	3	5	5	5	5	5	5	5	5	5	-3	60	4,3
How important is the standards, quality management systems and procedures compared to training, information and certification?	1	1	1	1	1	1	1	1	1	1	1	1	1	-3	10	0,7
How important are standards, quality management systems and procedures compared to contingency plans?	5	5	5	5	5	5	5	5	5	5	5	5	5	-3	62	4,4
How important is the standards, quality management systems and procedures compared to the safe manning level?	3	3	3	3	3	3	3	3	3	3	3	3	3	3	42	3,0
How important are the standards, quality management systems and procedures compared to authority, audit, control?	3	3	3	3	3	3	3	3	3	3	3	3	3	1	40	2,9
How important are standards, quality management systems and procedures compared to safe working equipments?	3	3	3	3	3	3	3	3	3	3	3	3	3	5	44	3,1
How important is training, information and certification compared to contingency plans?	3	5	5	5	3	5	5	5	5	5	5	3	5	3	62	4,4
How important is training, information and certification compared to a safe manning level?	5	5	3	3	3	3	3	3	5	5	5	3	3	7	56	4,0
How important is it to education, information and certification compared with authority, audit and control?	3	3	3	3	5	3	3	3	3	3	3	3	3	3	44	3,1

How important is training, information and certification compared to safe working equipment?	3	3	3	3	3	3	3	3	3	3	3	5	3	5	46	3,3
How important is the contingency plans compared to the safe manning level?	5	-3	1	-3	-3	-3	-3	-3	-3	-3	-3	5	-3	5	-14	-1,0
How important is the emergency plans compared to authority, audit and control?	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	1	-3	-3	-5	-40	-2,9
How important is the contingency plans compared to safe working equipment?	1	1	1	1	1	1	1	1	1	1	1	1	1	5	18	1,3
How important is the level of safe manning level compared to authority, audit and control?	1	1	3	1	3	1	1	1	1	1	3	1	1	-5	14	1,0
How important is the level of safe manning levels compared to safe working equipment?	3	3	3	3	3	3	3	3	3	3	3	3	3	-3	36	2,6
How important is authority, audit, control, compared to safe working equipment?	3	3	3	3	3	3	3	3	3	3	3	3	3	5	44	3,1
Sub criteria evaluation>Human factor	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
How important is skill compared to experience?	-3	-3	-5	-5	-5	-5	-5	-5	-5	-3	-5	-3	-5	-3	-60	-4,3
How important is the skill compared to the level of education?	-5	-5	-5	-5	-5	-5	-5	-5	-3	-5	-5	-5	-5	-5	-68	-4,9
How important is skill, compared to fatigue and extreme working conditions?	-5	-5	-5	-5	-5	-5	-5	-3	-5	-5	-3	-5	-5	-5	-66	-4,7
How important is skill compared to intentional factors?	3	3	3	3	3	1	3	3	3	1	3	3	3	3	38	2,7

How important is the experience when compared to the level of education?	3	3	3	3	1	1	5	3	3	3	3	3	3	1	38	2,7
How important is experience compared to fatigue and extreme working conditions?	1	1	1	1	1	-3	1	1	1	1	1	1	1	1	10	0,7
How important is experience when compared to intentional factors?	3	3	3	3	3	3	3	3	3	3	3	3	3	5	44	3,1
How important is the level of education compared to fatigue and extreme work conditions?	-3	-3	1	-3	-3	-3	-3	-3	-3	-3	1	-3	-3	3	-28	-2,0
How important is the level of education compared to intentional factors?	3	3	3	3	3	3	3	3	3	3	3	3	3	3	42	3,0
How important is fatigue and extreme work conditions compared to intentional factors?	5	3	3	5	5	5	5	3	5	5	3	5	5	5	62	4,4
Sub criteria evaluation>Environment	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
How important is equipment repair compared to workplace conditions?	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	5	-34	-2,4
How important is equipment repair compared to weather conditions?	5	3	3	5	3	3	5	5	3	5	5	5	5	5	60	4,3
How important is equipment repair compared to mechanical failure?	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-5	-44	-3,1
How important is the equipment repair compared to the storage location?	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	7	-32	-2,3
How important is equipment repair compared to the possibility of arson?	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	5	-34	-2,4
How important is equipment repair compared to laws, notification?	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	1	-3	-5	-40	-2,9
How important is the workplace conditions compared to the weather conditions?	5	5	5	5	5	5	5	5	5	3	-3	5	5	7	62	4,4

How important is the workplace conditions compared to mechanical failure?	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	3	-3	-3	3	-30	-2,1
How important is the workplace conditions compared to the storage location?	5	5	5	5	5	5	5	5	5	3	5	5	5	7	70	5,0
How important is the workplace conditions compared to the probability of arson?	5	5	3	3	5	3	3	3	3	3	5	5	3	7	56	4,0
How important is the workplace conditions, compared to laws, and notification?	1	3	1	-5	1	1	1	1	1	1	3	1	1	-3	8	0,6
How important is weather conditions compared to mechanical failure?	-5	1	-5	-5	-5	-5	-5	-5	-5	-5	1	-5	-5	-7	-60	-4,3
How important is the weather conditions compared to the warehouse location?	-3	-5	-3	1	-3	-3	-3	-3	-3	-3	-5	-3	-3	1	-38	-2,7
How important is weather conditions compared to the probability of arson?	1	1	1	-3	1	1	1	1	1	1	1	1	1	-5	4	0,3
How important is the weather conditions, compared to laws, notifications?	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-7	-46	-3,3
How important is mechanical failure compared to the location of the storage?	3	3	3	5	3	3	3	3	3	3	3	3	3	5	46	3,3
How important is mechanical failure compared to the probability of arson?	5	5	5	3	5	5	5	5	5	5	5	5	5	3	66	4,7
How important is mechanical failure, compared to laws, notifications?	3	3	3	3	3	3	3	3	3	3	3	3	3	1	40	2,9
How important is the warehouse location compared to the probability of arson?	3	3	3	3	3	3	3	3	3	3	3	3	3	-5	34	2,4
How important is the warehouse location compared to laws, notification?	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-5	-44	-3,1
How important is the arson probability compared to the laws, notifications?	-5	-5	-5	-5	-5	-3	-5	-5	-5	-3	-5	-5	-5	5	-56	-4,0

