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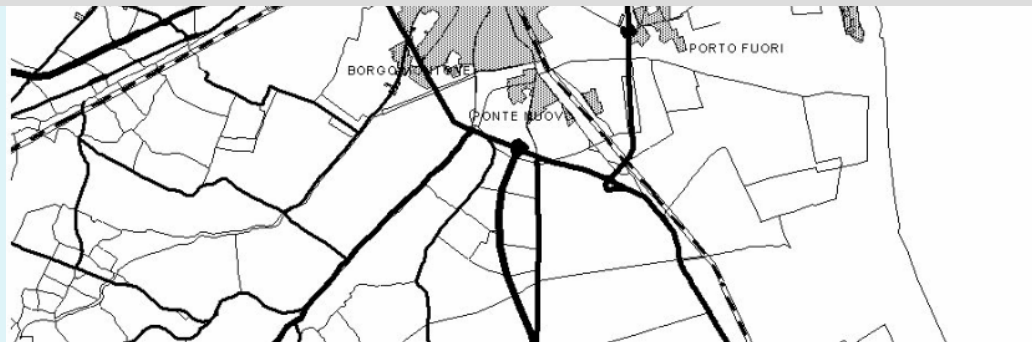
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**AN INTEGRATED APPROACH TO THE
SAFETY OF RAVENNA PORT:
the ARIPAR Project**





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INTRODUCTION

Petrochemical and chemical plants are often located in the same industrial site (immediate transfer of substances among plants, rational and cheap integration of services) and the site is near a coast to guarantee raw materials supplies by ships.

increase of the global risk which characterizes the site owing to the large amounts of **dangerous substances** processed



Flixborough, Seveso, Bophal and, more recently, Enschede, Baia Mare and Tolosa

dangerous substances can provoke major accidents (fire, explosions, release of toxic/carcinogenic chemicals) and these can also happen during **activities of transport and loading/unloading in Port.**



..... INTRODUCTION

To eliminate or reduce such risk typologies a great effort is requested

Measures (due to voluntary tools or imposed by regulations) **act on:**

risk sources through safety

receptors through the adoption of active and passive protective measures (emergency procedures, policies of territory planning)

public administrations control risks through a deep qualitative and quantitative analysis of safety reports of plants

Number of large industrialized areas in Italy: 20

But a global picture of risks can only result from evaluating together all plants and transportation → **INTEGRATED APPROACH**

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ARIPAR Project

The first Italian study on quantitative risks of a high industrialized area
(Ravenna)

The study was promoted in 1989 by the Italian Department for Civil Protection and by Region Emilia-Romagna and its progress was monitored by scientific and technical committees.

The risk quantification considered plants and **transportation by** road, rail, pipeline and **ship** involving dangerous substances.

The paper focuses on **the part of ARIPAR Project concerning transportation by ship** and on **the evolution in time of the whole Project, from 1990 up to 2003.**

Main aim:

to highlight how risk analysis performed can help central and local administrations in suggesting measures of risk reduction.

A list of actions taken and measures adopted puts in evidence in which way QARA has been used to improve safety of citizens.

