The Role Of Pavement Permeability And Satellite Tracking In Abating Risks In Hazmat Road Transportation

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Synopsis

As is well known, about 15-20% of road freight transports in Europe concern hazmat (hazardous materials).
In particular, in Italy there are about 10^9 Kilometres per year of hazmat road transports; about the 93.7% of hazmat transports choose road vehicles.
Given that, it becomes more and more important to formalize methods and to design devices in order to validate the effectiveness of techniques and infrastructures in reducing hazmat risks.
Pavement contribute to abate risk is herein considered in terms of Hot Mix Asphalts (HMA) outflow times.
In order to evaluate the influence of the quality and quantity of the fluid that get off the vehicle, a specific device was designed and constructed by the Authors at the DIMET laboratory (DIMET Department at the Mediterranean University of Reggio Calabria). The use of the new device followed the formalization of a suitable experimental procedure.
Weather influence on the process was also considered.
Satellite tracking by the new satellite system GALILEO was analyzed as a strategy to contribute to decrease hazmat risks. So, in the formalized model, Authors tried to quantify both probability and magnitude consequences.
The practical applications of this work can be divided into two main sets: a) analyze how much a new European satellite network could be useful in reducing hazmat risks in road transportations; b) designing and assessing a procedure (by an apt device) to estimate how much a transported fluid can be dangerous for the environment near/below the road.

The Role Of Pavement Permeability And Satellite Tracking In Abating Risks In Hazmat Road Transportation

The objective of this study is to analyze the role of pavement permeability and satellite tracking in abating risks in hazmat road transportation. Nowadays, it becomes more and more important to formalize methods and to design devices in order to validate the effectiveness of techniques and infrastructures in reducing hazmat risks. Pavement contribution to abate risk is herein considered in terms of Hot Mix Asphalts (HMA) outflow times. The satellite tracking by the new GALILEO system was analyzed as a more effective strategy to decrease hazmat risks.

PROBLEM STATEMENT

This paragraph concerns the state of the art for:

- risk models;
- influence of satellite tracking;
- pavement permeability and outflow times.

Risk

This section concerns the analysis of different risk models.

In order to model the above stated problem (permeability and satellite role) many risk models were previously analyzed. An inventory of the analyzed models is reported in table 1 (appendices). Figure 1 summarizes in four sets the analyzed models.

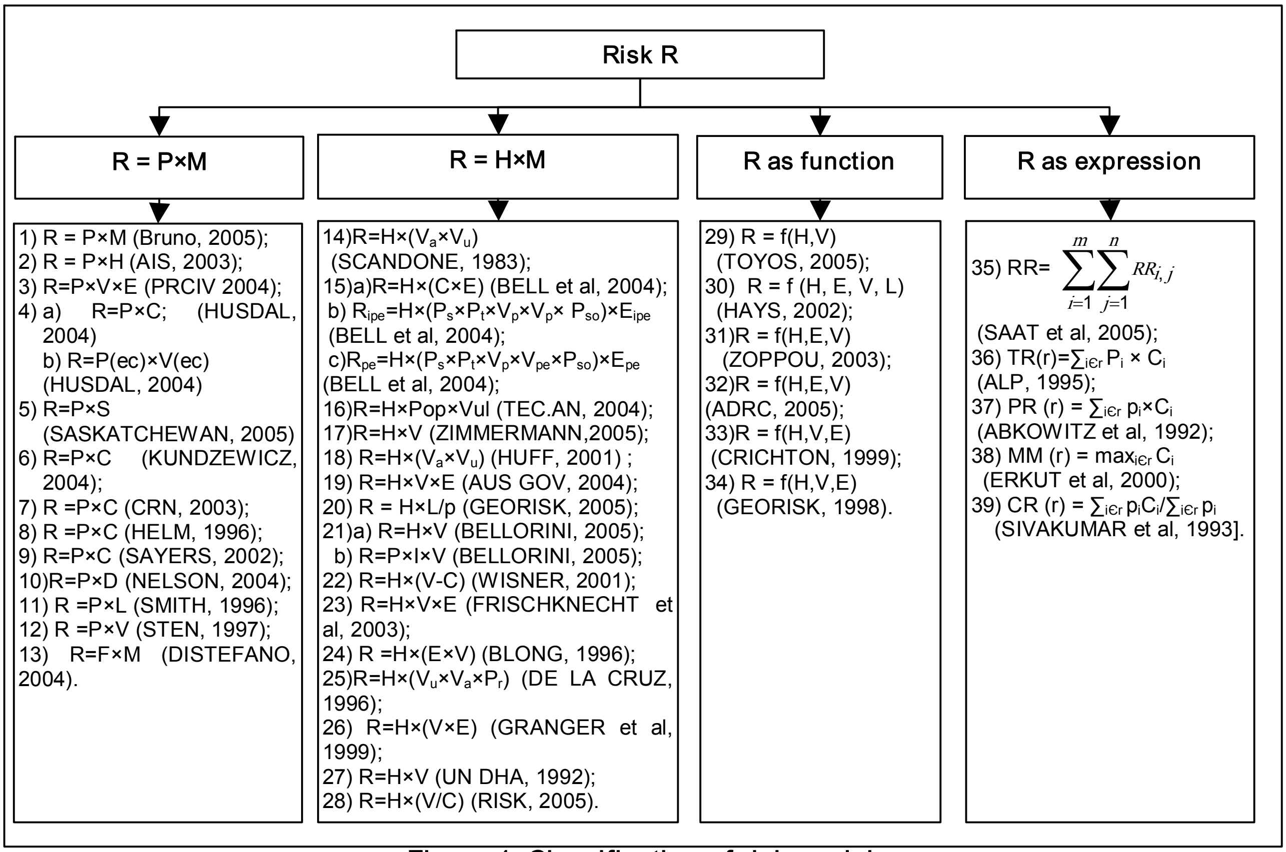


Figure 1: Classification of risk models

In the light of the above analyses it is possible to remark that the well-known expression of the risk in terms of Probability (or Hazard) for Magnitude has a lot of specifications dealing with the Magnitude; in this latter the following concepts are pursued: a) consequences (costs, severity, amount of damage, loss); b) vulnerability (as a degree of susceptibility); c) exposure (as a measure of the elements at Risk); d) Capacity (as aptitude to exercise a loss mitigation by existing resources or preparedness). So, in first approximation, three main concepts can be considered related to Risk: Probability, Vulnerability and Exposure.

Towards a new satellite system for tracking in hazmat road transportation

This section concerns the analysis of the effectiveness of a new European satellite network in reducing hazmat risks in road transportation. A quantification of the benefits and requirements is presented in terms of:
1) principal benefits;
2) principal requirements;
3) principal applications;
4) relationship between benefits, users, requirements and services.

In table 2 (in appendices) benefits, requirements, application for the new satellite network GALILEO are summarized. In the light of the analyses, the following observations can be drown:

a) Basic. Infield processes management is a common set of benefits which can be easily related to satellite systems. This means that they can be helpful in the management of parking, traffic, violations, communications and may have a remarkable social and economical return. Another benefit that is common the different systems (GPS, GLONASS, GALILEO) is a substantial compatibility and possibility of synergetic operations, with an appreciable upgrading in performance;
b) Advanced. Two surplus items can be easily identified for the GALILEO system: the first is technical: more accuracy (from 10 ÷ 20 m to about 1 m); the second deals with politics: GALILEO isn't military controlled and it is European.

Pavement permeability and hazmat road transportation

This section concerns some researches that have been previously conducted in order to evaluate the role of pavement outflow times (with or without weather influence) on the risks associated with the release of hazardous materials on road pavements.

Table 12 (in appendices) summarizes some researches performed on the topic.

In the light of the analyses performed the following leading concepts must be taken into account in order to evaluate and control permeability influence on risks for Hazmat transportations:

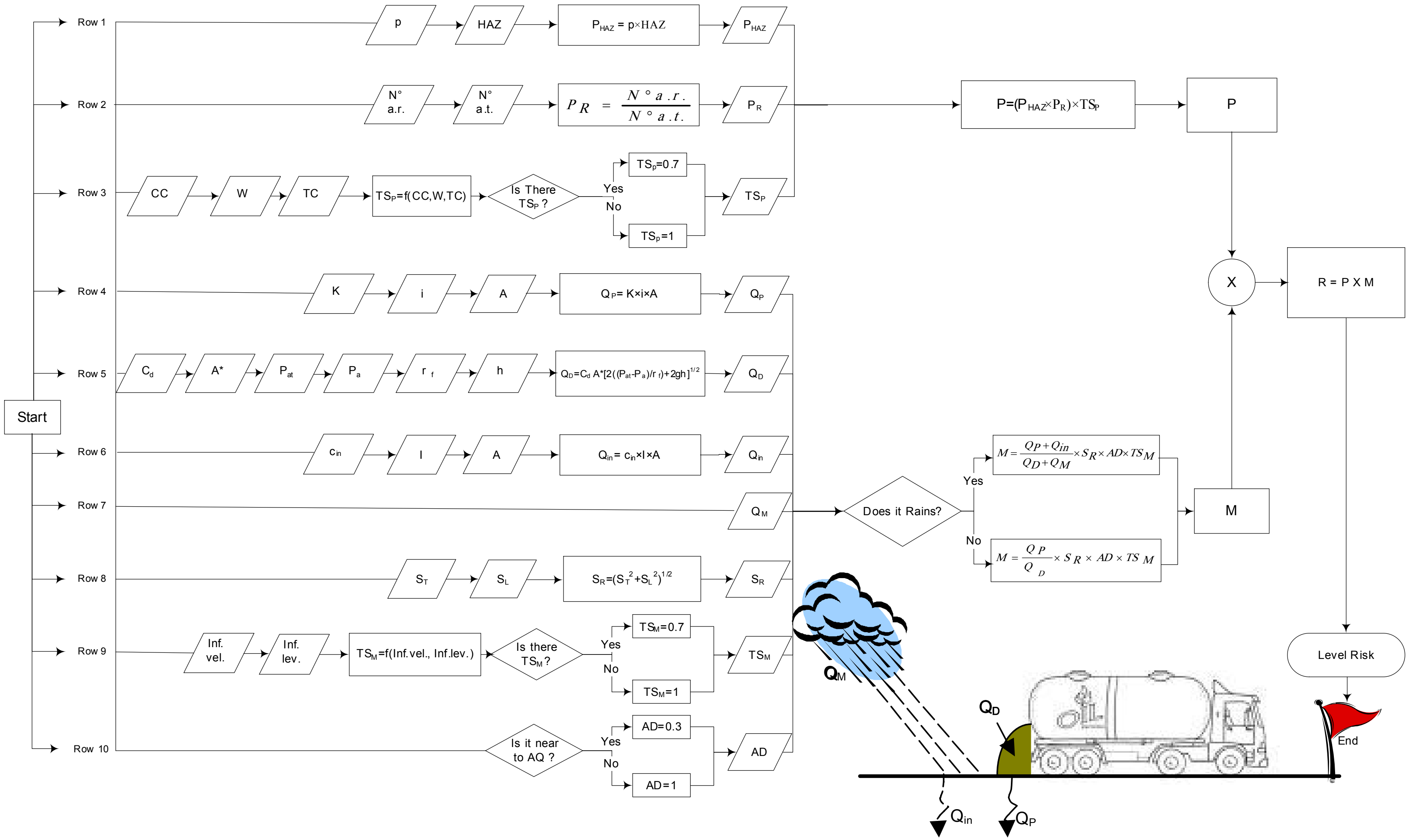
a) released Hazmats can affect both mechanical (durability, …) and surface (friction, raveling, stripping,..) performance (magnitude of the risk). These phenomena depend both on pavement and hazmat typologies;
b) released Hazmats can seriously damage aquifers; these phenomena depend on pavement and subgrade permeability;
c) road alignment (in particular transverse slope) and road auxiliary facilities (in particular ditch, basin of accumulation) can greatly influence the magnitude of the associated risks;
d) percolating Hazmats can substantially modify the permeability of asphalt courses, so specific experiments are needed in order to investigate sensitivity to different Hazmats and bituminous mixes.