REFERENCES

- 1) E. Erkut.,V. Verter(1998) “*Modeling of transport risk for hazardous materials*” McGill University, Montreal, Quebec, Canada University of Alberta, Edmonton, Alberta, Canada
- 2) R.Bubbicoa., G.Maschio., B.Mazzarotta., M. F. Milazzo., E.p Messina,(2006) “*Risk management of road and rail transport of hazardous materials in Sicily*”
- 3) B.Y. Kara., V.Verter (2004) “*Designing a Road Network for Hazardous Materials Transportation*” Department of Industrial Engineering, Bilkent University, 06533, Bilkent, Ankara, Turkey, bkara@bilkent.edu.tr Faculty of Management, McGill University, 1001 Sherbrooke Street West, Montreal, Quebec, Canada
- 4) R Bubbico., S. D Cave, B. Mazzarotta(2004) “*Risk analysis for road and rail transport of hazardous materials: a GIS approach*” Dipartimento di Ingegneria Chimica, Universita ` di Roma “La Sapienza”, Via Eudossiana 18, 00184 Rome, Italy
- 5) B.Y.Kara,E.Erkut;V.Verter (2002) “*Accurate calculation of hazardous materials transport risks*” Department of Industrial Engineering, Bilkent University, Bilkent, Ankara 06533, Turkey bSchool of Business, University of Alberta, Edmonton, Alberta, Canada T6G 2R6 cFaculty of Management, McGill University, Montreal, Quebec, Canada H3A 1G5 31 August 2002
- 6) C. Barnhart and G. Laporte (Eds.)(2006), Erhan Erkut Stevanus A. Tjandra Vedat Verter “*Hazardous materials transportation*” Handbook in OR & MS, Vol. 14 Chapter 9 –2006
- 7) M.Verma., V.Verter,(2005) “*Railroad transportation of dangerous goods*”: Population exposure to airborne toxins Faculty of Business Administration, Memorial University, St. John’s, NL, Canada A1B 3X5 bFaculty of Management, McGill University, Montreal, Que., Canada H3A 1G5 25 July 2005
- 9) O.Berman., V.Verter., B.Y. Kara Joseph L.(2007) “ *Designing emergency response networks for hazardous materials transportation*” Rotman School of Management, University of Toronto, Canada bFaculty of Management, McGill University, Montreal, Que., Canada H3A 1G5 cDepartment of Industrial Engineering, Bilkent University, Turkey
- 10) V. Verter., B. Y. Kara(2005) “*A Path-Based Approach for Hazmat Transport Network Design*” Desautels Faculty of Management, McGill University, Montreal, Quebec H3A 1G5, Canada, vedat.verter@mcgill.ca Department of Industrial Engineering, Bilkent University, 06800 Bilkent, Ankara, Turkey, December 15,2005

- 11) P. Marcotte., A. Mercier ., G Savard, V. Verter. (2009) "*Toll Policies for Mitigating Hazardous Materials Transport Risk*" "Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT), Université de Montréal, . École Polytechnique de Montréal, Université de Montréal, Faculty of Management, McGill University, 1001 Sherbrooke St. West, Montréal, Canada H3A 1G5
- 12) V.Verter., M.,Verma (2010) "*A Lead-Time based Approach for Planning Rail-Truck Intermodal Transportation of Dangerous Goods*" Desautels Faculty of Management, McGill University, Montreal, PQ, Canada Faculty of Business Administration, Memorial University, St. John's, NL, Canada.
- 13) M. Bagheri., M. Verma., V.Verter. (2013) "*Transport Mode Selection for Toxic Gases: Rail or Road?*"
- 14) M.Verma.,V. Verter(2013) "*Railroad Transportation of Hazardous Materials: Models for Risk Assessment and Management*"
- 15-)M. Mansson., A. Lönnermark., P. Blomquist., V. Barbauskas(1996) "*Assessment of Fires in Chemical Warehouses An overview of the TOXFIRE Project.*"CEC Environment project "TOXFIRE. Guidelines for Management of Fires in Chemical Warehouses". in the period 1994 - 1996 in a multi-national co-operation between partners from United Kingdom, Sweden, Finland and Denmark.
- 16) L.Smith.,H. Rise. ,(1994) "*Pesticide warehouse fire consequences: experiences from a Danish risk analysis study*" National Laboratory, Risk Analysis Group.
- 17) M. Francesca., R..Lisi., G. Maschino.,G..Antonini.,G. Spadoni;(2010) "*A study of Land transport of dangerous substances in Eastern sicily*"
- 18) P. Han.,H.Rosas.,J.Pineda.,Mannan; (2014) "*Lessons to be learned from an analysis of Ammonium nitrate disasters in the last 100 years*"
- 19) M.D. Christou; (1999) "*Analysis and control of major accidents from the intermediate temporary storage of dangerous substances in marshalling yards and port areas*" European Commission, DG JRC, 1-21020 Ispra (Va), Italy
- 20) C.T. Kiranoudisa,*, S.P. Kourniotisa, M. Christolisa, N.C. Markatosa, K.G. Zografosb, I.M. Giannoulisb, K.N. Androutsopoulosb, I. Ziomas, E. Kosmidisc, P. Simeonidisc, N. Poupkouc; (2001)"*Case study An operational centre for managing major chemical industrial accidents*" a Department of Chemical Engineering, National Technical University of Athens, Greece c Department of Physics, Aristotle University of Thessaloniki, GR 54006, Thessaloniki, Greece 2 July 2001
- 21)) R. Bubbico; M.Marchini;(2008) "*Assessment of an explosive LPG release accident --a case study*" Departmenta di Ingegneria Chimica,Universita di Roma Italy