QARA steps

2.1 Industrial and impact areas

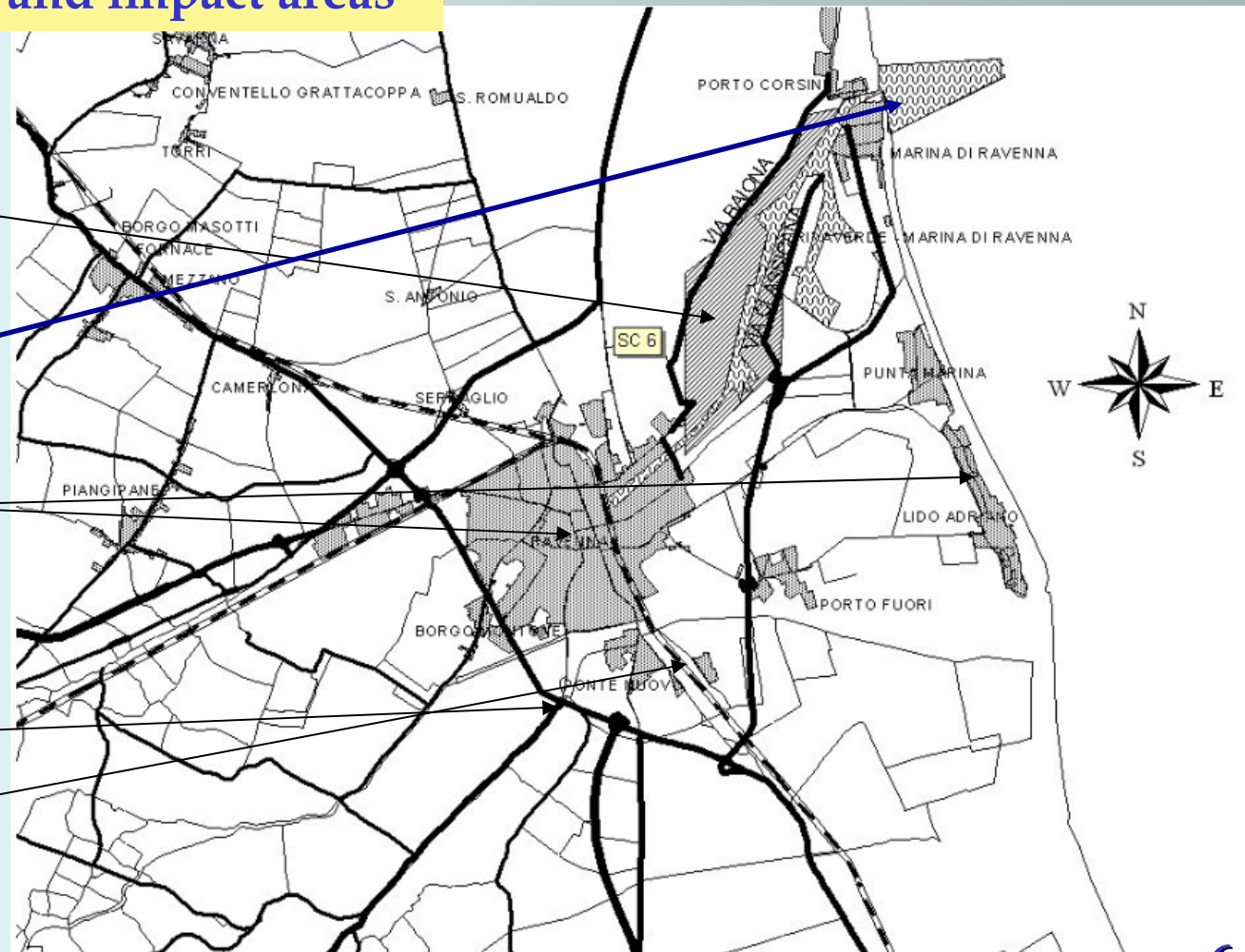
Map of the impact area

Dashed area:
chemical plants

dotted area:
channel port

grey areas:
Ravenna and coast
cities

continuous lines:
roads;
dashed lines:
railways



Example of meteorological data of the Ravenna territory in summer-autumn season

**TERRITORY
of Ravenna**

	B-3	D-5	D-1	D-2	F+G-2
0.0° - 22.5°	5.572E-03	1.057E-02	3.858E-03	5.672E-03	1.196E-02
22.5° - 45.0°	9.060E-03	2.085E-02	7.943E-03	5.969E-03	1.293E-02
45.0° - 67.5°	1.515E-02	2.230E-02	7.980E-03	7.137E-03	1.400E-02
67.5° - 90.0°	2.866E-02	3.340E-02	1.092E-02	9.771E-03	1.679E-02
90.0° - 112.5°	2.792E-02	2.935E-02	1.089E-02	1.279E-02	2.059E-02
112.5° - 135.0°	2.302E-02	2.805E-02	9.556E-03	1.909E-02	2.861E-02
135.0° - 157.5°	5.237E-03	1.849E-02	8.278E-03	1.759E-02	2.838E-02
157.5° - 180.0°	3.308E-03	1.011E-02	5.585E-03	9.324E-03	1.925E-02

2.2 Inventory of accident risk sources

**45 Plants in
RAVENNA site**

Main production lines of the industrial site

Petroleum refining, technical gas storage and production, ammonia storage and plants for producing fertilizers, maleic anhydride, polymers.

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.... **Inventory of accident risk sources**

Transportation of dangerous

large differences in some toxic and flammable substances owing to different transport means (ammonia is now transferred by pipeline...).

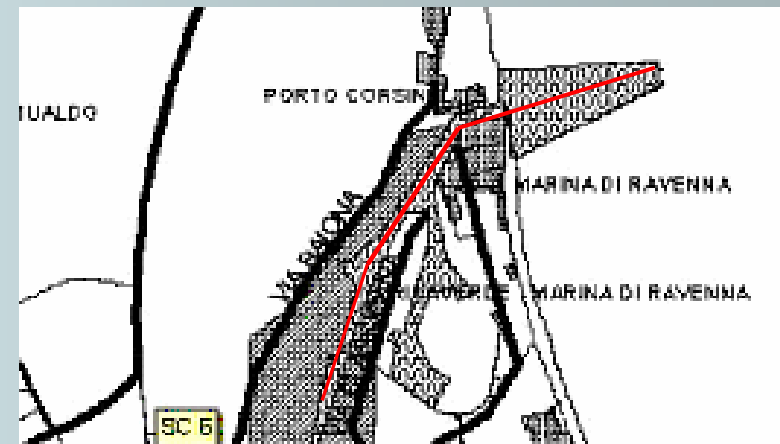
Class	Reference Substance	Road			Railways		
Liquefied toxic gases	Ammonia	-	344	19 408	-	15	248
	Chlorine	-	46	74	220	252	290
Liquefied flammable gases	LPG	92730	68 700	187 000	1710	14 291	24 907
Highly flammable liquid	gasoline	448887	1 139 000	740 000	22810	-	-
	MTBE	-	-	-	21065	-	-
Flammable liquid	gas oil	1 032 194	550 000	1 450 000	13750	-	-
Global transport of dangerous substances		2 892 120	2 964 000	3 001 000	66 405	130 662	183 393