MODEL DEVELOPMENT

In this section a model is developed in order to investigate the risk in hazmat road transportation. Important aspects considered in the development of the risk model (see Figures 1 and 2) are:
1) Hot Mix Asphalts (HMA) permeability influence (K);
2) Satellite Tracking (TS) influence, both in probability (TS_P) and magnitude (TS_M);
3) Weather influence (Rain);
4) Influence of the slope of the pavement (S);
5) Aquifer Distance influence (AD).

By referring to Figure 2 it is possible to specify that:

- Row 1 deals with the probability P_{HAZ} that an accident can occur to a vehicle transporting Hazmats;
- Row 2 deals with the probability (P_R) of a consequent release;
- Row 3 concerns the influence of satellite tracking in abating accident probability (TS_P);
- Rows 1 to 3 are the bases for the determination of Probability (P);
- Row 4 concerns the flow rate Q_P of the Hazmat through the pavement;
- Row 5 deals with the discharge rate Q_D of the Hazmat;
- Row 6 concerns the rate of rain infiltration Q_{in} in the pavement;
- Row 7 represents the rate of rain Q_M;
- Row 8 concerns the road slope S_R;
- Row 9 deals with the influence of satellite tracking in decreasing the Magnitude (TS_M);
- Row 10 concerns the presence of the aquifer (AQ) in the area of the hazmat release;
- Rows 4 to 10 are the bases for the determination of Magnitude.



SYMBOLS

A = total cross-sectional Area (m^2); A^*=flow area (m^2); AQ = Aquifer; AD = Aquifer Distance; CC=Collision Circles; C_d= orifice of the tank discharge coefficient (for example 0.6); c_{in}=coefficient of infiltration; g = gravitational acceleration (9.8 m/s^2); h=height of liquid above discharge point (m); HAZ = number of hazmat transportation/number of truck; K=pavement permeability (cm/s); i = hydraulic gradient; I = intensity of rain (mm/h); Inf. vel.= Information velocity; Inf. lev. = Information level (Accident typology, characteristics vehicle, hazmat typology, amount of hazmat, hazmat state, weather conditions); M=magnitude; N°a.r.=Number accident with release; N°a.t.= Total Number of accidents; P=probability; p=(number of accidents of truck/year)/(number of accidents of vehicle/year); P_{HAZ}=probability of hazmat accident; P_R= probability of release; P_a= absolute ambient pressure (N/m^2); P_{at}=absolute tank pressure (N/m^2); Q_{in}=rate of rain infiltration (mm^3/h); Q_M= rate of rain (mm^3/h); Q_P= flow rate (m^3/s); Q_D= discharge rate (m^3/s); R=risk; ρ_f= liquid density (kg/m^3); S_R= road slope; S_T= Transverse Slope; S_L= longitudinal slope; TC=Traffic Condition and vehicle position; TS=Satellite Tracking System; TS_M = Satellite Tracking coefficient for Magnitude; TS_P = Satellite Tracking coefficient for Probability; W=Weather conditions and forecast. Values of TS_P, TS_M, AQ are only exemplificative.

Figure 2: Model development

EXPERIMENTAL INVESTIGATION

The main objective of the experimental investigation was the validation the formalized procedure for the estimation of hazardous material aptitude to percolate trough different pavement types.

Experimental plan

This section describes the design of experiments (see Figure 3).

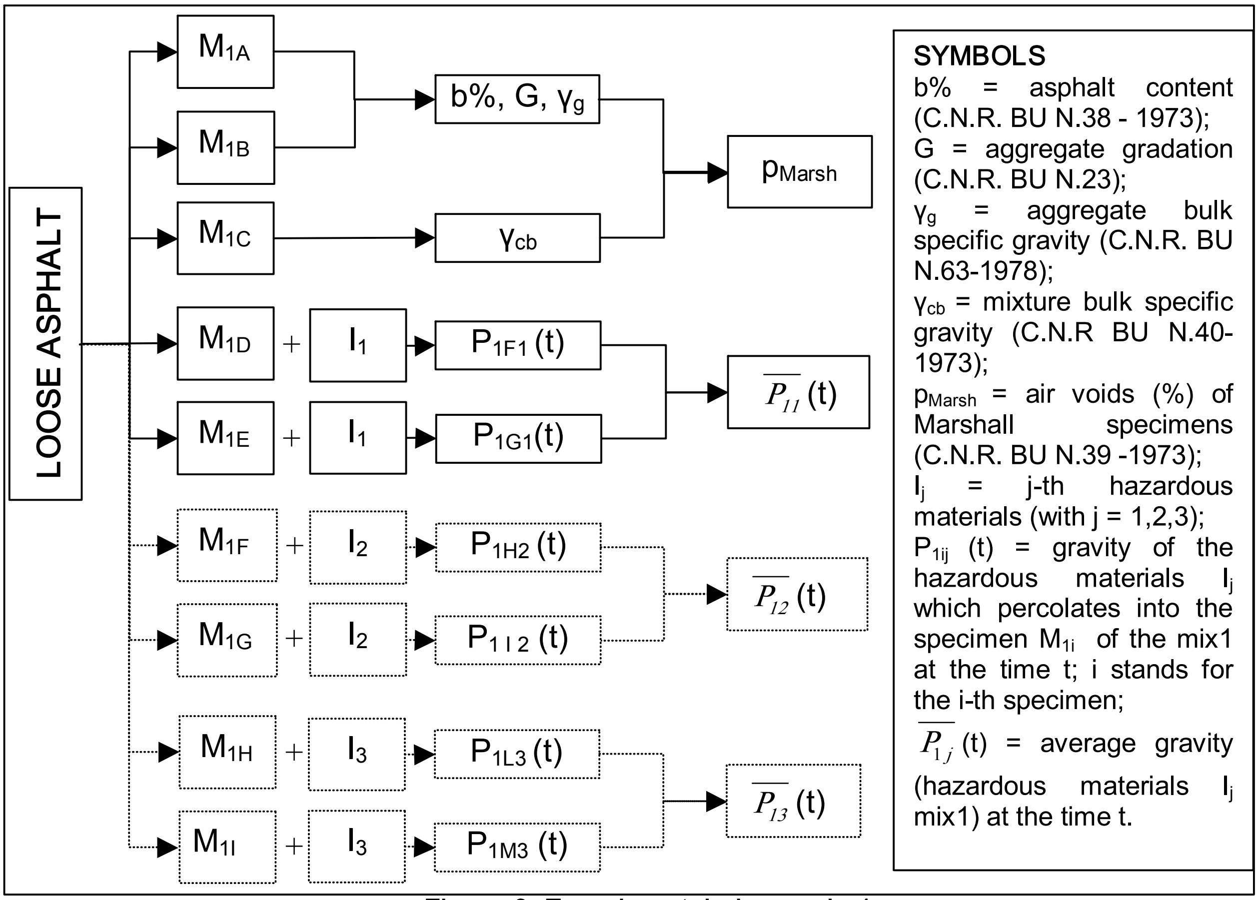


Figure 3: Experimental plan – mix 1

In order to perform the tests summarized in figure 3 it was chosen, for each mix, to obtain information both on HMA volumetric (asphalt content b%, grading G, stone apparent specific gravity γ_g, mix bulk specific gravity γ_{cb}, air void of Marshall specimens p_{Marsh}) and specific outflow times for a given j-th Hazardous material (I_j). The underlying idea was to analyze the percolation in time of the Hazmat in a specially constructed Marshall specimen. In order to reduce boundary conditions' influence (lateral percolation) many preliminary experiments were performed with different types of stoppers embedded in the Marshall specimens before compacting them (see table 3 in appendices and figures 4 to 10 where PI stands for preliminary investigation). Once analyzed the consequence on compaction level and percolation flows for different stoppers (preliminary investigation), the stopper number 1 was chosen (see table 3 in appendices); the following procedure was designed (see Figures 11 to 20):

- Preparation of stoppers (Figure 11).
- Preparation of Marshall specimens (compaction procedure) [B.U. C.N.R., n.30]:
  Heating hot mix asphalt and Marshall moulds in the oven (Figure 12);
  Extracting the elements from oven and embedding the stoppers into the Marshall specimens (Figure 13);
  Introducing hot mix asphalt + stoppers in the Marshall mould (Figure 14);
  Compaction (number of blows = 75 for face);
  Cooling Marshall specimens;
  Extraction of the stoppers from Marshall specimens (Figures 15 to 16).
- Weighting procedures (Figures 17 to 20):
  Weighting the empty steel container (Figures 17 to 18);
  Weighting Marshall specimen;
  Weighting steel container and the Marshall specimen;

Letting the hazardous material in the Marshall specimen (Figure 19);
Weighting steel container and hazardous material in the Marshall specimen (Figure 20);
Weighting steel container and the percolated hazardous materials at different times.