- 22) B. Fabiano*, F. Currò, E. Palazzi, R. Pastorino; **(2002)** *"A framework for risk assessment and decision-making strategies in dangerous good transportation"* Chemical and Process Engineering Department (DICheP) G.B. Bonino, University of Genoa, Via Opera Pia 15, 16145 Genoa, Italy 2002
- 23) Z. N. Pintaric; (2007) *"Assessment of the consequences of accident scenarios involving dangerous substances"* University of Maribor, Faculty of Chemistry and Chemical Engineering, Maribor, Slovenia. 2007
- 24) K. Bichou;(2008) *"Security and risk based Models in Shipping and Ports"* International Transport Forum, OECD Review and Critical Analysis .
- 25) H.Hill, Buxton; (1999) *"International co-operation in hazardous materials accident prevention"* International Group of Experts on the Explosion Risks of Unstable Substances Health and Safety Laboratory, Derbyshire, SK17 9JN, UK Bruce J. Thomson 1999
- 26) P.Haastруп., H. Romer;(1995) *"An analysis of the database coverage of industrial accidents involving hazardous materials in Europe"* European Commission, Joint Research Centre Ispra, 21020 Ispra, Italy.
- 27) R.Olivares,S.Rivera,E.Nunez,McLeod;(2015) *"Database for accidents and incidents in the fuel ethanol industry"* Cediac Institute, Engineering Faculty National Uni of Cuyo Mendoza, Argentina 2015
- 28) R.M.Darbra, J.Casal; (2003) *"Historical analysis of accidents in seaports"* Department of Chemical Engineering University of Catalonia Spain. 2003
- 29) C.R.Pearson;(1985) *"Assessment of risk of significant environmental contamination from storage and distribution sites"*
- 30) J.Vilchez,V.Espejo,J.Casal;(2011) *"Generic event trees and probabilities for the release of different types of hazardous materials"* Center for studies on technological risk(CERTEC)Department of chemical Engineering Barcelona, Spain 2011
- 31) F. Rigas, S. Sklavounos;(2004) *"Major hazard analysis for populations adjacent to chemical storage facilities"* National Technical University of Athens, School of Chemical Engineering, Athens, Greece 2004
- 32) P. G. Rao and K. V. Raghavan; (1995) *"Hazard and risk potential of chemical handling at ports"* Cell for Industrial Safety and Risk Analysis (CISRA), Central Leather Research Institute, Adyar, Madras - 600 020, India 12 September .
- 33) J. A. Viichez., S. SeviUa., H. Montielt., J. Casalt; (1994) *"Historical analysis of accidents in chemical plants and in the transportation of hazardous materials"* Barcelona, Catalonia, Spain, December

- 34) A.Labodova; (2003) *"Implementing integrated management systems using a risk analysis based approach"* Czech Republic, August
- 35) W.Pittman, Z.Han,B.Harding, C.Rosas,J.Jiang,A.Pineda,M.Mannan Mary;(2014) *"Lessons To Be Learned From an Analysis of Ammonium Nitrate Disasters in The Last 100 Years"* Kay O'Connor Process Safety Center,Artie McFerrin Department of Chemical Engineering Texas AGM University system,College Station United States.
- 36) F.Khan, S.Abbasi;(1999) *"Major Accidents In Process Industries and An Analysis of Causes and Consequences"* Pondicherry University India.
- 37) G.Walker, J.Mooney, D. Pratts;(1999) *"The people and the hazard: the spatial context of major accident hazard management in Britain"* Sustainability, Environment and Risk Research Group, Division of Geography, Staffordshire University, College Road, Stoke on Trent ST4 2DE, UK 13
- 38) J. Wettig ., S.Porter ., C. Kirchsteiger;(1998) *"Major industrial accidents regulation in the European Union"* A European Commission, DG XI, 1160, Brussels, Belgium b European Commission, DG JRC, 21020, Ispra (Va), Italy
- 39) O.Heran-L.Roy., I.Niedhammer., N.Sandret., A.Leclerc; (1998) *"Manual materials handling and related occupational hazards: a national survey in France"* Paris, France .
- 40) P. Leonelli, S. Bonvicini, G. Spadoni;(1999) *"New Detailed Numerical Procedures For Calculating Risk Measures In Hazardous Materials Transportation"* Department of Chemical, Mining Engineering and Environmental Technologies, University of Bologna, Viale del Risorgimento 2, I-40136 Bologna, Italy .
- 41) Ronza, S. Fe ´lez, R.M. Darbra, S. Carol, J.A. Vilchez, J. Casal; (2003) *"Predicting The Frequency of Accidents in Port Areas By Developing Event Trees From Historical Analysis"* Centre d'Estudis del Risc Tecnolò gic (CERTEC), Department of Chemical Engineering, E.T.S.E.I.B., Universitat Politècnica de Catalunya– Institut d'Estudis Catalans, Diagonal 647, 08028 Barcelona, Catalonia, Spain
- 42) M.Verma,V.Verter;(2005) *"Railroad Transportation of Dangerous Goods: Population Exposure to Airborne Toxins"* Faculty of Business Administration, Memorial University, St. John's, NL, Canada A1B 3X5 Faculty of Management, McGill University, Montreal, Que., Canada .
- 43) N.P Høj, W.Kroger;(2001) *"Risk analyses of transportation on road and railway from a European Perspective"* Laboratory for Safety Analysis, ETH Zurich, Weinbergstrasse 11, 8001 Zurich, Switzerland
- 44) N. Batarlienė; (2008) *'Risk Analysis and Assessment for Transportation of Dangerous Freight'* Dept of Transport Management, Vilnius Gediminas Technical University, Plytinės g. 27, LT-10105 Vilnius, Lithuania;