.... Inventory of accident risk sources

Transportation of dangerous substances by ship in the Candiano canal

Annual ship traffic characteristics

specific data of each single transport of wharfed ships; quality and quantity of goods (charged, discharged or in transit); residence time in harbour



Conveyed Goods (year 1989)

Arrivals: 11.5×10^6 t

Shipments 2.3×10^6 t

Ships: 3600

Dangerous substances: 25 % of total goods

Conveyed Goods (year 1993)

Arrivals: 13.5×10^6 t

Shipments 2.5×10^6 t

Ships: 3800

Dangerous substances: 28 % of total goods

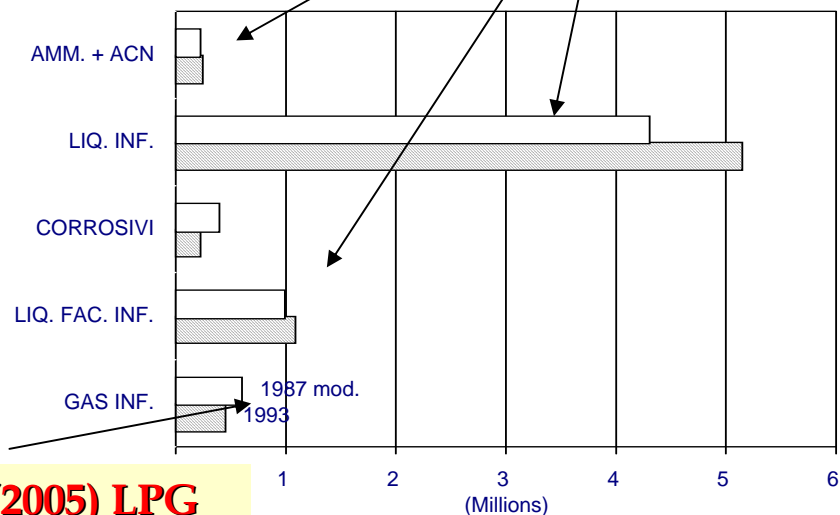
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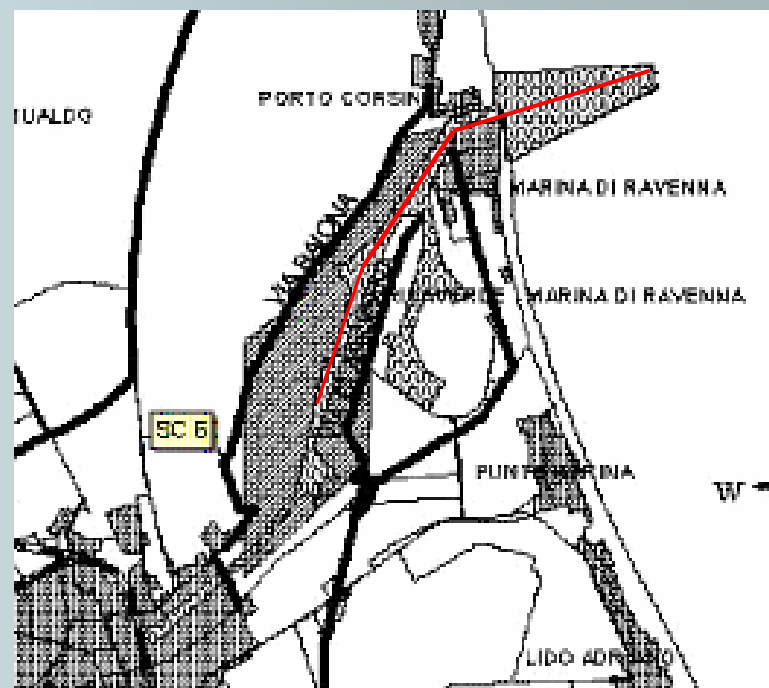
.... Inventory of accident risk sources

Transportation of dangerous substances by ship in the Candiano canal

SOSTANZE PERICOLOSE 1993-1987 mod.
(milioni di tonnellate)



(2005) LPG
~400 000 t



Conveyed Goods (year 2005)
Arrivals: 14.0x10⁶ t
Shipments 2.8x10⁶ t
Ships: 3900

2.3.1 Remarks on risk analysis of risk sources- plants

Identification of risk sources



Typologies



Accidental scenarios



Quantification of probabilities and consequences

Fire	Explosion	Atmospheric dispersion of toxic release
Jet fire	Vapour Cloud Explosion	Low velocity neutral gas
Pool fire	BLEVE	Low velocity heavy gas
Tank fire	Confined Explosion	high velocity stream (jet)
fireball		
Flash fire		

2.3.1 Remarks on risk analysis of risk sources- transportation by ship

How to perform risk analysis of HAZMAT transport by ship?

Harbour system is analysed by using a simulation method

TWO STEPS: 1. information 2. modelling

INFORMATION STEP

1. Topological characteristics of port (physical configuration and unloading wharf locations)

Harbour configuration is divided in parts, each of them is classified according to:

percentage of sandy bank, wharf without or with moored ships and dangerous structures, i. e. protuberances or submerged obstacles

peculiarities of the surrounding area (free, urbanised and with or without presence of dangerous substances)

2. Annual ship traffic characteristics

Some output of **DATA COLLECTION** (useful to analyse risks)
classification of ships according to both tonnage and conveyed substances; analysis of the traffic of different substances (global or in a wharf)

3. detailed information on

- operative procedures established for access, navigation, right of way and berthing of ships
- instructions for loading/unloading operations.