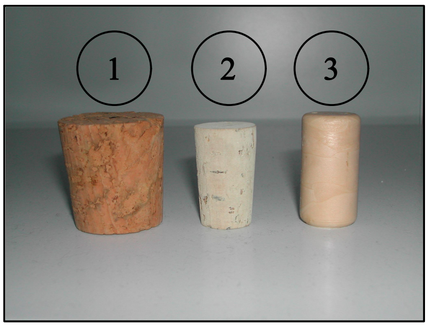


Figure 4: Stoppers (Preliminary Investigation PI)

Figure 5: Preparation of the stoppers (PI)

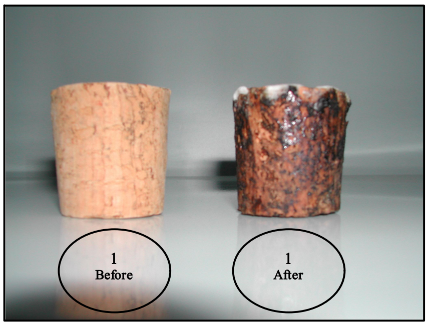


Figure 6: Stopper type 1 before/after compaction (PI)

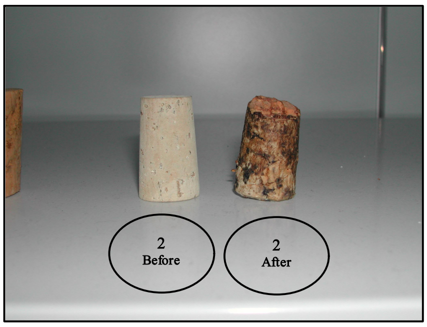


Figure 7: Stopper type 2 before/after compaction (PI)

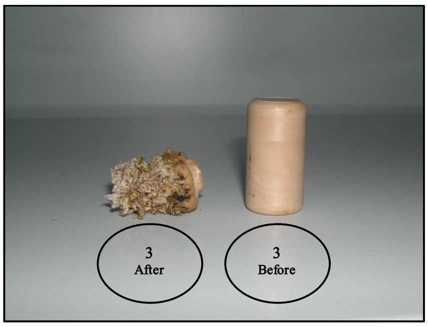


Figure 8: Stopper type 3 after/before compaction (PI)

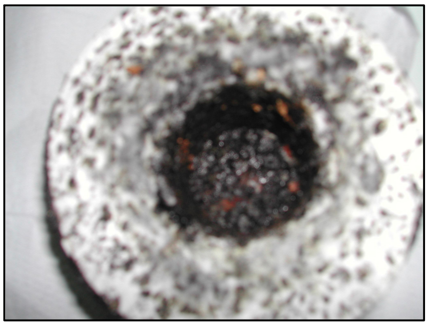


Figure 9: Holed specimen and corke 1 (PI)

Figure 10: Holed specimen and corke 2 (PI)

Figure 11: Spreading glycerolo on the stopper n.1

Figure 12: Oven

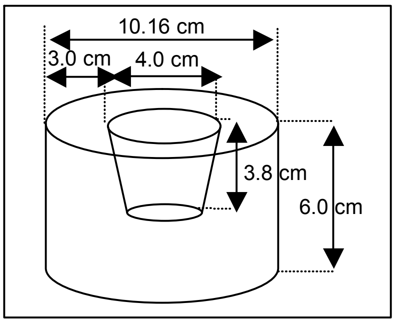


Figure 13: Scheme of specimen and corke 1

Figure 14: Hot mix asphalt in the Marshall mould

Figure 15: Compacted Marshall specimen and embedded stopper

Figure 16: Extraction of the stopper

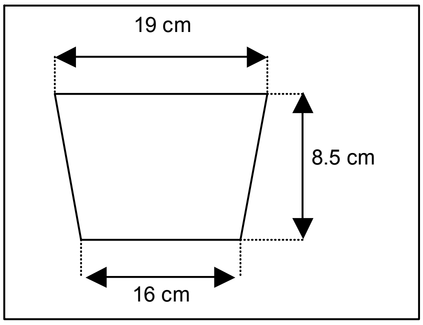


Figure 17: Scheme of the steel container

Figure 18: Steel container

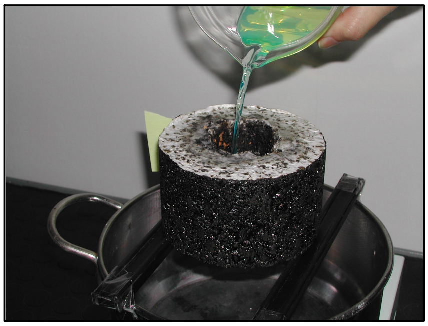


Figure 19: Letting hazardous material in the Marshall specimen

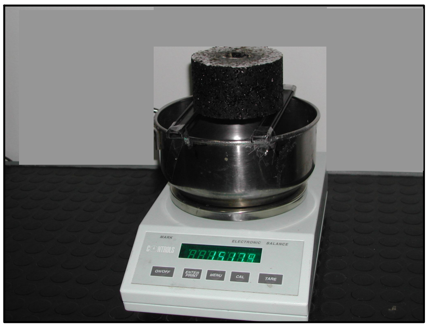


Figure 20: Weighting operations

RESULTS AND DISCUSSION

Herein results and discussion are reported by referring to the following scenario (see table 4):

Tab 4: Case-history considered

Course	Hazardous material	Number of specimens
Friction Course	Diesel oil	4
Binder Course	Diesel oil	4
Base Course	Diesel oil	4

Diesel oil characteristics are detailed in table 5.

Tab 5: Diesel characteristics

Density at 15°C		Viscosity at 40°C		Flash Point	Evaporation (% VV)	
Min=8.2 KN/m^3	Max=8.5 KN/m^3	Min=2 mm^2/sec	Max=4 mm^2/sec	55 °C	150 °C	2
					250 °C	64,5
					350 °C	85
					370 °C	95

Weighting procedure is herein explained (see Figure 21):

$G_D(t) = G_{MS}(t)+G_{SC}(t)+G_{HM}(t)+G_{HP}(t)$ (all the elements considered);
$G_{DW}(t) = G_{SC}(t)+G_{HP}(t)$ (without specimen);
$G_{HP}(t) = G_{DW}(t) - G_{SC}(t)$.
Where:
$G_D(t)$ = weight displayed in t (with Marshall specimen);
$G_{DW}(t)$ = weight displayed in t (without Marshall specimen);
$G_{MS}(t)$ = weight of Marshall specimen at time t (included plastic stirrups);
$G_{SC}(t)$ = weight of steel container at time t;
$G_{HM}(t)$ = weight of Hazmat contained in Marshall specimen at time t;
$G_{HP}(t)$ = weight of Hazmat percolated into the steel container, at time t.

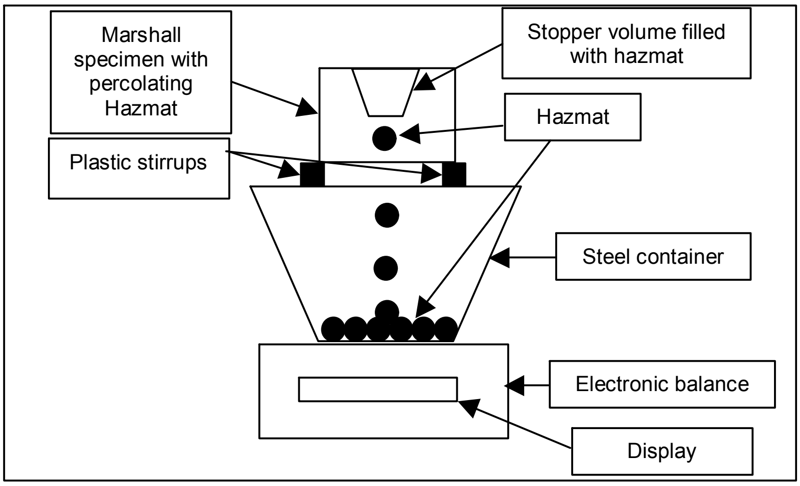


Figure 21: Weighting procedure

At first, below, the results for friction, binder and base course are separately reported and discussed.

Friction course.
Table 6 and Figure 22 show friction course composition. Figure 23 shows averaged $G_{MS}(t)$ (weight of Marshall specimen at time t) and $G_{HP}(t)$ (weight of Hazmat percolated into the steel container at time t).

Tab 6: Friction course characteristics (averaged values)

Thickness	Gradation			Gradation		
6,12 cm	Sieve [mm]	ANAS range	Percent Passing [%]	Sieve [mm]	ANAS range	Percent Passing [%]
Air voids	40	100	100,0	5	60-40	43,2
4.9 %	30	100	100,0	2	38-25	25,8
Asphalt content related to aggregates	25	100	100,0	0,4	20-10	13,9
5.7 %	15	100-90	99,7	0,18	15-8	7,7
	10	90-70	82,7	0,075	10-6	4,2

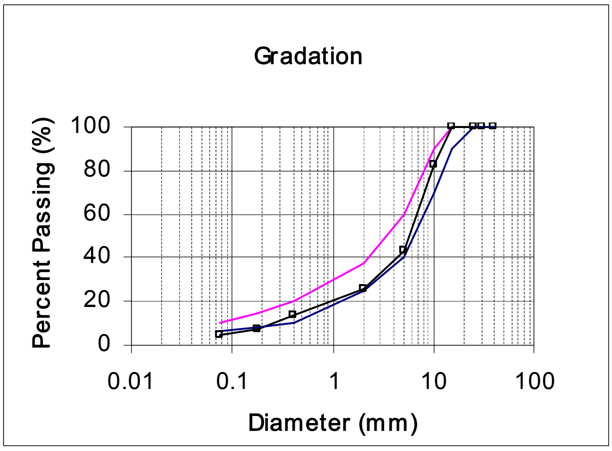


Figure 22: Gradation (Friction course)

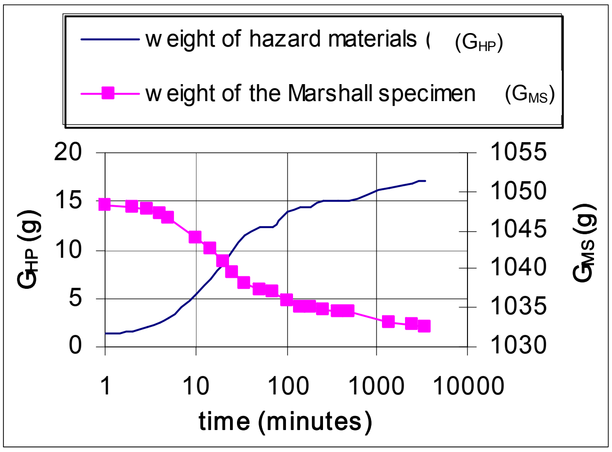


Figure 23: Weights G_{MS} and G_{HP} versus time (friction course, averaged values)

Figure 23 shows how G_{HP} increases and G_{MS} decreases in time. One can remark that three main ranges can be detected in figure 23: a) first ten minutes, with small gradient and positive second derivative; b) t=10~100 minutes, with a somewhat linear behavior; c) t>100 minutes, with a behavior approaching a zero–derivative condition (negative second derivative). A particular log-logistic fitting curve was successfully tested. Results are summarized in table 11.