- 45) M.G.C.Campos,H.O.C.Campos;(2015) ‘*Security Risk Level Classification of Stock Keeping Units in A Warehouse*’ Mexican Institute of Transportation Transportation and Logistics systems National Laboratory Sanfandila Queretaro Mexico.
- 46) G.Rechkoskaa, R.Rechkoskia, M. Georgioskaa;(2011) “*Transport of dangerous substances in the Republic of Macedonia*” St.Kliment Ohridski University - Bitola, Faculty of Tourism and Hospitality - Ohrid, Kej Mars47)hal Tito 95, Ohrid, 6000, Macedonia
- 47) N P. Button;(1999) “*Uncertainty in Incident Rates For Trucks Carrying Dangerous Goods*” Park M. Reilly Department of Ci6il Engineering, University of Waterloo, Waterloo, Ont., Canada N 2 L Department of Chemical Engineering, University of Waterloo, Waterloo, Ont., Canada N 2 L R 7 December.
- 48) A.Ronza, A.Vilchez, J.Casal;(2006) “*Using Transportation Accident Databases To Investigate Ignition and Explosion Probabilities of Flammable Spills*” Department of Chemical Engineering Barcelona Catalonia, Spain .
- 49) J. A. Vilchez, S. Sevilla, H. M. J. Casal;(1993) “*Historical Analysis Of Accidents in Chemical Plants And in The Transportation of Hazardous Materials*”
- 50) P.H.H. Rømer;(1992) “*An analysis of the database coverage of industrial accidents involving hazardous materials in Europe*”.
- 51) A.Oggero., R.M. Darbra., M. Muñoz., E. Planas., J. Casal;(2004) “*A Survey of Accidents Occurring During The Transport Of Hazardous Substances By Road and Rail*”.
- 52) E. Planas.,Cuchi., H. Montiel.,J. Casal;(1993) “*A Survey of the Origin, Type and Consequences of Fire Accidents in Process Plants and in the Transportation of Hazardous Materials*”
- 53) S.Roed.,Larsenal.,T Valvistob.,L Harms.,Ringdahlc.,C Kirchsteigerd.,(2001) “*Accident investigation practices in Europe—main responses from a recent study of accidents in industry and transport*”
- 54) H. Rømer., P. Haastrup., H.J. Styhr Petersen., (1995)”*Accidents During Marine Transport Of Dangerous Goods Distribution of Fatalities*”
- 55) P. Haastrup, L. Brockhoff;(1988) “*Severity of accidents with hazardous materials: A comparison between transportation and fixed installations*”
- 56) B. Fabiano’ , F. Currò,A.P. Reverberi,R. Pastorino; (2002) “*Dangerous Good Transportation By Road: From Risk Analysis To Emergency Planning*”
- 57)-. L.B. Shappert, W.A. Brobst, J.W. Langhaar, J.A. Sisler;(1973) “*Probability And Consequences of Transportation Accidents Involving Radioactive - Material Shipments in The Nuclear Fuel Cycle*”, Nuclear Safety 14(6), 597-604. 1,

- 58-) R. Scanlon, E. Cantilli; (1985) "*Assessing The Risk And Safety in The Transportation Of Hazardous Materials*" TRB, National Research Council Washington, D.C. Transportation Research Record 1020, 06-11.
- 59-) V. Akgün, A. Parekh, R. Batta, C. Rump; (2007) "*Routing of a Hazmat Truck in The Presence Of Weather Systems*". Computers & Operations Research 34, 1351-1373 .
- 60-)S. Alumur, B. Kara;(2007) "*A New Model For The Hazardous Waste Location-Routing Problem*" Computers & Operations Research 34, 1406-1423.
- 61-)O. Berman, V. Verter, B. Kara (2007).; "*Designing Emergency Response Networks For Hazardous Materials Transportation*". Computers & Operations Research 34, 1374-1388.
- 62-)P. Carotenuto, S. Giordani, S. Ricciarelli; (2007) "*Finding Minimum And Equitable Risk Routes For Hazmat Shipments*", Computers & Operations Research 34, 304-1327.
- 63-)E. Erkut, O. Alp;(b)(2007) "*Designing A Road Network For Dangerous Goods Shipments*", Computers & Operations Research 34, 1389-1405.
- 64-)E. Erkut, O. Alp;(a) (2007) "*Integrated Routing And Scheduling Of Hazmat Trucks With Stops En-Route*" Transportation Science 41(1), 107-122.
- 65-)E. Erkut, S. Tjandra, V. Verter; (2007) "*Hazardous materials transportation: In C. Barnhart and G. Laporte (Eds.) Transportation*" Handbook in OR & MS Vol. 14, Elsevier, 539-621.
- 66-)E. Floros, A. Ziliaskopoulos, E. Chang;(2006) "*Intermodal Hazmat Transportation Problem With Timedependent Travel Risk*" TRB 2006 Annual Meeting.
- 67-)B. Huang, P. Fery,. (2005) "*Aiding route decision for hazardous material transportation*". TRB 2005 Annual Meeting.
- 68-)Q. Meng, D. Lee, R. Cheu,(2005) "*Multiobjective vehicle routing and scheduling problem with time window constraints in hazardous material transportation.*" Journal Of Transportation Engineering 131(9), 699-707.
- 69-)K. Zografos, K. Androutsopoulos, (2004) "*A heuristic algorithm for solving hazardous materials distribution problems*". European Journal of Operational Research, 152(2), 507-
- 70-)G. Atkinson,(2000) "*Measuring Corporate Sustainability*", Journal of Environmental Planning and Management, Vol. 43, pp. 235-252.
- 71-)M.Marsh, D. Schilling,. (1994) "*Equity measures in facility location analysis: a review and framework*". European Journal of Operations Research 74(1), 1-17.