- Candiano canal (divided, for a good simulation of traffic, in 17 peculiar parts)
- traffic at alternate one-way
- maximum navigation velocity of 6 knots

MODELLING STEP

For each canal segment, evaluation of:
frequencies and consequences of releases of dangerous substances

Accidental frequencies by a SIMULATION METHOD

Probabilities of **initiating events** (manoeuvre errors,..)

Accidental Sequencies (on the basis of: particular geographic conditions and traffic regulations)

Harbour incidents which can cause dangerous substance releases

incidents referred to navigation and moorings
human errors during loading/unloading operations
fire/explosion on board

Initiating Events

1. loss of course; 2. fire/explosion on board ; 3. incidents during moorings ;
4. incident during loading/unloading operations.

Occurrence probabilities (events/ship): historical data of the port (events n. 1 and 2); bibliographic searches (events n. 3 and 4)

....MODELLING STEP

Procedure for calculation of release frequencies

Simulation through a Monte Carlo technique

accidental scenarios
 (pool fire, fireball, flash fire,
 UVCE, confined explosion,
 passive/heavy gas dispersion
 at low or high velocity,..)

ARIPAR Project

Total release frequencies for the canal (events/y)

toxic flammable	flammable gases	flammable liquids	toxic
1.6×10^{-3}	1.3×10^{-2}	2.0×10^{-2}	7.0×10^{-3}

Consequences of the releases depend on:

rupture typology and involved substance

rupture classes in ARIPAR Project

minor (equivalent hole diameter = 4")

major (equivalent hole diameter = 8")

catastrophic (for ships without double hulls)

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PLANTS

Generally the initiating events of accidents can be internal and external

Important external events: natural events like **floods and earthquakes**

Typologies of accidental scenarios are the same...

The Ravenna area

seismic risk: **seismic risk neglected**

domino effects among contiguous installations **cannot be neglected**

(a threshold approach has been initially used)



PLANTS

Initial Project: about 300 accidents considered.

Few (but important) new installations were evaluated in the updating phases (5)

TRANSPORTATION by rail, road and SHIP:

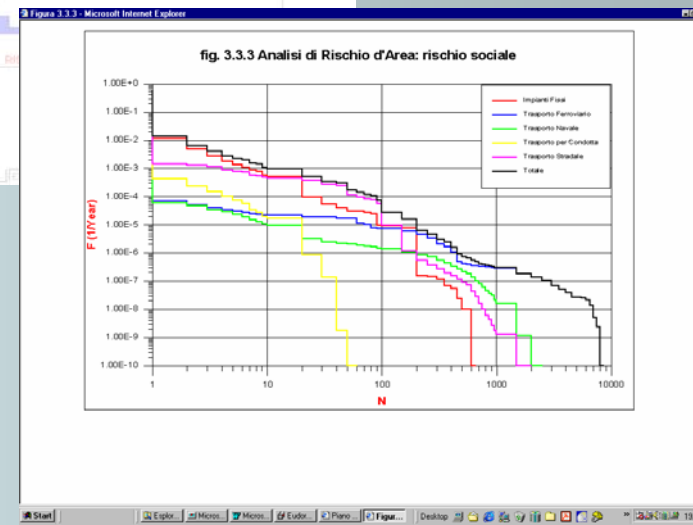
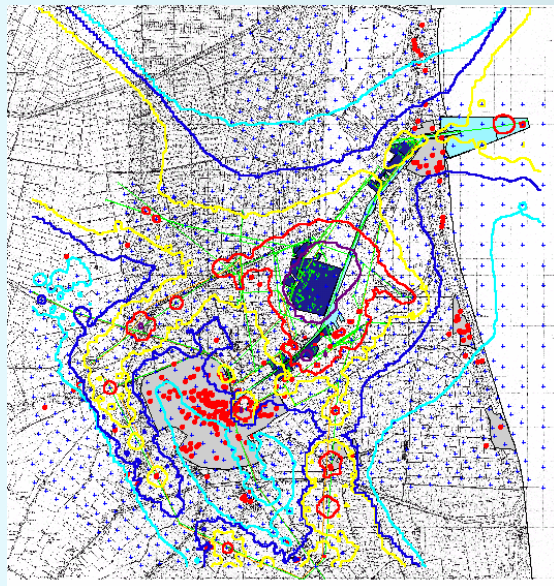
the updating requested to evaluate only new accident frequencies (reference scenarios were the same)

