COST Action C17: "Built Heritage: Fire Loss to Historic Buildings"
International Workshop, Santa Maria della Scala, Siena, Italy: 7 - 8th April 2005

Summary Report

International Workshop Associated Introductory Papers

Effectively arranged by WG 1 member *Luca Nassi* of the Ministry of Interior, Fire Department of Siena, the Workshop Seminar involved c100 attendees from a wide range of disciplines. As a number of papers were delivered in Italian, simultaneous translation into English was provided throughout.

In opening the Workshop an outline introduction to the Santa Maria della Scala complex, and its rehabilitation project, was provided by the Director *Anna Carli*. Themes addressed included :

- Improve management of fire safety.
- Exchange of ideas.
- Restoration 13/14th Century frescos – considerable work/applauded.
- Safety is important but difficult to achieve. Co-operation with the Siena fire fighters was exemplary and many problems were solved as a result – This was founded on an Agreement signed between the Museum and the Provincial Fire Brigade that had the aim to strengthen co-operation and ties with both bodies. It was suggested that this successful approach could provide the model for other museums and monuments to follow in future. The Agreement also allowed compliance with the Regulations too.
- University research was also important and the joint work has achieved high results
- Future improvements to protect work of art required to be developed (The next steps).
- Also look to field of new technology and to identify new innovative Solutions in conjunction with others.

Mr Giorgio Chimenti (Engineer) Session chairman and Regional Head of Fire-fighters in Tuscany discussed the Agreement between fire-fighters and Museum authorities as being a workable arrangement.

Dr Giuseppina De Rosa, Prefect of Siena, also welcomed delegates to Siena and stressed the importance of the occasion, the benefits of collaboration between authorities, and of sharing experiences with other countries. She also hoped for solutions to emerge from workshop for safeguarding the built heritage.

Mr Alessandro Minuti, Councillor for Town Planning of City Siena, welcomed delegates on behalf of Mayor. He thanked the organisers and discussed the Santa Maria della Scala history, background, and current functions. He also stressed how the exchange of knowledge was important on how to deal with the safety and protection of the heritage.

Mr Stefano Cappelli, representative of the Banca Monte dei Paschi di Siena, also welcomed participants. He noted that the Bank was an owner of much heritage, and had a great interest in the topic and the need for co-operation. Emphasising the difficulty in applying compulsory solutions to Historic Buildings, he argued the need to take a flexible approach in the application of flexible solutions. He also emphasised the need for collaboration within the different Ministries on the practical application of legislation.