- 72-)J. Current, S. Ratick,.(1995) “*A model to assess risk, equity, and efficiency in facility location and transportation of hazardous materials*”. Location Science 3, 187-202 .
- 73-)W. Vesely, E. Goldberg, N. Roberts, D. Haasl,(1981) “ *Fault tree handbook*”, U.S. Nuclear Regulatory Commission. NUREG-0492.
- 74-)S. Chin, P. Cheng,.(1989) “*Bi-criterion routing scheme for nuclear spent fuel transportation*”. Transportation Research Record 1245, 60-64 .
- 75-)T. Chow, R.M. Oliver, G.A. Vignaux,.(1990) “*A Bayesian escalation model to predict nuclear accidents and risk.*” Operations Research 38(2), 265-277
- 76-)T. Glickman, D. Golding,.(1991) “ *For a few dollars more: Public trust and the case for transporting nuclear waste in dedicated trains*”. Policy Studies Review 10 4, 127-138.
- 77-)S. Miaou, S. Chin, (1991) “*Computing k-shortest path for nuclear spent fuel highway transportation*” European Journal of Operational Research 53(1), 64-80.
- 78-)G.M.Sandquist, J.S. Bennion, J.E. Moore, D.M. Slaughter,(1993) “*A route-specific transportation risk assessment model*”. Transactions of the American Nuclear Society (ANS) annual meeting 20-24 San Diego, United States CA .
- 79-)J. Ferrada, R. Michelhaugh;(1994) “*Development Of An Expert System For Transportation Of Hazardous And Radioactive Materials*” International Topical Meeting on Nuclear and Hazardous Waste Management, Spectrum '94, American Nuclear Society, American Nuclear Society, Atlanta 1994
- 80-)J. Moore, G. Sandquist, D. Slaughter, (1995) “*A route-specific System for Risk Assessment of Radioactive Materials Transportation Accidents*” Nuclear Technology.
- 81-)H. Neill, R. Neill;(2000) “*Transportation Of Transuranic Nuclear Waste To Wipp: A Reconsideration Of Truck Versus Rail For Two Sites*” Natural Resources Journal 40(1), 93-124.
- 82-)K.G. Zografos, G.M. Vasilakis, I.M. Giannouli;(2000) “*A Methodological Framework For Developing A Decision Support Systems (DSS) For Hazardous Material Emergency Response Operations*” Journal of Hazardous Materials 71(1-3), 503-521.
- 84-)U.D. (2004) “*List Of Hazardous Materials*” The Office of Hazardous Materials Safety, U.S. Department of Transportation, Washington, DC.
- 85-) A. Gheorghe, M. Nicolet-Monnier(1995)” *Integrated regional risk assessment-volume1: continuous and non-point source emissions*”: Air, water, soil..

- 86-) A. Gheorghe, M. Nicolet-Monnier,(1995) “*Integrated Regional Risk Assessment-Volume2: Consequence Assessment Of Accidental Releases*”.
- 87-)A. Lavell, (2000) “*An approach to concept and definition in risk management terminology and practice*”. Latin American Social Science Faculty (FLACSO) and the Network for the Social Study of Disaster Prevention in Latin America, LA RED.
- 88-) N.A. Pons, O.J. Pejon, L.V. Zuquette;(2007) “ *Use of geoprocessing in the study of land degradation in urban environments: the case of the city of São Carlos, state of São Paulo, Brazil*”. *Environmental Geology*, 53(4), 727-739. .
- 89-)C.M. Lewis, K.C. Murdock; (1999) “*Alternative Means of Redistributing Catastrophic Risk in a National Risk-Management System. The Financing of Catastrophe Risk*”, edited by K.A. Froot, 51-85. Chicago: National Bureau of Economic Research.
- 90-)E. Alp, M. Zelensky; (1996) “*Risk quantification for meteorology-and direction-dependent hazards due to point and linear risk sources*” *Journal of Loss Prevention in the Process Industries* 9(2), 135-145.
- 91-)S.L. Ellinas, (1999) “*Risk Assessment-An Insurer's Perspective*”, *Journal of Hazardous Materials*, 65(1-2), 123-130.
- 92-)R. Gregory, S. Lichtenstein,(1994) “ *A hint of risk-tradeoffs between quantitative and qualitative riskfactors. Risk Analysis*” 14(2), 199-206. G. Centrone et al. / *Hazardous Materials Transportation* 55
- 93-)] S. Kaplan, J. Garrick(1991) “*On The Quantitative Definition Of Risk*”, *Risk Analysis* 1(1), 11-27.
- 94-)B. Bottelberghs,(2000) “*Risk Analysis And Safety Policy Developments In The Netherlands. Journal Of Hazardous Materials*” 71(1), 59-84.
- 95-) D. Harwood, E. Russell, J. Viner,(1989) “*Characteristics Of Accidents And Incidents In Highway Transportation Of Hazardous Materials*” *Transportation Research Record* 1245, 23-33.
- 96-)R. Batta, S. Chiu;(1988) “*Optimal Obnoxious Paths On A Network: Transportation Of Hazardous Materials*”, *Operations Research* 36(1), 84-92..
- 97-)] G. Beroggi, W. Wallace;(1991) “*Closing The Gap-Transit Control For Hazardous Material Flow*”. *Journal of Hazardous Materials* 27(1), 61-75.
- 98-)C. Barkan, T. Treichel, G. Widell,(2000) “*Reducing Hazardous Materials Releases From Railroad Tank Car Safety Vents*”, *Transportation Research*, 27-34. .
- 99-)A. Ang, J. Briscoe, (1989) “*Development Of A Systems Risk Methodology For Single And Multimodal Transportation Systems*”. Final Report, Office of University Research, US DOT, Washington, DC.