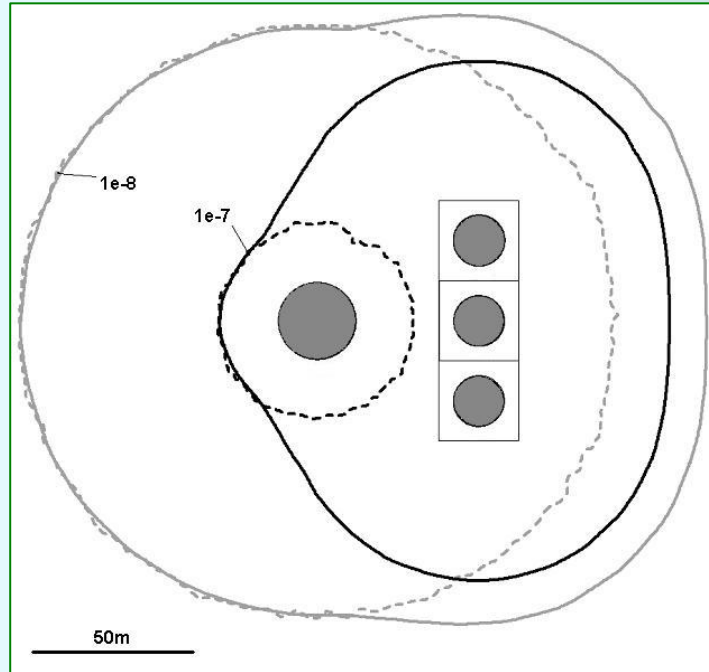
The reassembling of risk source analysis: performed by ARIPAR- GIS software tool

Results obtainable: RISK measures...

Local and Individual risk, F/N curves, I-N histograms, importance of risk sources, of substances,... **damage area** of each considered scenario,...