Binder Course.

Table 7 and Figure 24 deal with binder course composition. Figure 25 shows averaged G_{MS} (t) and G_{HP}(t) for the analyzed specimens.

Tab 7: Binder course characteristics (averaged values)

Thickness	Gradation			Gradation		
6,20 cm	Sieve [mm]	ANAS range	Percent Passing [%]	Sieve [mm]	ANAS range	Percent Passing [%]
Air voids	40	100	100.0	5	30-60	40.0
5,7 %	30	100	100.0	2	20-45	27.2
Asphalt content related to aggregates	25	100	92.2	0.4	7-25	13.7
4,8 %	15	65-100	69.9	0.18	5-15	7.0
	10	50-80	50.2	0.075	4-8	4.0

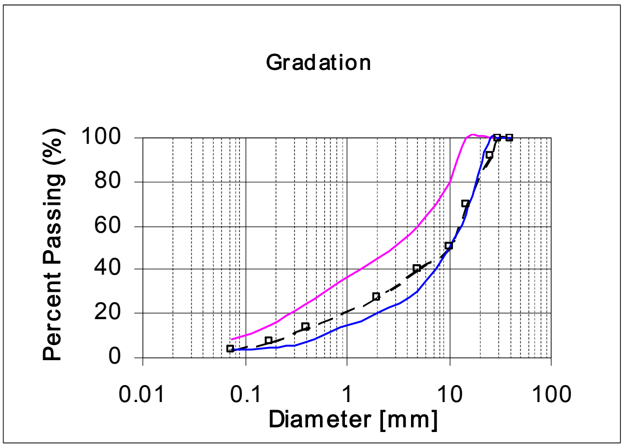


Figure 24: Gradation (Binder course)

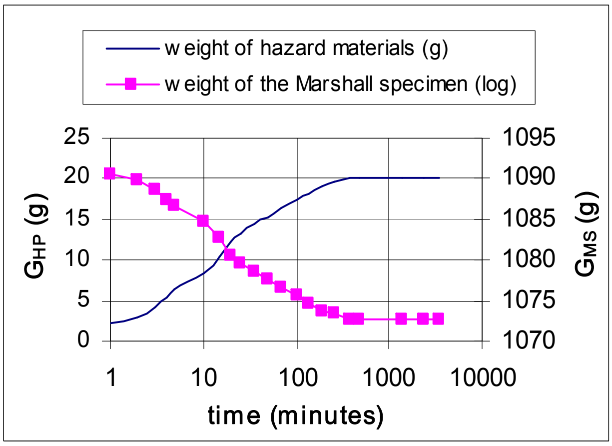


Figure 25: G_{MS}(t) and G_{HP} (t) for binder course (averaged values)

Figure 25 shows how G_{HP} increases (with a log-logistic behavior) and G_{MS} decreases in time.

Base Course.

Table 8 and Figure 26 deal with Base course composition.

Tab 8: Base course characteristics (averaged values)

Thickness	Gradation			Gradation		
6,36 cm	Sieve [mm]	ANAS range	Percent Passing [%]	Sieve [mm]	ANAS range	Percent Passing [%]
Air voids	40	100	100.0	5	25-50	35.6
6,2 %	30	80-100	87.1	2	20-40	27.8
Asphalt content related to aggregates	25	70-95	64.3	0.4	6-20	15.4
4.5 %	15	45-70	50.4	0.18	4-14	8.5
	10	35-60	42.3	0.075	4-8	4.3

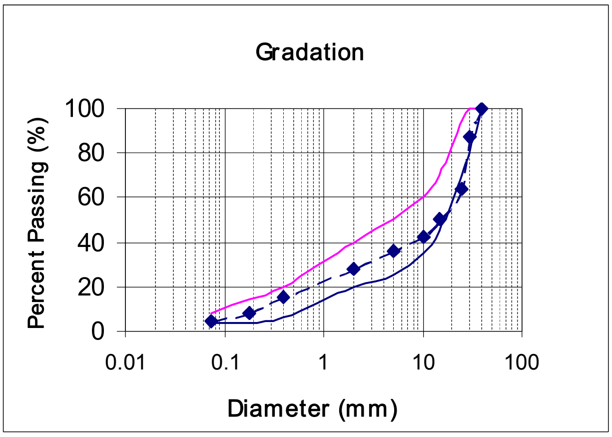


Figure 26: Gradation (Base course)

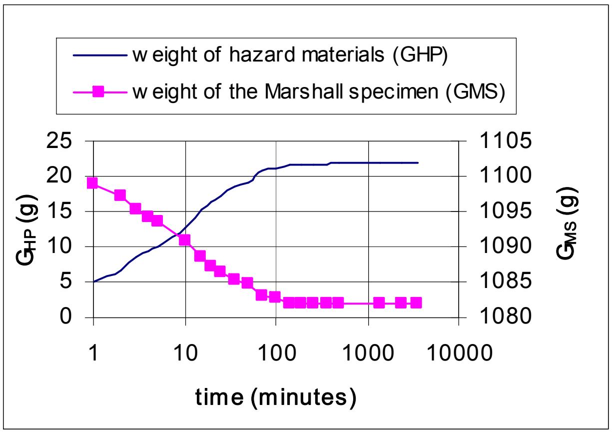


Figure 27: G_{HP} (t) and G_{MS} (t) (base course, averaged values)

Figure 27 shows how G_{HP} increases and G_{MS} decreases in time. Also in this case, the behavior seems well fitted by a log-logistic curve (see table 11).

Comparison.
Table 9 (in appendices), tables 10 to 11, and figures 28 to 33 deal with the comparison among the different courses.

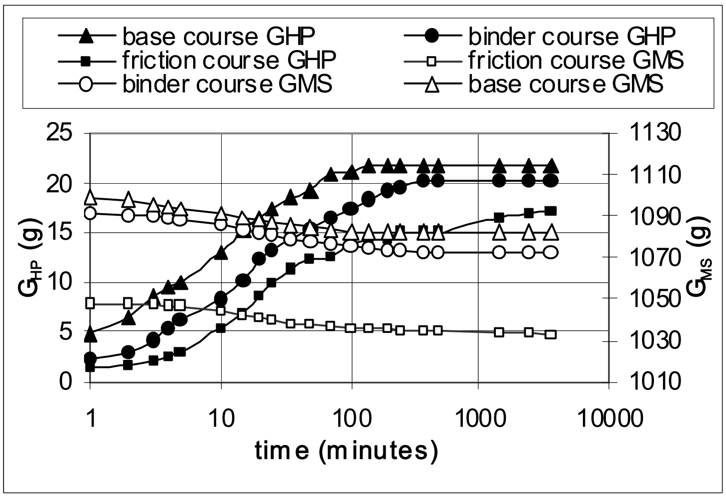


Figure 28: Weight of hazardous material (G_{HP}) for the different courses, versus time

Figure 28 shows an asymptotic behavior as time increases. On the contrary, Hazmat flow rate seems to have a different behavior in time (see figures 29 and 30). Power fitting curves well interpolate real values and R-square coefficients range from 0.94 to 0.99. Figures 31 to 33 deal with G_{HP} percentages in time.

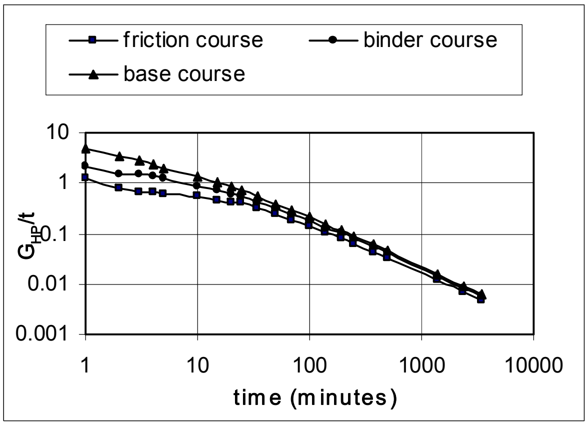


Figure 29: Flow rate (G_{HP}/t) in the different courses versus time

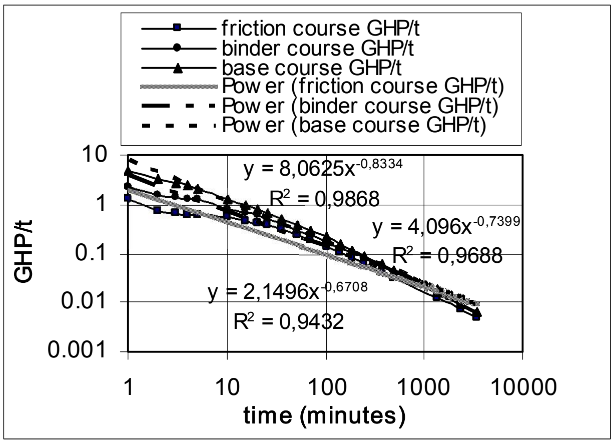


Figure 30: G_{HP}/t (t) and fitting power curves

Given that, G_{HP} percentages were obtained (see figures 31 to 33).