The Restoration of Santa Maria della Scala, Siena

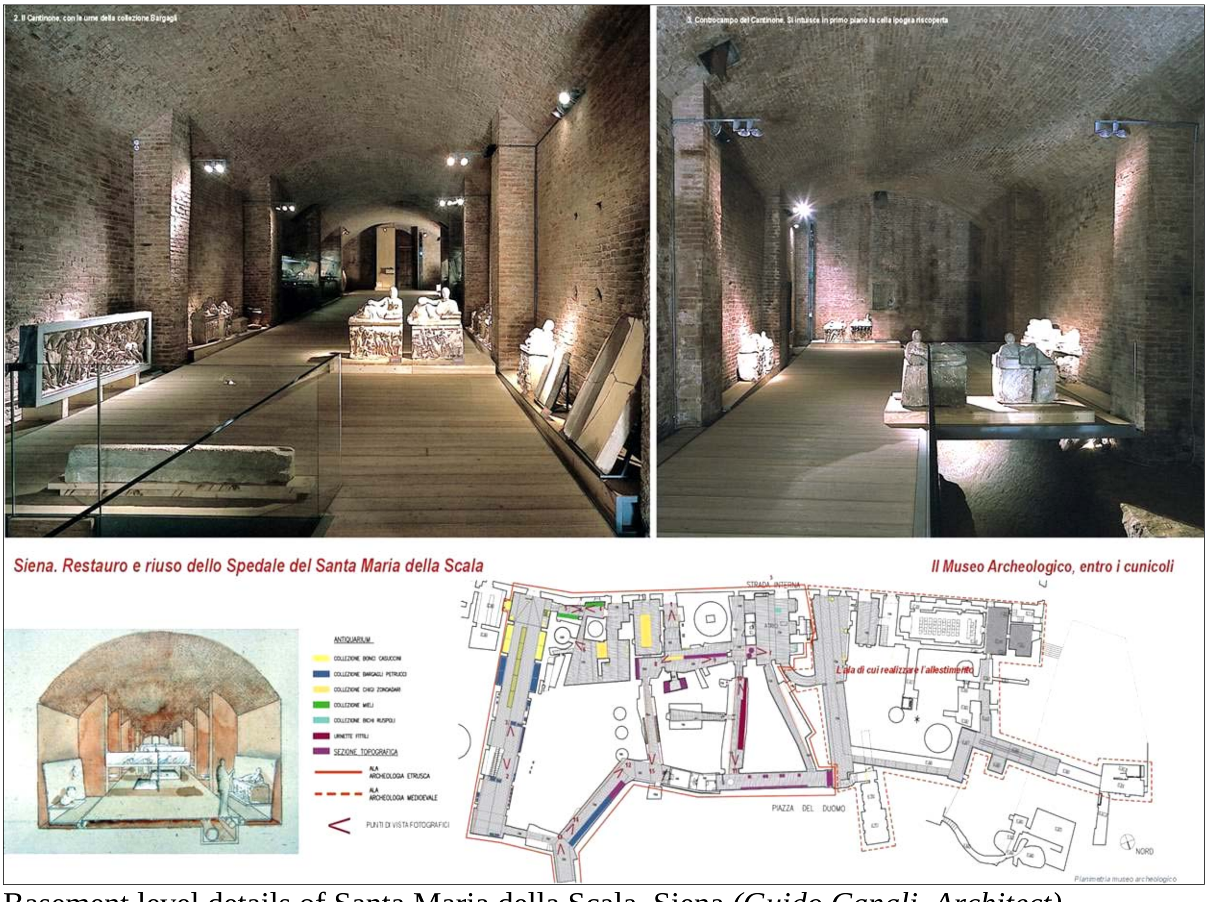
Dr Guido Canali, Architect.

Dr Canali emphasised the value of research work and collaboration involved in the project as this had introduced a new approach with the Fire Brigade to devise new and appropriate solutions. (Polytechnic of Turin and University of Siena were also involved).

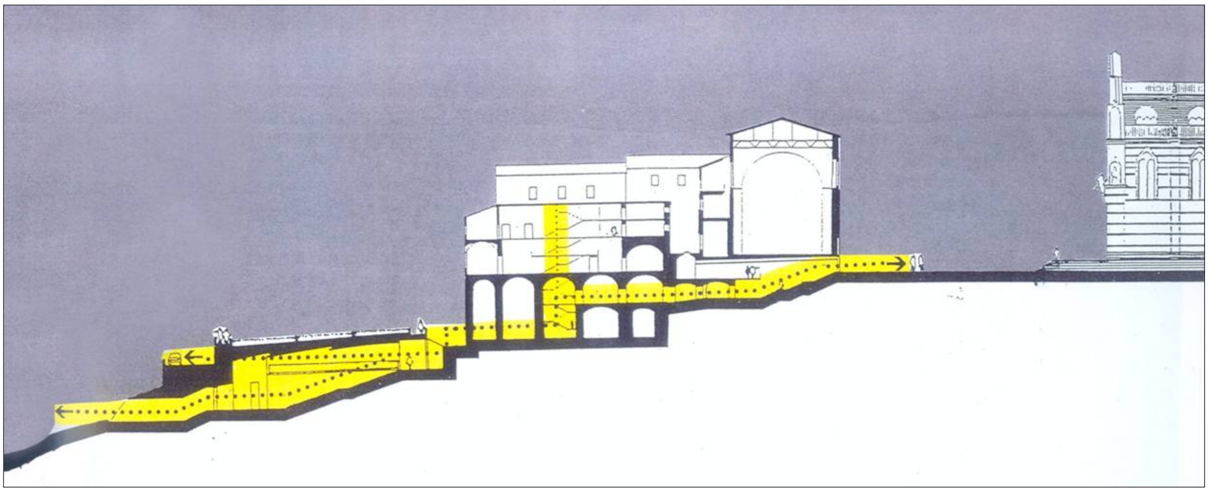
The restoration project started mid 1990's with the challenge of how to integrate an intense programme of work within a functioning building. This included coping with the difficulties of access/storage/delivery of materials – all challenges requiring a unique approach to the construction phases.