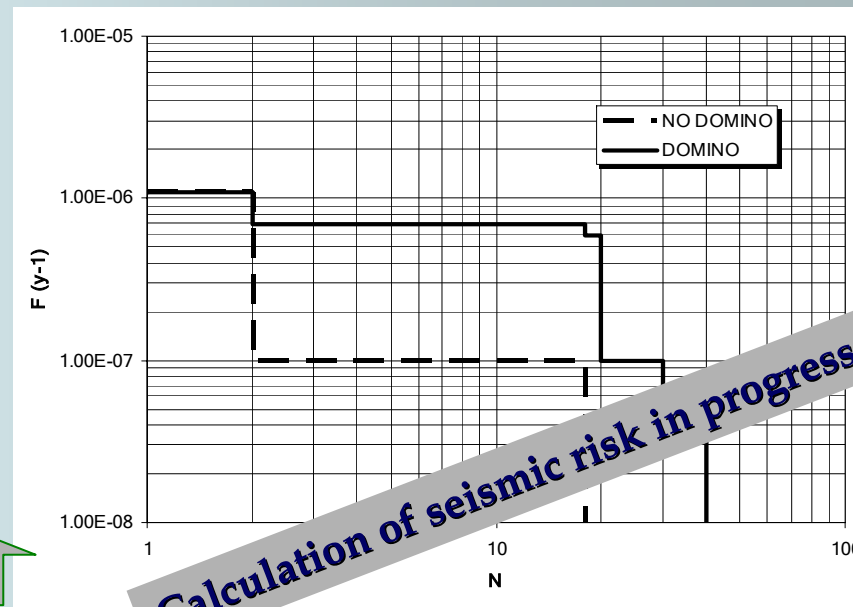
3.1 Risk measures





The new version of ARIPAR-GIS code will include

Domino effects

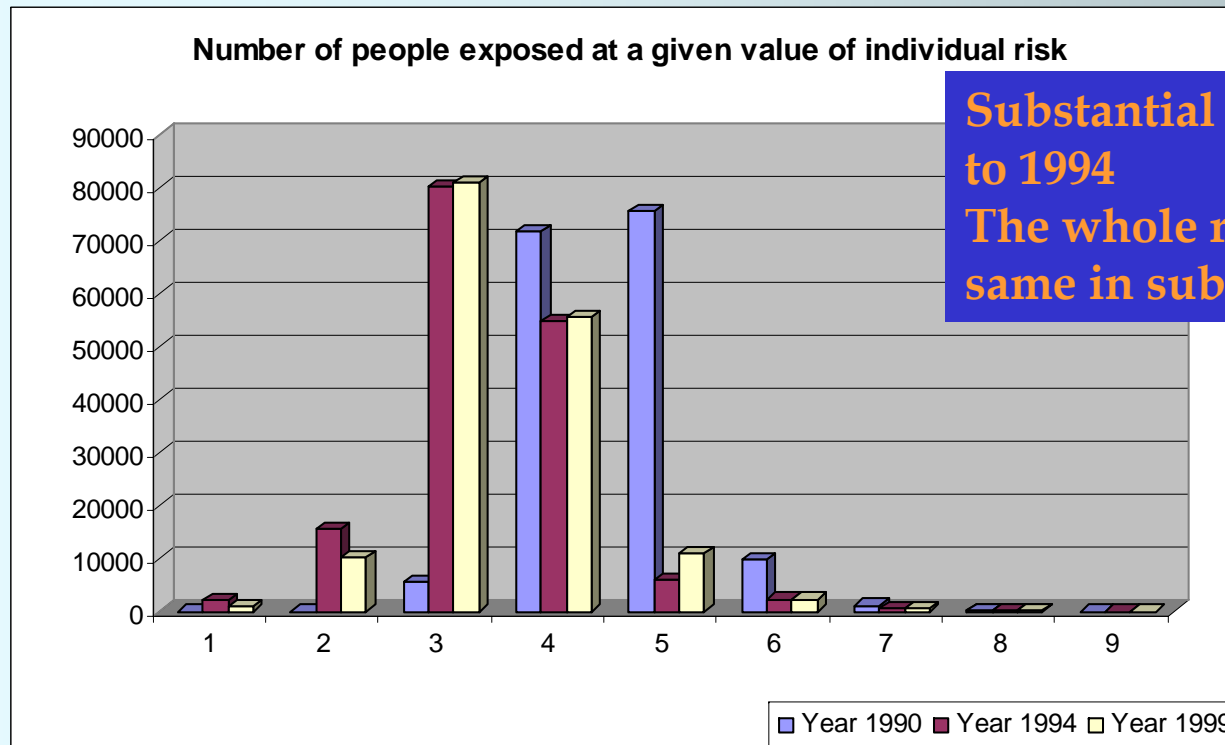


Map of individual risk (events/year) and (b) F-N societal risk curves obtained from the analysis of a case-study

Probabilistic procedure...

3. Discussion on QARA results

3.2 Ravenna industrial area and time evolution of societal, local and individual risks






Substantial decrease of risk from 1990 to 1994
 The whole risk level is practically the same in subsequent years

Class of IR	1	2	3	4	5	6	7	8	9
Class values	1.00-11 - 1.00-10	1.00-10 - 1.00-9	1.00-9 - 1.00-8	1.00-8 - 1.00-7	1.00-7 - 1.00-6	1.00-6 - 1.00-5	1.00-5 - 1.00-4	1.00-4 - 1.00-3	1.00-3 - 1.00-2

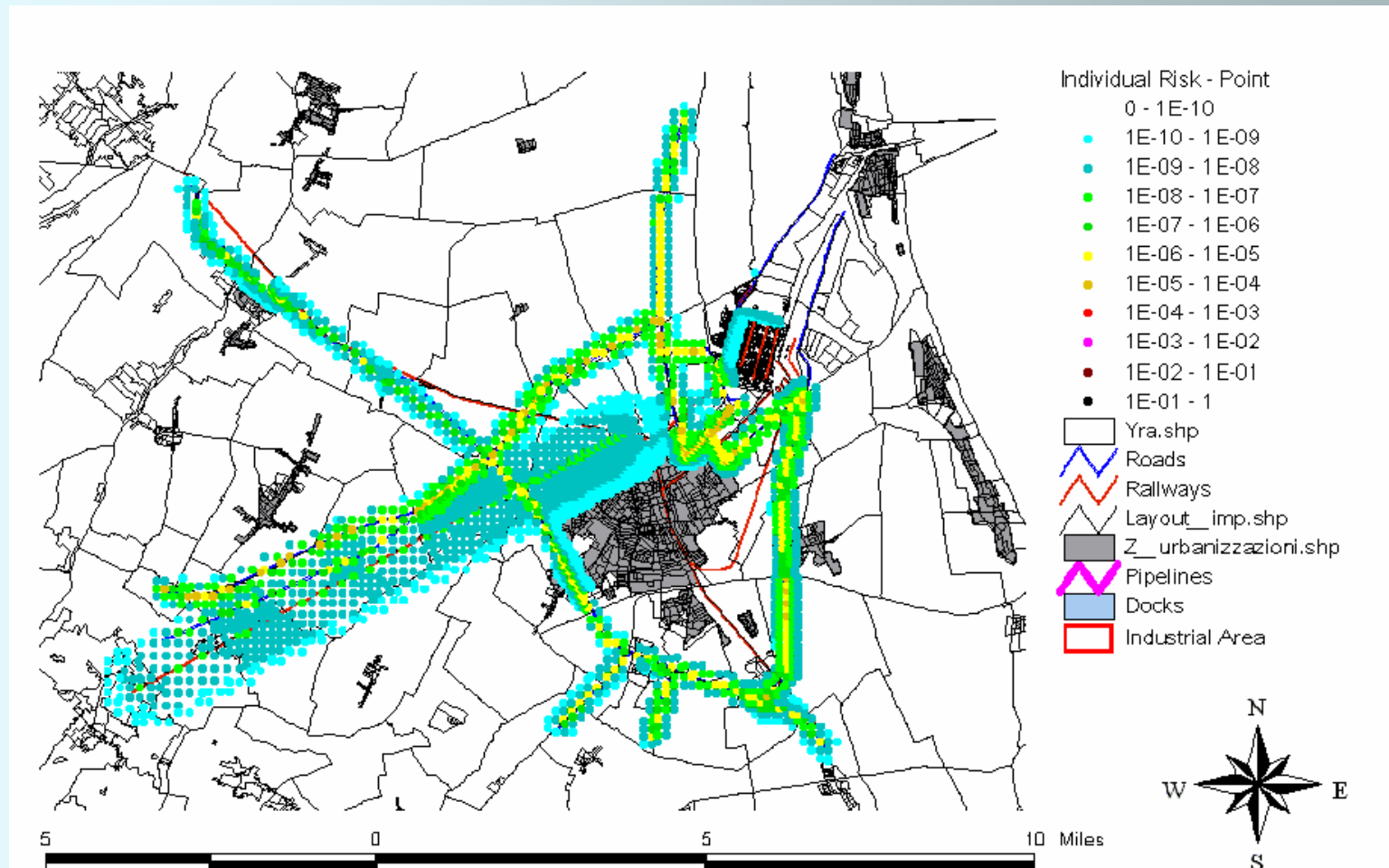
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 Year 1990
 Year 1994
 Year 1999