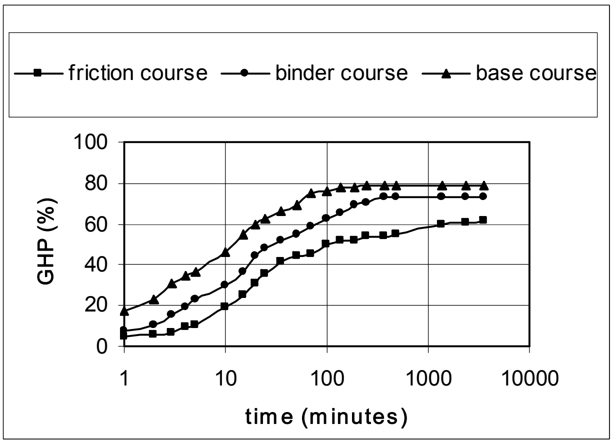


Figure 31: G_{HP} values (percentages) in the different courses versus time

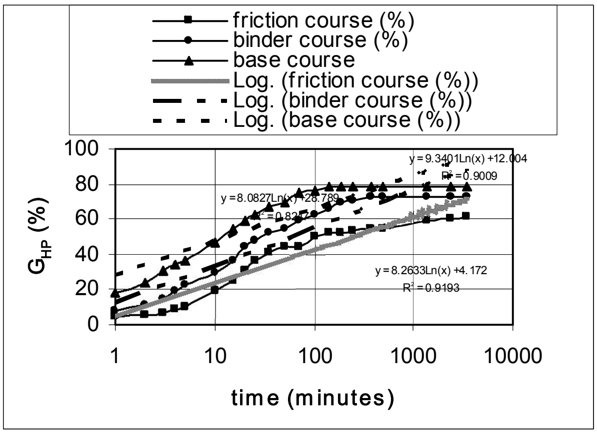


Figure 32: G_{HP} (%) and fitting logarithm curves

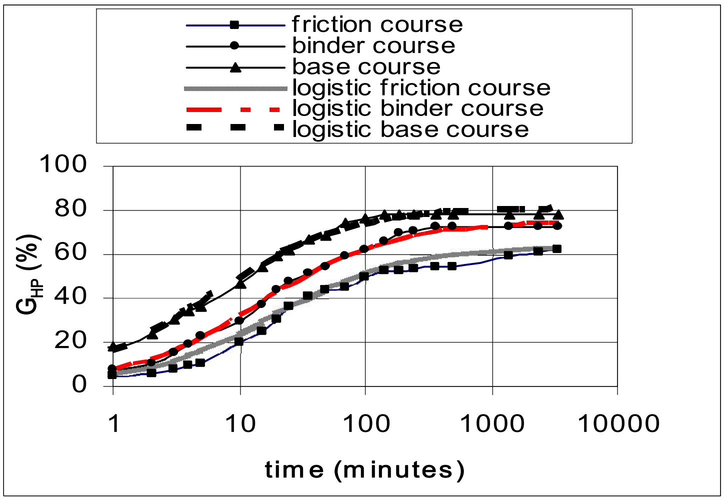


Figure 33: G_{HP} (%) and log - logistic approximation

Typical values and fitting curves are herein listed (see tables 10 to 11).

Tab 10: G_{HP} percentages in time

Time	Friction course	Binder course	Base course
First minute	4,60 %	7,91 %	17,73 %
First 10 minutes	19,53 %	29,68 %	46,26 %
First 100 minutes	49,78 %	62,23 %	75,72 %
From 10 to 100 minutes	30, 25 %	32,55 %	29,46 %

Tab 11: Experimental curves

Course	G_{HP} (t)	G_{HP} (%)	G_{HP}/t (t)
Friction	$G_{HP} = \frac{18}{1+10\cdot(0,2)^{Log(t)}}$ $R^2 = 0,981$	$G_{HP}(\%) = \frac{64}{1+11\cdot(0.15)^{Log(t)}}$ $R^2 = 0,992$	y = 2,1496x-0,6708 $R^2 = 0,943$
	y = 2,2972Ln(x) + 1,1598 $R^2 = 0,9193$	y = 8,2633Ln(x) + 4,172 $R^2 = 0,9193$	
Binder	$G_{HP} = \frac{20}{1+12\cdot(0,1)^{Log(t)}}$ $R^2 = 0,994$	$G_{HP}(\%) = \frac{75}{1+9\cdot(0.15)^{Log(t)}}$ $R^2 = 0,997$	y = 4,096x-0,7399 $R^2 = 0,969$
	y = 2,5965Ln(x) + 3,3372 $R^2 = 0,9009$	y = 9,3401Ln(x) + 12,004 $R^2 = 0,9009$	
Base	$G_{HP} = \frac{24}{1+4\cdot(0,2)^{Log(t)}}$ $R^2 = 0,983$	$G_{HP}(\%) = \frac{81}{1+4\cdot(0.16)^{Log(t)}}$ $R^2 = 0,995$	y = 8,0625x-0,8334 $R^2 = 0,987$
	y = 2,247Ln(x) + 8,0033 $R^2 = 0,8247$	y = 8,0827Ln(x) + 28,789 $R^2 = 0,8247$	

As one can observe the particular log-logistic fitting curves here used (see table 11) better take into account two basic concepts:
- if $t \to 0$, then G_{HP} (%) $\to 0$;
- if $t \to \infty$ G_{HP} (%) tends to max G_{HP}.

Importantly the gradient in 1' – 100'', apart from theoretical aspects, results quite constant: about 30% of the Hazmat percolates in this period. It is significant to remark that, by referring to $y = \frac{a}{1+b\cdot q^{Log(t)}}$, for each course, $a \cong$ max G_{HP}, $b \cong 4 \div 11$, $q \cong 0,15 \div 0,16$. Importantly a is different from 100 because real cases were considered (observation time = 2÷3 days).

FINAL OBSERVATIONS

In the light of the above the following observations can be drown:

- GALILEO satellite system, thanks to the improved accuracy, could greatly upgrade emergency processes in road transportation of Hazmat; the formalized model focuses the consequent upgrades both in term of probability and magnitude;
- Permeability can be a strategic parameter in ruling the magnitude of the risk when accidents occur involving Hazmats; the formalized model tries to quantify the relative effects;
- Experiments and studies show two leading concepts. Permeability can be substantially different also for slight variations of air voids of asphalt mixes. Though permeability must be considered a main factor in reducing magnitude, it doesn't explain exhaustively the chemical compatibility between asphalt and pollutant.

REFERENCES

ABKOWITZ M., M. Lepofsky, and P. Cheng (1992), "Selecting Criteria for Designating Hazardous Materials Highway Routes", *Transportation Research Record*, 1333, 30-35.

AIRSAFE.com (2003), "Risk Assessment Basics", Critical information for the traveling public

ALP, E. (1995), "Risk –based Transportation Planning Practice: Overall Methodology and a case Example", *INFOR* 33, 4-19.

ARCHITETTURA TELEMATICA ITALIANA PER IL SISTEMA DEI TRASPORTI (2003), "L'architettura logica", Ministero delle Infrastrutture e dei trasporti

ASIAN DISASTER REDUCTION CENTER (2005), "Total disaster Risk Management", ch.1

ASTORRI F., Cerritelli R., Colombo F., Ferrari C., Lombardi M., Rossini V., Spadoni G., Stefanelli R. (2000), "La Valutazione del rischio ambientale connesso alla diffusione nel terreno di sostanze classificate R50 e R51/53: Affidabilità delle previsioni in relazione alla disponibilità di dati"

AUSTRALIAN GOVERNMENT (2004), "What is risk?", Geoscience Australia

BELLORINI A. (2005), "Overview of risk assessment principles and methodologies", La ricerca europea nell'ambito del rischio tecnologico

BELL R., Glade T. (2004), "Quantitative risk analysis for landslides – Examples from Bildudalur, NW-Iceland", Natural Hazards and Earth System Sciences, 117-131

BLINKOVA O. (2002), "GPS/Galileo", Expert, p. 62-63, No. 46

BLONG, R. (1996), "Volcanic Hazards Risk Assessment", pp. 675-698 in R. Scarpa and R.I. Tilling (eds.), 1996, *Monitoring and Mitigation of Volcano Hazards*, Springer-Verlag Berlin Heidelberg New York.
BOOTH S. (2003), "GPS+GLONASS: vale la pena ?", Engineering surveying show case, issue two
BORSI I (2000), "Progetto Soils: diffusione degli inquinanti nei suoli e nelle falde acquifere", I2T3
BOSCAINO G., Praticò F. G., Vaiana R. (2001), "Sversamenti inquinanti su pavimentazioni stradali e rischi conseguenti al decadimento delle proprietà superficiali: indagine sperimentale", XI Convegno SIIV, Verona
BRUNO V.(2005), "Convivere con il Rischio", *Asti Contemporanea*, 3, p.145
COMPREHENSIVE RISK ANALYSIS AND MANAGEMENT NETWORK (2003), Zurich
CONTRERAS H. (1998), "GPS+GLONASS Technology at Chuquicamata Mine", Geocom S.A., Chile
CRICHTON, D. (1999), "The Risk Triangle", pp. 102-103 in Ingleton, J. (ed.), *Natural Disaster Management*, Tudor Rose, London.
DE LA CRUZ-Reyna, S. (1996), "Long-Term Probabilistic Analysis of Future Explosive Eruptions", pp. 599-629 in R. Scarpa and R.I. Tilling (eds.) (1996), Monitoring and Mitigation of Volcano Hazards, Springer-Verlag Berlin Heidelberg New York.
DISTEFANO (2004), "I principi della sicurezza"
ERKUT E., Ingolfsson A. (2000), "Catastrophe avoidance Models for hazardous materials route planning", Transportation Science, 34, 165-179
ESA - EUROPEAN COMMISION (2003), "Galileo The European Programme for Global Navigation Services", ESA Publications Division, Netherlands
EUROPEAN COMMISION (2003), "Intelligent Transport Systems" , Energy and Transport DG B-1049 Brussels
FRISCHKNECHT C., Romerio F., Rossiaud J., Wagner J-J., Bertrand S., Laporte J-D., Harding T.-W. (2003), "Integrated "Natural" Risk Management: The basic assessment; an essay ", DRPI-IIASA 3rd International Conference on Intrgrated Disaster Risk Management, Kyoto, Japan
GEOGRAPHY HAZARDS (2005), "Risk Research"
GEORISK (1998), "Management Terminology"
GRANGER, K., T. Jones, M. Leiba, and G. Scott. (1999), *Community Risk in Cairns: A Multi-hazard Risk Assessment.* AGSO (Australian Geological Survey Organisation) Cities Project, Department of Industry, Science and Resources, Australia
HAYS W. W. (2002), "Risk Assessment – Involves Hazard, exposure, and vulnerability on local, national, regional, and global scales"
HELM P. (1996), "Integrated Risk Management for Natural and Technological disaster", Tephra, vol. 15, no. June 1996, pp.4-13
HEWITSON S., Wang J. (2003), "GPS/GLONASS/GALILEO integration: separation of outliers", School of Surveying and spatial information systems, The University of New South Wales, Sydney, Australia
HUFF Warren D. (2001), "Volcanic Hazard vs. Volcanic Risk"
HUSDAL J (2004) , Molde Unjiversity college, Molde, Norway "Reliability and vulnerability versus costs and benefits"
LABORATORIO GEOMATICO "Navstar GPS", GPS Basics della Leica Geosystems
LANGLEY R. B. (2001), "GPS and E-911: an update on the technology", Geodetic Research Laboratory Department of Geodesy and geomatics engineering, University of New Brunswick Fredericton, N.B.
MAGELLAN CORPORATION (2000), "GPS+GLONASS Technology and the GG24™ Receiver"
NATIONAL IMAGERY and MAPPING AGENCY, "Satellite Navigation", ch. 11
NELSON S.A. (2004), "Assessing Hazards and Risk", *Earth & Environmental Sciences 204 & 605*
PITEA D., De Cesaris A.L, Marchetti G. (1997), *Criteri per la valutazione della qualità dei suoli*, Fondazione Lombardia per l'ambiente, Milano (Italy)
PROTEZIONE CIVILE (2004), "Rischio Vulcanico"
REVNIVYKH S. (2004), "Developments of the Glonass system and Glonass Service", 10th Anniversary of the international GPS Service IGS Work Shop and Symposium, Berne, Switzerland
RISK awareness and assessment, 2, (2005)
SAAT M. R., Barkan C.P.L. (2005), "Release Risk as Metric for Evaluating Tank Car Safety Performance", [CD-ROM] TRB Annual Meeting
SASKATCHEWAN Labour (2005)
SAYERS, P.B., B.P. Gouldby, J.D. Simm, I. Meadowcroft, and J. Hall. (2002). Risk, Performance and Uncertainty in Flood and Coastal Defence – A Review. R&D Technical Report FD2302/TR1 (HR Wallingford Report SR587), Crown copyright, London, U.K. See also Sayers, P., J. Hall, and I. Meadowcroft, "Towards Risk-Based Flood Hazard Management in the U.K.". Proceedings of the Institution of Civil Engineers, vol. 150, special issue 1, pp. 36-42.
SCANDONE et al. (1983), Problems Related with the Evaluation of Volcanic Risk, In H. Tazieff, J.C. Sabroux editors: "Forecasting Volcanic Events" pp. 57-67, Elsevier Pu.Co., Amsterdam
SIVAKUMAR, R., R. Batta, and M. H. Karwan (1993a), "Establishing Credible Risk Criteria for Transporting Extremely Dangerous Hazardous Materials", in Transportation of Dangerous Goods: Assessing the Risks, ed. By F.F. Saccomanno and K. Cassidy, Institute for Risk Research, Univ. of Waterloo, Canada, pp.335-342