- 100-)E. Erkut, V. Verter,(1998) “*Modeling of transport risk for hazardous materials. Operations Research*” 46(5), 625-642.
- 101-)J. Mumpower,(1986) “ *An analysis of the de minimis strategy for risk management*”. Risk Analysis 6, 437-446.
- 102-)P. Leonelli, S. Bonvicini, G. Spadoni, (1999) “ *New detailed numerical procedures for calculating risk measures in hazardous materials transportation*”. Journal of Loss Prevention in the Process Industries 12(6), 507-515.
- 103-)P. Leonelli, S. Bonvicini, G. Spadoni, (2000) “*Hazardous materials transportation: a risk analysis-based routing methodology*”. Journal of Hazardous Materials 71(1), 283-300.
- 104-)F. Saccomanno, J. Shortreed, (1993) “*Hazmat transport risks-societal and individual perspectives*”. Journal of Transportation Engineering-ASCE 119(2), 177-188. 75.1993.
- 105-)J.K. Vrijling, W. van Hengel, R.J. Houben,(1995) “*A framework for risk evaluation*”. Journal of Hazardous Materials. 43(3), 245-261.
- 106-)S. Jonkman, P. van Gelder, J. Vrijling,(2003) “*An overview of quantitative risk measures for loss of life and economic damage*”. Journal of Hazardous Materials 99(1), 1-30.
- 107-)CCPS Center for Chemical Process Safety,(1995)” *Guidelines for chemical transportation risk analysis*”. New York: American Institute of Chemical Engineers.
- 108-)G. List, P. Mirchandani,(1991). “*An integrated network planar multiobjective model for routing and siting for hazardous materials and wastes*”. Transportation Science 25(2), 146-156.
- 109-)M. Abkowitz,(2002) “*Transportation risk management: a new paradigm. Security Papers*”, Southeastern Transportation Center, University of Tennessee, 93-103.
- 110-)TRB, (2002) “*Deterrence, protection, and preparation: the new transportation security imperative*”. Transportation Research Board, Special Report 270..
- 111-)M. Glaze, (2003) “*New security requirements for hazmat transportation*” Occupational Health & Safety 72(9), 182-185.
- 112-)E. Erkut, T. Glickman,(1997) “*Minimax population exposure in routing highway shipments of hazardous materials*”. Transportation Research Record 1602, 93-100.
- 113-)E. Erkut, A. Ingolfsson,(2000) “ *Catastrophe avoidance models for hazardous materials route planning*”. Transportation Science 34(2), 165-179.
- 114-)E. Paté-Cornell,(2002) “ Probabilistic modeling of terrorist threats: A system analysis approach to setting priorities among counter-measures”. Military Operations Research 7(4), 5-23.

- 115-)B. Huang, C. Long, Y. Liew,(2003) “ *GIS-AHP Model for hazmat routing with security considerations*”. IEEE 6th Int'l Conf on ITS. 86.2003.
- 116-)K. Zografos, K. Androutsopoulos,(2001) “ *Assessing impacts from introduction of advanced transport telematics technologies in hazardous materials fleet management*”. Proceedings of the 80th Annual meeting of Transportation Research Board, Washington DC.
- 117-)CCPS Center for Chemical Process Safety, (2000). “*Guidelines for chemical process quantitative risk analysis*”. New York: American Institute of Chemical Engineers.
- 118-)W. Burns, R. Clemen,(1993) “*Covariance structure models and influence diagrams*”. Management Science 39(7), 816-834.
- 119-)D. Harwood, E. Russell, J. Viner,(1993).” *Procedure for developing truck accident and release rates for hazmat routing.*” Journal of Transportation Engineering - ASCE 119(2), 189-199.
- 120-)S. Bonvicini, P. Leonelli, G. Spadoni,(1998) “ *Risk analysis of hazardous materials transportation: evaluating uncertainty by means of fuzzy logic*”. Journal of Hazardous Materials 62(1), 59-74.
- 121-)M. Abkowitz, P. Cheng, (1988) “*Developing a risk cost framework for routing truck movements of hazardous materials*”. Accident Analysis & Prevention 20(11), 38-51.
- 122-)N. Vayiokas, M. Pitsiava-Latinopoulou, (2004) “*Developing a framework for assessing risks involved in the transportation of dangerous goods.*” 11th International Symposium: Loss Prevention and Safety Promotion in the Process Industries, Praha, Czech Republic, 4495-4503.
- 123-) B. Kara, V. Verter,(2003). “*Accurate calculations of hazardous materials transport risks*”. Operations Research Letters 31(4), 285-292. 94.2003
- 124-)J. Karkazis, T. Boffey,(1995).” *Optimal location of routes for vehicles transporting hazardous materials*”. European Journal of Operational Research 86(2), 201-215.
- 125-)H. Bohnenblust, P. Slovic,(1998) “ *Integrating technical analysis and public values in risk-based decision making.*” Reliability Engineering & System Safety 59(1), 151-159.
- 126-)G. Purdy,. (1993) “*Risk analysis of the transportation of dangerous goods by road and rail.*” Journal of Hazardous Materials, 33(2), 229-259.
- 127-)C. Revelle, J. Cohon, D. Shobrys,(1991) “ *Simultaneous siting and routing in the disposal of hazardous wastes*”. Transportation Science 25(2), 138-145
- 128-)P. Blaikie, T. Cannon, I. Davis,(1994) “*At risk: natural hazards, people's vulnerability, and disasters*”. London, Routledge. 99. 1994

- 129-)W. Frank, J. Thill, R. Batta,.(2000) “ *Spatial decision support system for hazardous material truck routing*”. Transportation Research Part C - Emerging Technologies 8(1-6), 337-359.
- 130-)T. Chang, L. Nozick, M. Turnquist,.(2005) “*Multi-objective path finding in stochastic dynamic networks, with application to routing hazardous materials shipments*”. Transportation Science 39(3), 383-399.
- 131-)J. Diaz-Banez, F. Gomez, G. Toussaint, (2005) “*Computing shortest paths for transportation of hazardous materials in continuous spaces*”. Journal Of Food Engineering 70(3), 293-298.
- 132-)A. Boulmakoul,(2006) “ *Fuzzy graphs modelling for hazmat telegeomonitoring.*” European Journal of Operational Research 175(3), 1514-1525.
- 133-)M. Dell'Orco,(2006) “ *A dynamic network loading model for meso-simulation in transportation systems*”. European Journal of Operational Research 175(3), 1447-1454.
- 134)O. Berman, Z. Drezner, G. Wesolowsky, (2000). “*Routing and location on a network with hazardous threats.*” Journal of the Operational Research Society 51(9), 1093-1099.
- 134-)E. Erkut, V. Verter,. (1995a)”*Framework for hazardous materials transport risk assessment*”. “*Risk Analysis*”15(5), 589-601.
- 135-)M. Abkowitz, J. DeLorenzo, R. Duych, A. Greenberg, T. McSweeney,(2001) “ *Assessing the economic effect of incidents involving truck transport of hazardous materials*”. Transportation Research Record 1763, 125-129.
- 136-)K Zografos,S.Samara,(1989).” *A combined location-routing model for hazardous waste transportation*”
- 137)Bernardo Delagu.(2016) “*Risk analysis and Governance in EU policy making and Regulation*”
- 138) J.R. Thomson (2015).”*High Integrity Systems and Safety Management in Hazardous Industries*”. Springer.
- 139) Joshua Dinaburg; Daniel T. Gottuk.(2012)” *Fire Detection in warehouse facilities*”. Springer.
- 140) C.Bersani;, A.Boulmakul., E. Gorbolino., R. Sacile. (2008) “*Advanced Technologies and methodologies for Risk Management in the Global transport of dangerous goods*”.
- 141) C.J.Van Leeuwen and T.G.Vermeire. (2007) “*Risk assessment of Chemical*”s by Springer.
- 142) B. Martel (2004) “*Chemical Risk analysis. A practical handbook* “. Butterworth-Heinemann.
- 143) N.Monnier and A.V.Gheorge.(1996)”*Quantitative risk assessment of Hazardous Materials Transport systems*”. edited by Kluwer Academic publishers. Springer