N	F (1/y)	PIPELINES %	ROADS %	RAILWAYS %	SHIPS %	PLANTS %
10	3.00E-03	2.00	54.00	2.00	3.00	39.00
	9.89E-04	1.65	45.80	2.21	0.95	49.39
	9.81E-04	1.66	45.97	2.28	3.90	46.18
100	2.00E-04	1.00	70.00	8.00	1.00	20.00
	2.67E-05	0.00	35.40	26.59	5.09	32.92
	2.37E-05	0.00	40.80	30.13	23.50	5.57
500	3.00E-05	0.00	35.00	30.00	0.5	34.50
	7.25E-07	0.00	12.59	56.28	29.79	1.34
	1.30E-06	0.00	7.00	31.33	60.92	0.75
1000	8.00E-06	0.00	25.00	37.50	0.00	37.50
	2.93E-07	0.00	0.27	94.20	5.53	0.00
	3.42E-07	0.00	0.37	80.62	19.01	0.00
4000	7.00E-08	0.00	12.00	88.00	0.00	0.00
	3.86E-08	0.00	0.00	100.00	0.00	0.00
	3.86E-08	0.00	0.00	100.00	0.00	0.00

Individual risk distribution - transportation by road and railways

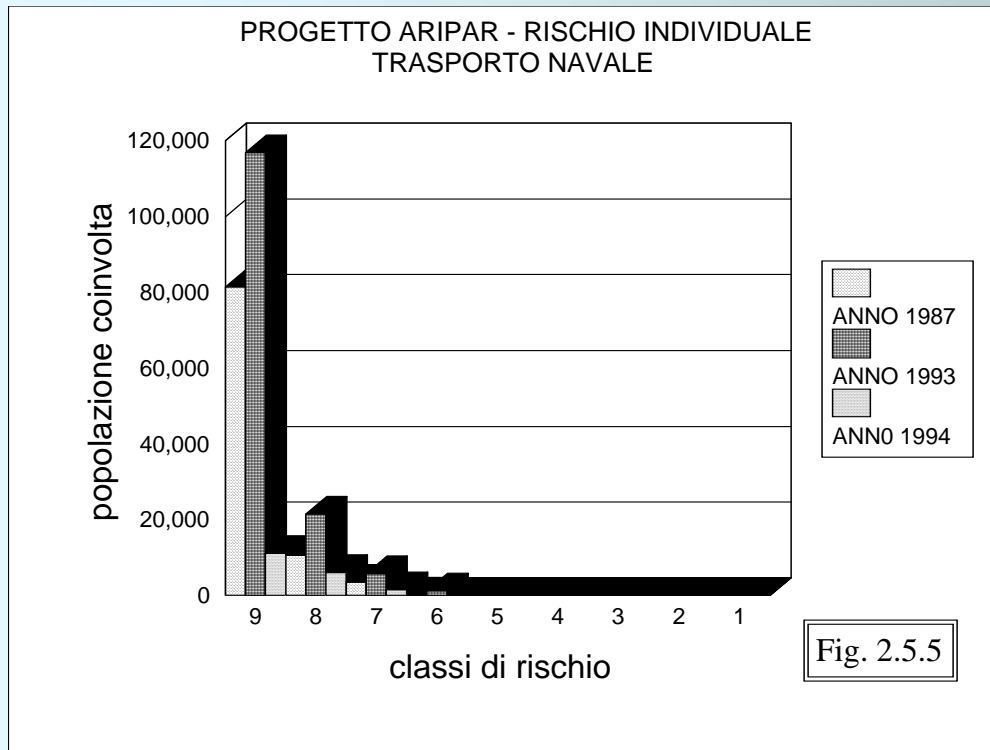


Last updating: year 2004

Other typologies of results

Contribution of the single installations to the overall risk

N	Activity	F (1/yr) 1990	Contr . % 1990	F (1/yr) 1994	Contr. % 1994	F (1/yr) 1999	Contr. % 1999
10	Refinery	1.00E-4	0.8	4.89E-4	79.32	4.53E-4	85.37
	Chlorine storage		2.7		0.55		0.6
	Ammonia pressurized storage		54.7		10.96		11.82
	Storage (LPG, flammable liquids...)		41.8		9.17		2.21
100	Chlorine storage	2.00E-5	4.7	8.79E-6	1.97	1.33E-6	13.04
	Ammonia pressurized storage		55.3		12.96		85.90
	Storage (LPG, flammable liquids...)		40.0		85.07		1.06



The risk is mainly connected with loading/unloading operations of dangerous substances because of the very stringent traffic regulations

Some conclusions on risk analysis in Candiano Canal contribution of the port to the overall risk in the Ravenna town negligible maximum values located in the vicinity of some wharves (load-ing/unloading, berthing, crash against a moored ship,...). **small contributions**, if compared with fixed installations and different typologies of transportation

3. Discussion on QARA results

Risk measures can help public authorities to assume decisions moving towards an always increasing safety for citizens

3.3 QARA and administration decisions

Administration decisions

Emilia-Romagna region:

from 1992 uses ARIPAR results to support decisions directed to risk reduction. **Supports due in:**

1. controlling **future** industrial and commercial **developments** on the area;
2. doing **proposals** for a better **risk control**;
3. **planning land use**.