SMITH K (1996), *Environmental Hazards: Assessing Risk and Reducing Disaster, 2nd ed.* Routledge, London/U.S.A./Canada.
STENCHION, P. (1997), “Development and disaster management”. *The Australian Journal of Emergency Management*, vol. 12, no. 3, Spring 1997, pp. 40-44
TECHINICAL ANNEX (2004)
TOYOS G. (2005), “GIS & Volcanic Risk”, Napoli & Mt. Somma – Vesuvio
UN DHA. (1992), *Internationally Agreed Glossary of Basic Terms Related to Disaster Management.* UN DHA (United Nations Department of Humanitarian Affairs), Geneva
WISNER B. (2001), “Notes on Social Vulnerability: Categories, Situations, Capabilities, and circumstances”, Environmental Studies Program Oberlin College
ZIMMERMANN M. N. (2005) “The Risk Concept”, World Conference on Disaster Reduction (WCDR), Kobe, Session 1.8, pp.1-12
ZBIGNIEW W. KUNDZEWICZ (2004), “Vulnerability, risk and adaptation to climate change”, Bonn, Germany
ZOPPOU C. (2003), “Risk business”, AusGEO

APPENDICES

Tab 1: Some definitions of the Risk

Relation			Definition [Author(s)]
R = P×M			
R =	P ×	M	R = Risk; P = frequency of the event in the given time [event/year]; M = magnitude of the damage [damage/event]. (BRUNO, 2005)
R =	P ×	H	R = Risk; P = Probability; H = Hazard. *Risk (R) is defined as the product of a hazard (H) (such as damage cost) and the probability (P) that this hazard occurs.* (AIS, 2003)
R =	P ×	V × E	R = Risk; P = Hazard is the probability of occurrence of a potentially damage within a specified period of time, within a given area and given magnitude; V = Vulnerability of the element (people, building, infrastructure, economic activity) is the propensity to suffer damages for external circumstance; E = Exposition elements at risk (such as population or buildings). (PR.CIV, 2004)
a) R = b) R =	P × P (ec) ×	C V (ec)	a) R = Risk; P = Probability; C = Consequence; b) P (ec)= Probability of an external circumstance occurring; V(ec) = Vulnerability to the occurrence of an external circumstance (ec) or threat. (HUSDAL, 2004)
R =	P ×	S	R = Risk describes the odds that a hazard will cause harm. It refers to the probability and severity of potential accidents and dangerous occurrences (so called “near misses”); P = Probability is the chance that a hazard will cause harm; probability is often categorized as: frequent (workers are frequently at risk), probable (the hazard is likely to cause harm), occasional (workers are occasionally at risk), remote (the hazard could cause harm, but is very unlikely to do so), improbable (the hazard is unlikely to ever cause harm); S = Severity is the seriousness of the harm that could result from contact with a hazard; it is described as: catastrophic (death and/or severe destruction), critical (serious injury and/or property damage), marginal (minor injury - property damage), negligible (no injury and/or property damage). (SASKATCHEWAN, 2005)
R =	P ×	C	R = Risk; P = probability of failure; C = Cost of failure. (KUNDZEWICZ, 2004)
R =	P ×	C	R = Risk; P = probability conditional of event occurring; C = consequences of the event *The estimation of risk is usually based on the expected value of the conditional probability of the event occurring, multiplied by the consequences of the event, given that it has occurred. (Society of Risk Analysis).* (CRN, 2003)
R =	P ×	C	R = Risk; P = Probability; C = Consequences. (HELM, 1996)
R =	P ×	C	R = Risk; P = Probability; C = Consequences *“Risk is a combination of the chance of a particular event, with the impact that the event would cause if it occurred. Risk therefore has two components – the chance (or probability) of an event occurring and the impact (or consequence) associated with that event. The consequence of an event may be either desiderable or undesiderable.* (SAYERS et al, 2002)
R =	P ×	D	R = Risk; P = probability that an event will cause; D = amount of damage, or a statement of the economic impact in monetary terms that an event will cause. (NELSON, 2004)
R =	P ×	L	R = Risk; P = Probability; L = Loss *“Risk is the actual exposure of something of human value to a hazard and is often regarded as the combination of probability and loss”.* (SMITH, 1996)
R =	P ×	V	R = Risk; P = Probability; V =Vulnerability *“Risk might be defined simply as the probability of the occurrence of an undesired event [but] be better described as the probability of a hazard contributing to a potential disaster.. importantly, it involves consideration of vulnerability to the hazard”.* (STEN, 1997)
Tab 1: Some definitions of the Risk - continued			

R =	F ×	M	R = Risk; F = Frequency wait of event undesired; M = Magnitude damage (DISTEFANO, 2004)
R = H×M			**Definition [Author(s)]**
R =	H ×	$V_a \times V_u$	R = Risk; H = The Hazard is the probability that a certain area will be invested by a certain volcanic phenomenology; V_a = The Value is the number of lives or the monetary value of goods at risk in a volcanic area; V_u = The Vulnerability is the percentage of lives or goods likely to be lost because of a given volcanic event. (SCANDONE et al, 1983)
a) R= b) R_{ipe}= c) R_{pe}=	H × H × H ×	C × E $(P_s \times P_t \times V_p \times V_{pe} \times P_{so}) \times E_{ipe}$ $(P_s \times P_t \times V_p \times V_{pe} \times P_{so}) \times E_{pe}$	H=Natural hazard defined as the probability of occurrence of a potentially damaging phenomenon within a specified period of time, within a given area and given magnitude; E=Elements at risk referring to people, houses, etc; C=Consequence defined as the (potential) outcomes arising from the occurrence of a natural phenomenon (including the vulnerability, the probability of temporal and spatial impact as well as the probability of seasonal occurrence), where **(*)** $\mathbf{C=P_s*P_t*V_p*V_{pe}*P_{so}}$ with: P_s=probability of spatial impact given an event (i.e. of the hazardous event impacting a building); P_t=probability of temporal impact given an event (i.e. of the building being occupied); V_p=vulnerability of the building; V_{pe}= vulnerability of the people; P_{so}=probability of seasonal occurrence (e.g. snow avalanches only in winter). From Eqs. a) and (*) result: b) Individual risk to people in buildings, where R_{ipe}= Individual risk to people in buildings (annual probability of loss of life to an individual), E_{ipe}=individual person in a building; c) Object risk to people in buildings, where R_{pe}= risk to people in buildings (annual probability of loss of life), E_{pe}=number of people in building. (BELL et al, 2004)
R = R =	H × P_h ×	Pop×Vul E_{xp}×Vul	R = is the risk (number of killed people); H = is the hazard, which depends on the frequency and strength of a given hazard; Pop = is the population living in a given exposed area; Vul = is the vulnerability and depends on the socio-political-economical context of this population Hazard multiplied by the population was used to calculate physical exposure: P_hE_{xp} = is the physical exposure, i.e. the frequency and severity multiplied by exposed population. (TEC.AN 2004)
R =	H ×	V	R = Risk; H = Hazard (frequency, magnitude); V = Vulnerability (exposure, value, susceptibility). (ZIMMERMANN, 2005)
R =	H ×	$V_a \times V_u$	R = Risk: "seriousness" of effects in terms of the value; H = Hazard: solely related to the event (i.e. value independent); V_a = Value: cost (can be economic, or in human lives, no of buildings etc); V_u = Vulnerability: probability that value will be effected by hazard. (HUFF, 2001)
R =	H ×	V × E	R = Risk; H = Hazards; V = Vulnerability; E = Elements at Risk (such as population or buildings) (AUS.GOV, 2004)
R =	H ×	L /p	R = Risk; H = Hazard (probability); L = Loss (expected); p = preparedness (loss mitigation). (GEOGRAPHY, 2005)
R =	H ×	V - C	R = Risk; H = Hazard; V = vulnerability (social vulnerability); C = capability (coping, adjustment, adaptation) (WISNER, 2001)
R =	H ×	V/C	R = Risk (the probability of harmful consequences, or expected loss (of lives, people injured, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human induced hazards and vulnerability/capable conditions); H = Hazard (the probability of occurrence for a given threat); V = Vulnerability (the degree of susceptibility of the element exposed to that source); C = Capacity (The manner in which people and organizations use existing resources to achieve various beneficial ends during unusual, abnormal, and adverse conditions of a disaster event or process. (RISK, 2005)
a) R = b) R =	H × P×	V I ×V	R = Risk (a measure of the expected losses due to hazard event of a particular magnitude occurring in a given area over a specific time period) V = vulnerability (the extent to which a community, structure, service or geographical area is likely to be damaged or disrupted by the impact of a particular hazard) H = Hazard = Probability (P) * Intensity (I) (time) P = Probability (or Return Period) I = Intensity (e.g. peak discharge, peak ground acceleration). (BELLORINI, 2005)
R =	H ×	E × V	R = Risk; H = Natural Hazard (probability of occurrence, within a specific period of time, in a given area, of a potentially damaging natural phenomenon); V = Vulnerability (the degree of loss between 0 and 1 of an element a risk, or of a number of such elements, resulting from the occurrence of a natural phenomenon of a given magnitude); E = Elements at risk (population, buildings and civil engineering works, economic activities, public services,