- 144) Rhyne WR, Van Norstrand Reinhold.(1994) “ *Hazardous materials transportation risk analysis*”
- 145) Saccomanno, D.Leming and A.Steward.(1993) “*Comparative assessment of Risk model estimates for the Transport of hazardous materials by road and rail*”.
- 146) L.N. Moses and D.Lindstrom (1993)” *Transportation of hazardous materials*”; Kluwer Academic Publishers. Springer.
- 147) F.Saccomanno and K.Cassidy. (1993) “*Transportation of hazardous materials. Risk assessment*”.
- 148) P.Leonelli; S.Bonvicini; G.Spadoni;(2004) “*Quantitative transport risk analysis on a regional scale: an application of TRAT-GIS to East-Sicily*”
- 149) Zografos,K.G.Androutsopoulos. (2008) “*Algorithms for Itinerary Planning in Multimodal Transportation Networks*”. IEEE Transactions on Intelligent Transportation Systems,
- 150) J Zhang, J Hodgson, E Erkut.(2000) “*Using GIS to assess the risks of hazardous materials transport in networks*”. European Journal of Operational Research, 121
- 151) V.M.Rayas; M.A.Serrate (2017).”*A framework of the risk assessment for the supply chain of hazardous materials*” .
- 152) D. Brown, W. Dunn.(2007) “*Application of a quantitative risk assessment method to emergency response planning*”.
- 153)X.Shen,Y.Yan,X.Li,C.Xie,L.Wang (2013).”*Analysis on tank truck accidents involved in road hazardous materials Transportation in China*”
- 154) Yang J, Li F, Zhou J, Zhang L, Huang L, Bi J(2010).”*A survey on hazardous materials accidents during road transport in China from 2000 to 2008.*”;
- 155) Ellis, J. (2011) “*Analysis of accidents and incidents occurring during transport of packaged dangerous goods by sea*”. Safety Science.
- 156) L.Zhao,X.Wang,Y.Qian (2012) “*Analysis of factors that influence hazardous material transportation accidents based on Bayesian networks: A case study in China*”
- 157) A. Boulmakoul. (2006) “*Fuzzy graphs modelling for hazmat telegeomonitoring*”
- 158) Y.Kang, R.Batta, C.Kwon .(2014)”*Generalized route planning model for hazardous material transportation with VaR and equity considerations*”.

- 159) F.Samanlioğlu. (2013) "*A multi-objective mathematical model for the industrial hazardous waste location-routing problem*".
- 160) A. R. Anderson, MPH Jennifer Wu, MS.(2015) "*Top Five Industries Resulting in Injuries from Acute Chemical Incidents.*"
- 161) Z. Török, A. Ozunu (2010) "*Chemical risk assessment for storage of hazardous materials in the context of Land Use Planning*"
- 162)K.W.Lee (2001)."*A methodology for assessing risk from released hydrocarbon in an enclosed area.*"
- 163) M.U Kim. S, Shin . S.H Byeon.(2015) "*Comparison of chemical risk assessment methods in South Korea and the United Kingdom.*"
- 164)O. Gaci., H. Mathieu. (2011)"*Simulation of a Segregation Strategy in a Warehouse of Dangerous Goods by a MultiAgent System.*"
- 165) O.Gaci ., H.Mathieu (2011) "*Deployment of Communicating Objects for A Dynamic Risk Management in Warehouses of Dangerous Goods.*"
- 166) X, Liu, X., Wang, (2015) "*Fire risk forecast and early warning technology for large oil and gas storage & transport tank areas*".
- 167) W,H Ju.,(2016) "*Study on Fire Risk and Disaster Reducing Factors of Cotton Logistics Warehouse Based on Event and Fault Tree Analysis*"
- 168) H.Y. Wang., P. Russo., P, Joulain., A, Carrau (2014) "*Risk assessment of a fire involving combustible materials in a warehouse*"
- 169) F. Markert.,(1998) "*Assessment and mitigation of the consequences of fires in chemical warehouses*".
- 170) K, P. Moder., J, P. Russo, F, Justiniano., W, F. Marshall., T, H, Mcghee., R, Stankovich., W,L, Frank., (2007)"*Development of a Hazardous Material Compatibility Storage Guideline and Tool.*"
- 171) P, Baybutt.,(2013) "*The Use of Risk Matrices and Risk Graphs for SIL (Safety Integrity level)Determination.*"
- 172)A, Tyldesley., P, J, REW .,R. C, Houlding., (2004)"*Benefits of fire compartmentation in chemical warehouses.*"
- 173) P. Kinsman., T,E, Maddison., (2001)"*Hazard Assessment for fires in agrochemical warehouses. The Role of Combustion Products*"
- 174) A,Menrad., T, Goedecke, K.P, Gruender., M, H. Wagner. (2012) "*Influence of the Wall Thickness Variation and the Change of the Packaging Behavior after the Impact of Standard Liquids*"
- 175) R.Vrabel., M.Abas, P.Tanuska, P.Vazan, M. Kebisek., M. Elias, Z. Sutova, and D. Pavliak. (2015)
"*Mathematical Approach to Security Risk Assessment*"