Examples of actions :

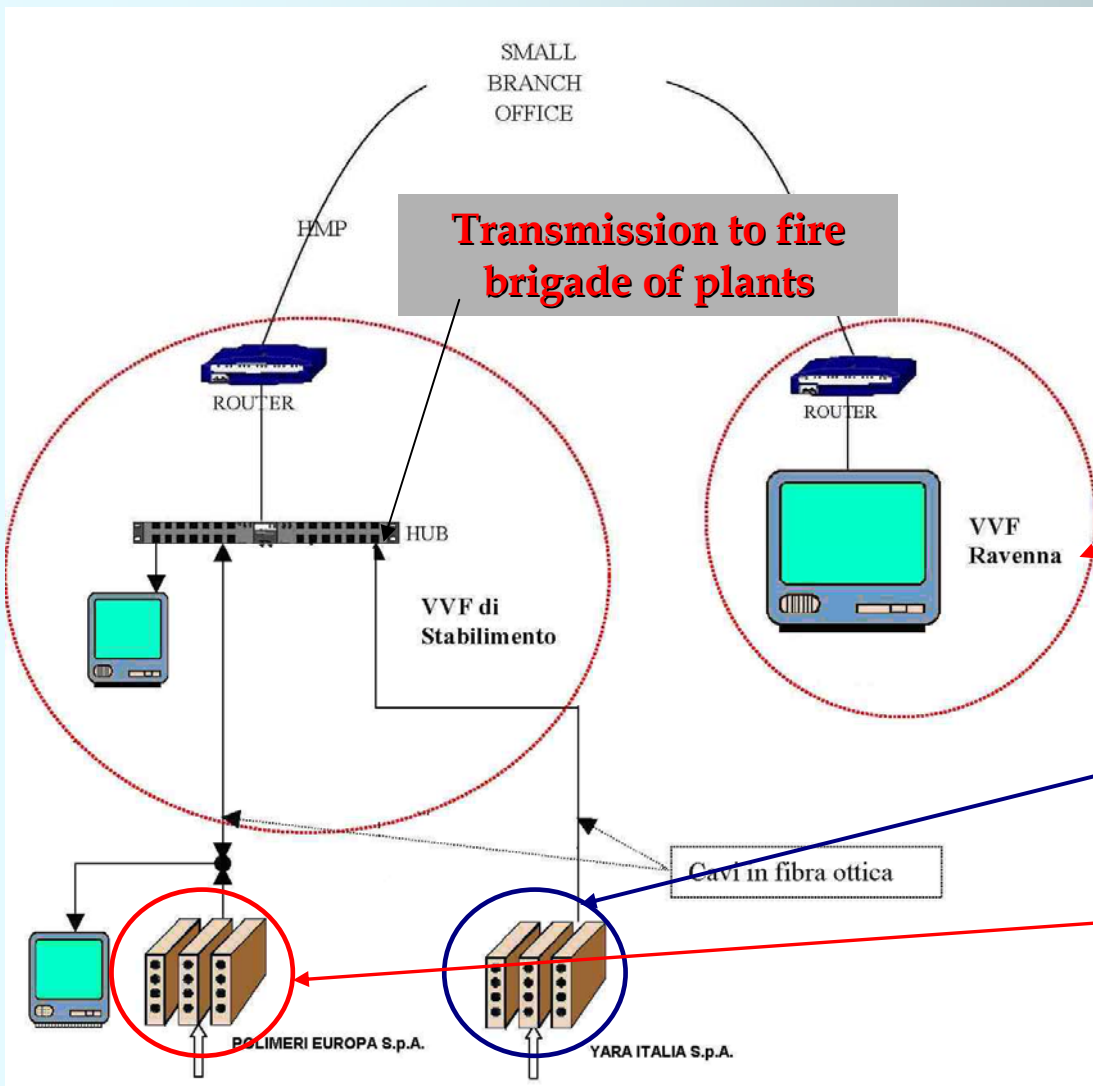
1. the **consultation of the technical scientific committee** in case of new developments (storage of LPG buried vessels);
2. the **adoption of a traffic control system of the Port (PAC)** which will be able to control ship movements in the roadstead and verify that very stringent traffic regulations are applied in the Candiano canal;
3. a **new road stretch** which changes a route conflicting with town, the **displacement of the marshalling yard** whose location near the town originates a great societal impact.

Activities based on risk assessment are in complete agreement with the law n.45/95 of Emilia-Romagna Region (it introduced the criterion of evaluating the vulnerability of territorial areas subject to specific risks to address activities)

National decree on land use planning was promulgated in 2001, May. (... probabilistic risk assessment in evaluating large industrial site allowed...,... lack of tolerability criteria)



The MONITORING OF PRECURSORS OF ACCIDENTS



MAIN AIM: to avoid or give an early warning of accidents.

Which measures and instruments are foreseen?

Transmission to fire brigade of Ravenna

Detection of high pressure in liquified ammonia pipe feeding pressure vessel

Detection of releases from ammonia pipeline

...END...