Tab 1: Some definitions of the Risk - continued

R =	H ×	E × V	R = Risk; H = Hazard; E = Elements at risk; V = Vulnerability of elements at risk. (BLONG, 1996)
R =	H ×	$V_u \times V_a \times P_r$	R = Risk; H = Hazard; V_u = Vulnerability; V_a = Value (of the threatened area); P_r = Preparedness. (DE LA CRUZ, 1996)
R =	H ×	V × E	R = Risk; H = Hazard; V = Vulnerability; E = Elements at Risk *"Risk (i.e. total risk) means the expected number of lives lost, persons injured, damage to property and disruption of economic activity due to a particular natural phenomenon, and consequently the product of specific risk and elements at risk".* (GRANGER et al, 1999)
R =	H ×	V	R = Risk; H = Hazard; V =Vulnerability *"Risk is expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability."* . (UN DHA, 1992)
R as function			**Definition [Author(s)]**
R = f(H, V)			R = Risk: expected loss in terms of human lives, assets, etc; H = Hazard: probability that natural event of a given magnitude will affect a given location within a certain period of time; V = Vulnerability: Characteristics of an individual or group to cope with, resist, and recover from the impact of a natural phenomenon (i.e. resistance, resilience and susceptibility). Also defined with respect to the losses expected for an element at risk exposed to a specific hazard intensity. (TOYOS, 2005)
R = f(H, E, V, L)			R = Risk; H = Hazard; E = Exposure; V = Vulnerability; L = Location (HAYS, 2002)
R = f(H, E, V)			R = Risk; H = Hazard (is a natural event with the potential to cause harm. It is characterized by a certain probability of occurrence and a spatially variable intensity); E = Exposure (refers to elements such as people, buildings and lifelines that are subject to the impact of a hazard); V = Vulnerability (refers to the likelihood that these elements, when exposed to a hazard, will be affected by it. (ZOPPOU, 2003)
R = f(H, E, V)			R = Risk (is defined as the expectation value of losses (deaths, injuries, property, etc.) that would be caused by a hazard; H = Hazard (Earthquakes, torrential rains, storms etc.); E = Exposure (is another component of disaster risk, and refers to that which is affected by natural disasters, such as people and property); V = Vulnerability (is defined as a condition resulting from physical, social, economic, and environmental factors or processes, which increases the susceptibility of a community to the impact of a hazard). (ADRC, 2005)
R = f(H, V, E)			R = Risk; H = Hazard; E = Exposure; V = Vulnerability of elements at risk *"Risk is the probability of a loss, and this depends on three elements, hazard, vulnerability and exposure". If any of these three elements in risk increases or decreases, then risk increases or decreases respectively.* (CRICHTON, 1999)
R = f(H,V,E)			R = Risk: The convolution of exposure, hazard and vulnerability H = Hazard: Refers to the frequency and severity of a threat inflicting losses on people, property, systems or functions V =Vulnerability: The susceptibility to losses due to exposure to hazard. Vulnerability reflects the extend of losses any given hazard. E = Exposure: People, property, systems or functions at risk of partial or total loss exposed to hazards. (GEORISK, 1998)
R as expression			**Definition [Author(s)]**
RR =	$\sum_{i=1}^{m}\sum_{j=1}^{n} RR_{i,j}$		RR = Relase Risk for a tank car in percentage of tank capacity lost per mile traveled m = number of release sources considered n = number of release sizes considered $RR_{i,j}$ = Risk for Release size i from release source j. (SAAT et al, 2005)
RR_{TR} =	(1) $\sum_{i=1}^{m} F_{i,TR} \cdot V_{i,TR}$		RR_{TR}=Risk for tank-caused release $F_{i,TR}$(frequency of tank-caused release of size i)= $P_{i,TR}$ * M M = number of car – miles $P_{i,TR}$ (Probability of tank-caused release of size i) =P(R_i|TR)*(P(TR)) Where: P(R_i|TR) = conditional probability of release size i given a tank - caused P(TR) (probability of a tank-caused release occurrence)= P(TR|A)*P(A) Where: P(TR|A) =(conditional probability of a tank-caused release occurrence given the car is derailed in an accident) P(A)=(probability of a tank car derailed in an accident per mile traveled) Thus, equation (1) can be modified as follows: $F_{i,TR}$ = P(R_i|TR)* P(TR|A)* P(A)*M $V_{i,TR}$=(average percentage of a tank capacity lost for release size i in a tank-caused release occurrence) (SAAT et al, 2005)

Tab 1: Some definitions of the Risk - continued

RR_{NR} =	(2) $\sum_{i=1}^{m} F_{i,NR} * V_{i,NR}$	$F_{i,,NR}$(frequency of non-tank-caused release of size i)= $P_{i,NR}$ * M M = number of car – miles; $P_{i,NR}$ (probability of non-tank-caused release of size i)= $P(R_i\|NR)*P(NR)$ Where: $P(R_i\|NR)$ (conditional probability of release size I given a non-tank-caused release occurrence) P(NR) (probability of a non-tank-caused release occurrence = P(NR|A)*P(A) Where: P(NR|A) (conditional probability of a non-tank-caused release occurrence given the car is derailed in an accident) P(A) (probability of a tank car derailed in an accident per mile traveled) Thus, equation (2) can be modified as follows: $F_{i,TR} = P(R_i\|NR)* P(NR\|A)* P(A)*M$ $V_{i,\ NR}$=(average percentage of a tank capacity lost for release size i in a non-tank-caused release accident) (SAAT et al, 2005)
MM (r) =	$\max_{i\in r} C_i$	MM =Minimax; C_i = measure of the consequence of a release accident on link i of a path r. (ERKUT et al, 2000)
CR (r) =	$\sum_{i\in r} p_iC_i / \sum_{i\in r} p_i$	CR = Conditional Risk; p_i = probability of a release accident on link I; C_i = measure of the consequence of a release accident on link i of a path r (SIVAKUMAR et al, 1993)
TR (r) =	$\sum_{i\in r} P_i$ C_i	TR = Traditional Risk; P_i =probability of a release accident on link I; C_i = measure of the consequence of a release accident on link i of a path r. (ALP, 1995)
PR (r) =	$\sum_{i\in r} p_i$ C_i	PR = Perceived risk; p_i = probability of a release accident on link I; C_i = measure of the consequence of a release accident on link i of a path r. (ABKOWITZ et al, 1992)

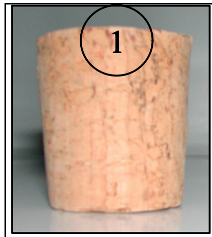
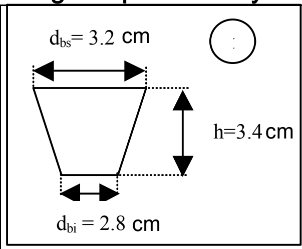
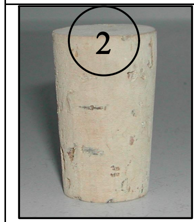
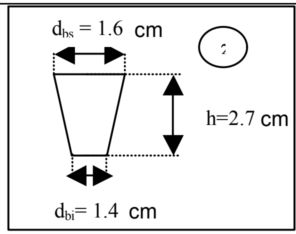
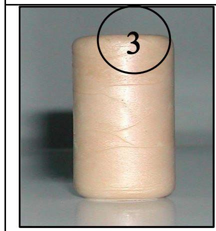
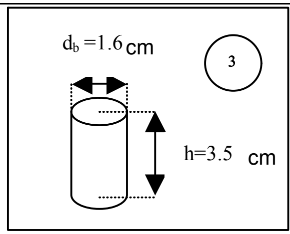
Tab 2: Benefits, requirements, applications of tracking systems