- 176) S.Golob.,M.Kozuh., (2016)"Methodology or determining the risk acceptance criteria for the Seveso establishments."
- 177) H.Zhang. Duan H, Zuo J, Song M, Zhang Y, Yang B, Niu Y, (2017)"Characterization of post disaster environmental management for hazardous materials incidents"
- 178)X.Segui.,D.Roman,R.Maria,V.Sanchez,J.Antonio,A.Viger" (2014) "Methodology for the quantification of toxic dispersions originated in warehouse fires and its application to the QRA in Catalonia(Spain)" .
- 179) X,Liu., J,Li., X,Li., (2017)"Study of dynamic risk management system for flammable and explosive dangerous chemicals storage area."
- 180) A.Labib. (2015) "Learning and (un)learning from failures: 30 years on from Bhopal to Fukushima an analysis through reliability engineering techniques."
- 181) H,Si.,H,Ji.,X,Zeng., (2012) "Quantitative risk assessment model of hazardous chemicals leakage and application"
- 182) E.Palazzi et all., (2014) "Development of a theoretical framework for the evaluation of risk connected to accidental oxygen releases."
- 183) Rosa.M,Darbra et all., (2012)"Risk analysis active learning through the investigation of real cases"
- 184)Ball, D.J. and Floyd, P.J., (1998), "Societal risks"
- 186) Lee T. Ostrom, Cheryl A. Wilhelmsen (2012). "Risk Assessment: Tools, Techniques, and Their Applications". John Wiley & Sons, Inc.
- 187) Bruce J.Thompson,(1999)"International co-operation in hazardous materials accident prevention"
- 188) (UNECE (2011a), <http://www.unece.org> (2011a), (5 January 2012.)
- 189) <http://www.businesslink.gov.uk> (2011)
- 190) (UNECE (2011c), <http://www.unece.org> (2011c)
- 191) Unece 2017 <http://www.unece.org>
- 192) Cefic(2017)www.cefic.org/Responsible-Care
- 193) Ostrom, C. A. Wilhelmsen.(2012) "Effect of potential failures (Risk Assessment: Tools, Techniques, and Their Applications pg:123".
- 194) T. Ostrom., C. A. Wilhelmsen,(2012). "Risk Assessment: Tools, Techniques, and Their Applications." FMECA Criticality pg: 129
- 195) T. Ostrom., C. A. Wilhelmsen,(2012). "Risk Assessment:Tools, Techniques, and Their Applications Accident sequence.pg:164
- 196) T. Ostrom, C. A. Wilhelmsen.(2012) " Risk Assessment:Tools, Techniques, and Their Applications. Event tree with path probabilities. pg:165

- 197) T. Ostrom, C. A. Wilhelmsen.(2012) . “*Risk Assessment: Tools, Techniques, and Their Applications Common Fault Tree Symbols*” pg: 206
- 198) www.ifeuk.com/downloads/Palletspecinfo.pdf accessed:02.02.2017
- 199) <https://www.unece.org/trans/.../adr/adr2017/17contentse.accsd.03.12.2017>
- 200) OSHA(2017) 29 CFR 1910.106 Flammable Liquids P:3
- 201) <https://www.ccohs.ca/oshanswers/.../flammable/flam.html> accessed dd 03.12.2017
- 202) HSE (2015) “*Storage of flammable liquid in containers*” HSG 51, p:42
- 203) HSE (2015)”*Storage of flammable liquids in containers* “ HSG 51,; P:14
- 204) https://www2.iccsafe.org/.../oregon/.../Chapter%2036_Flam accessed dd 04.12.2017
- 205) https://protect.iu.edu/doc/environmental.../lab_chp_sop_4.p...accessed dd 04.12.2017
- 206)https://protect.iu.edu/doc/environmental.../lab_chp_sop_4 accessed dd 03.12.2017
- 207) <https://Www.Epa.Gov/.../Chemical-Advisory-Solid-Ammonium> Accessed 04.12.2017
- 208) www.Hse.Gov.Uk/Pubns/Indg230.Pdf Accessed 04.12.2017
- 209) HSE, (1998), “*Storage and use of sodium chlorate and other similar strong oxidizers*” Guidance note CS 3 1998 P:5-6
- 210) HSE, (1998), “*The Storage and handling of organic peroxides*” HSE CS21;P:5
- 211) HSE, (1998), “*The Storage And Handling of Oxygen Peroxides*” HSE CS 21; P:6
- 212) HID (2017), “*Chemical Warehouses Safety Report Assessment Guide*” HSE p:11
- 213) HSE, (1999) “*Major accident prevention policies for lower-tier COMAH establishments*” Chemical sheet no:3 P:1
- 214) HSE, (2015) “*The control of major Accident Hazard Regulations*” p:29
- 215) HSE, (2009) “*Chemical warehousing.The storage of packaged dangerous substances*”HSG 71p:23
- 216) HSE, (2009) “*Chemical warehousing.The storage of packaged dangerous substances*”HSG 71p:39
- 218) M.D.Goh., E.M.Kwek(2008) “*Overview Of Fire Alarm Systems And Maintenance.*”
- 219)https://www.scdf.gov.sg/.../fire.../Appendix_B.pdf
- 220) Saaty, T.L.(1988)”*Mathematical Methods of Operational Research*”. McGraw Hill
- 221) HSE, 1995, EH 70 “*Fire Water Drainage System*” Pg:4
- 222)NFPA, 1995, “*The Design And Construction of A Chemical Warehouse*”
[ftp://Ftp.Feq.Ufu.Br/...Warehousing. Part 6 Design.accsd.2017](ftp://Ftp.Feq.Ufu.Br/...Warehousing.Part6Design.accsd.2017)
- 223) HSE , HSG 168, 2010 “*Fire Safety in Construction*” Pg:43
- 224) www.hse.gov.uk/cdg/manual/packaging.htm ADR Packaging Regulation

225) www.hse.gov.uk/pubns/indg345.pdf training pg:4-6

226) www.tksd.org.tr/rc.html,accesd:01.11.2017

228) [web.https://www.ecta.com/Responsible-Care](https://www.ecta.com/Responsible-Care).accesd:12.11.2017