Tracking System	Concept	Characteristics	Benefits/Difficulties	Requirements
GPS (Global **P**ositioning **S**ystem-USA)	The **G**lobal **P**ositioning **S**ystem measures distances between satellites in orbit and a receiver on Earth, and computes spheres of position from those distances. The intersections of those spheres of position then determine the receiver's position (NIMA).	Applications: world; **Accuracy: 10-20 m (BLINKOVA, 2002) (with Differential GPS (DGPS) corrections the accuracy is of 0.5-5m) (LAB GEOMATICO);** Altitude: 20.200 km; Orbital Period: 12 hrs (semi-synchronous); Orbital Plane: 55 degrees; Number of Planes: 6; Vehicles plane: 4-5; Constellation size: >24 satellites (LANGLEY, 2001); Signals: CDMA (Code Division Multiple Access for GPS). Each of the 24 satellites circles the earth twice per day and transmits on 2 sub-bands: The first carrier frequency (L1) transmits on 1575.42 MHz; The second (L2) transmits on 1227.60 MHz (NIMA); Separability (refers to the ability to distinguish or separate a measurements): 10.981 m (minimum maximum MSB – Minimal Separable Bias-Value); 42.310 m (average maximum MSB Value); 1276.655 m (Absolute maximum MSB Value) (HEWITSON, 2003); Military controlled system.	Extremely accurate, three-dimensional location information (providing latitude, longitude, and altitude); Precise timing services; A worldwide common spatial reference frame that is easily converted to any local frame, e.g., NAD 83; Continuous real-time information; Accessibility to an unlimited number of worldwide users. (LANGLEY, 2001) **Difficulties** GPS signals are relatively weak (actually buried in background noise); Signals cannot penetrate into concrete and steel buildings or underground; Signals can be blocked by buildings and other structures; Susceptible to interference or jamming; Reflected signals (multipath) cause position error (LANGLEY, 2001)	A higher degree of precision; Better reliability; A more homogeneous coverage; A guaranteed level of quality and continuity of service.
GLONASS (**GLO**bal **NA**vigation **S**atellite **S**ystem-Russian Federation)	The **GLONASS** under the control of the Russian military, has been in use since 1993. It continuously transmits coded signals in two frequency bands, which can be received by users anywhere on the Earth's surface to identify their position and velocity in real time. It is based on the same principles as GPS (NIMA).	Applications: world; **Accuracy: 10-20 m (BLINKOVA, 2002) (NIMA);** Altitude: 19.100 km; Orbital Period: 11 hrs (semi-synchronous); Orbital Plane: 64.8 degrees; Number of Planes: 3; Vehicles plane: 8 Constellation size : 24 satellites; Signals: FDMA (Frequency Division Multiple Access) system thus transmits using separate sub-bands for each satellite. The signals are in the L-band, operating in 25 channels with 0.5625 MHz separation in 2 bands: from 1602.5625 MHz to 1615.5 MHz and from 1240 to 1260 MHz; Military controlled system.	Benefits (REVNIVYKH, 2004): More robust navigation against interference, compensation of ionosphere delays due to new civil signals, Higher accuracy, availability, integrity, reliability, Supplementary functions (SAR, integrity and differential correction broadcasting). For Customers (REVNIVYKH, 2004): Operational cost reduction due to enhanced life-time of new satellites and ground control segment modernization. For International Cooperation (REVNIVYKH, 2004). Compatibility and interoperability of GLONASS, GPS, GALILEO and augmentations; No multipath (BOOTH, 2003).	Real time navigation information; Autonomous integrity checking; Accuracy sufficient for safe navigation.
GPS + GLONASS	**Accuracy: 7 m** (MACO, 2000); Satellite availability is increased by a factor of 1.5 (CONTRERAS, 1998); Positioning availability is increased by a factor of 2 (CONTRERAS, 1998); Ambiguity resolution is faster close to the base station (usually 5 km or less) and slower at about 5 km or more (CONTRERAS, 1998); GPS+GLONASS ambiguities are maintained fixed under literally every condition, with a very good response to multipath environment. GPS-only ambiguities are easily lost due to any nearby obstruction (CONTRERAS, 1998); Separability (refers to the ability to distinguish or separate a measurements): 9.502 m (minimum maximum MSB – Minimal Separable Bias-Value); 11.609 m (average maximum MSB Value); 29.905 m (Absolute maximum MSB Value) (HEWITSON, 2003).			
GALILEO (planned operation 2008) European Union	Satellite navigation pinpoints a location by measuring the distances to at least three known locations – the GALILEO satellites. The distance to one satellite defines a sphere of possible	Applications: world ; **Accuracy: 1 m (ESA, 2003);** Altitude: 23.616 km; Orbital Period: 14 hrs (semi-synchronous); Orbital Plane: 56 degrees; Number of Planes: 3; Vehicles plane: 10;	1. Benefits and management of parking; 2. Control and management of transit and stop of vehicles; 3. Control and management of transit of vehicles; 4. Traffic monitoring; 5. violation control; 6. freight and fleet management (EUC, 2003): reductions of trips made with empty or sparsely loaded cargo/passenger holds; optimizing the distance traveled, so as to	1. Useful in planning (ARTIST, 2003); 2. emergency measures (ARTIST, 2003); 3. information (ARTIST, 2003);

Tab 2: Benefits, requirements, applications of tracking systems - continued

	solutions. Combining three spheres defines a single, common area containing the unknown position. The accuracy of the distance measurements determines how small the common area is and thus the accuracy of the final location. In practice, a receiver captures time signals from the satellites and converts them into the respective distances.	Constellation size: 30 satellites (ESA, 2003); Signals : satellites spread their signals over designated bands (Code Division Multiple Access). The frequency band are: E5A-E5B, 1164-1215 MHz, allocated to RNSS (Radio Navigation Satellite Service) at WRC (World Radio Conference) -2000 in Istanbul (ESA, 2003); E6, 1260-1300 MHz, allocated to RNSS at WRC-2000 (ESA, 2003); E2-L1-E1, 1559-1591 MHz, allocated to RNSS prior to WRC-2000 and already used by GPS (ESA, 2003). Civil controlled system.	minimize the impact of vehicles on traffic flow and the environment; accident management programmes that enable response to accidents or breakdowns with the best and quickest type of emergency services, minimizing clean-up and response time; 7. driver assistance; 8. total coverage; 9. high reliability; 10. communication; 11. assurance; 12. people location; 13. competitiveness increase; 14. integration of systems (GPS); 15. social, policy, commercial return; 16. emergency and accident handling; 17. coordination of supervisory body (OI=supervisory body, CT=customer, T= truck driver); 18. rapid response to emergencies (EUC, 2003); 19. protection of coach and vehicle occupants.	4. traffic management (ARTIST, 2003); 5. driver assistance (ARTIST, 2003); 6. goods transportation and fleet management (ARTIST, 2003); 7. multimodal logistic cycle (ARTIST, 2003); 8. weather independence; 9. others.
GPS+GALILEO	Separability (refers to the ability to distinguish or separate a measurements): 9.292 m (minimum maximum MSB – Minimal Separable Bias-Value); 11.112 m (average maximum MSB Value); 23.963 m (Absolute maximum MSB Value) (HEWITSON, 2003).			
GPS+GALILEO+ GLONASS	Separability (refers to the ability to distinguish or separate a measurements): 8.926 m (minimum maximum MSB – Minimal Separable Bias-Value); 9.947 m (average maximum MSB Value); 14.487 m (Absolute maximum MSB Value) (HEWITSON, 2003).			

Tab 3: Characteristics of the stoppers used during the preliminary investigation

 	 	Cork of: height h=3.4 cm, diameter of the upper base d_{bs}=3.2 cm, diameter of the lower base d_{bi} = 2.8 cm. Note: chosen stopper.
 	 	Cork of: height h = 2.7 cm, diameter of the upper base d_{bs}=1.6 cm, diameter of the lower base d_{bi}=1.4 cm. Note: not chosen.
 	 	Plastic stopper of: height h = 3.5 cm, diameter d_b = 1.6 cm. Note: this stopper didn't resist to compaction temperatures.

Tab 9: Comparison among different courses

Friction Course		Binder course		Base course		T [minutes]
G_{HP} [g]	G_{MS} [g]	G_{HP} [g]	G_{MS} [g]	G_{HP} [g]	G_{MS} [g]	
1.28	1048.32	2.2	1091.28	4.93	1098.87	1
1.53	1048.07	3.01	1090.54	6.54	1097.26	2
2	1047.6	4.23	1089.89	8.52	1095.28	3
2.54	1047.06	5.4	1088.6	9.56	1094.24	4
2.96	1046.64	6.3	1087.98	10.05	1093.75	5
5.43	1044.17	8.25	1085.65	12.86	1090.94	10
6.99	1042.61	10.22	1083.8	15.18	1088.62	15
8.56	1041.04	12.3	1081.7	16.44	1087.36	20
9.99	1039.61	13.25	1080.7	17.29	1086.51	25
11.41	1038.19	14.4	1079.4	18.55	1085.25	35
12.28	1037.32	15.2	1077.7	19.17	1084.63	50
12.46	1037.14	16.4	1076.5	20.74	1083.06	70
13.84	1035.76	17.3	1075.6	21.05	1082.75	100
14.43	1035.17	18.2	1074.7	21.76	1082.04	140
14.46	1035.14	19.22	1073.68	21.78	1082.02	190
14.95	1034.65	19.5	1073.4	21.79	1082.01	250
15.02	1034.58	20.2	1072.7	21.8	1082	370
15.16	1034.44	20.22	1072.68	21.81	1081.99	490
16.49	1033.11	20.22	1072.68	21.82	1081.98	1390
16.82	1032.78	20.22	1072.68	21.84	1081.96	2410
17.19	1032.41	20.22	1072.68	21.84	1081.96	3490

Tab 12: Hazmat Risks and Damages affected by pavement permeability – some researches

<table>
<tr><th>Paper</th><th>Risks</th><th colspan="4">Damages</th></tr>
<tr><td>(ASTORRI et al, 2000)</td><td>Released LNAPL (Light Non Aqueous Phase Liquid)</td><td colspan="4">Aquifer pollution</td></tr>
<tr><td>(BORSI, 2000)</td><td>Percolation of pollutant with rain</td><td colspan="4">percolation in the insaturated zone; diffusion in the saturated zone</td></tr>
<tr><td>(PITEA et al, 1997)</td><td>Released pollutant</td><td colspan="4">• water-bed pollution;
• insaturated ground pollution;
• underground waters pollution.
The risk for water-bed depends on:
• the less permeable bed;
• the little distance of aquifer (<3m);
• the low thickness (<1m);
• the high coefficient of permeability (~10^{-3} cm/sec)</td></tr>
<tr><td rowspan="6">(BOSCAINO et al, 2001)</td><td rowspan="6">Released pollutant as: diesel oil, oil, acid</td><td rowspan="2">Properties of the material</td><td colspan="3">Released pollutant</td></tr>
<tr><td>Diesel oil</td><td>Oil</td><td>Acid</td></tr>
<tr><td>1) Mechanical Resistance of material</td><td>↓</td><td>↓</td><td>↓</td></tr>
<tr><td>2) Dry state (S) or lubricated (L) of the pavement surface</td><td>↓ (L)</td><td>↓(L)</td><td>↑↑ (S)</td></tr>
<tr><td>3) Average asperity density of the surface</td><td>↑↑ (S)</td><td>↑↑</td><td>↑</td></tr>
<tr><td>4) Friction resistance</td><td>↓</td><td>↓</td><td>↑</td></tr>
<tr><td colspan="6">Symbols:↓= negative result;↑ = positive result;↑↑ = very positive result</td></tr>
</table>