A variety of technical solutions were illustrated such as a brick faced door and "totem" service pillars on top of a floating timber floor, with sub-floor services – although this approach still cause concern about flame spread below the floor panels.

A plug in/plug out philosophy to new insertions was adopted where the detailing of the new equipment and display needs were sensitively worked out.



Basement level details of Santa Maria della Scala, Siena *(Guido Canali, Architect)*



Cross Section of Santa Maria della Scala, Siena *(Guido Canali, Architect)*

Problems of restoring Santa Maria della Scala
Ms Tatiana Campioni, Municipality of Siena.

Ms Campioni discussed the internal difficulties that needed to be considered during the project. The answers emerged over time, developing to suit its different needs to produce a very complex structure. It building complex hosts many different and diverse functions therefore it was difficult to meet safety requirements. The project principles were to preserve the complexity of the complex, but carefully consider how to adapt it to meet fire safety requirements at the same time. This led to new approaches to fire protection which focused on a performance based approach to obtain solutions. In particularly, due to the complexity of layout and levels, a system was devised to monitor particular groups of visitors. This focused on the provision of a lot of signage and will lead to investments in future on a greater degree of audio equipment. Simulated fire scenarios were also carried out, based on real life situations.

General Principles of Protection
Mr Mauro Marchini, Engineer

The Statistics of the Italian National Cultural Heritage included:-

- 3,500 Museums
- 18,500 libraries
- 5,500 in church
- 20,000 Castles
- 12000 kilometres of documents.
- Numerous Villas, Palaces and complexes
- 95,000 Churches
- 1,500 Monasteries
- 3,000 archaeological sites, on land and under water.

A project for the "Safety of Cultural Heritage" led to Law decree being issued in October 2001 (DM 10 maggio 2001-SOGUN 244 del 19.10.2001) where the 5th Chapter deals with safety.

Simulation tests to establish an appropriate risk-based analysis for the Santa Maria della Scala

Gabriele Ballocco: Canali Associates/ Fire Engineering Politecnico di Torino

Summarising the approach adopted it was concluded that in the Santa Maria della Scala:

- There are large volumes of certain proportions will act as 'lungs' for vapour
- Impact to determine real fire load
- Started classification work to note the information about visitor flow
- Attendance by visitor is a major variable
- Behaviour of visitors is critical in an emergency.
- Analysis of fire in areas is not enough information.
- Simulation is appropriate and will assist.
- Need to carry out sensitivity analysis.
- Need to study techniques – time required to evacuate – linked to human behaviour.
- How likely is a project to be safe?

RFID for Visitors Monitoring in **Santa Maria della Scala**

Prof. Alessandro Mecocci, University of Siena, Department of Information Engineering

Explaining the background history of the building, it was noted that it was the 2nd largest medieval hospital of its time in Europe with a 38,000 cubic metres volume, a 110,000 sq. m. floor area, with 6 underground levels and a medieval street. Essentially it was a city within the city but had considerable architectural complexity in its layout. This required a sensible approach towards innovation that was open to experimentation, where the end product will be a permanent laboratory devoted to advanced technologies

The challenge was to provide solutions that answered the needs to be operative flexibility; have minimalist and non invasive technologies to provide an integrated management approach of multidisciplinary and heterogeneous requirements in a self-sustainable manner.

RFID (Radio Frequency IDentification) it is a technology based on radio frequencies to transfer data between a reader and a moving object that is targeted to be identified, categorized and traced. It is fast, reliable and does not require any direct contact between the reader/scanner and the tagged element. The Remote Management Interface – reveals activity on the ground.

In the Visitor Tracking System Areas visitors need to be consistently monitored. A Multidisciplinary security approach overview was offered of the integrated approach, with an open architecture, noting that there were 4 main aspects of system: management, visualisation, communications and data gathering, with 2 sub systems also operated

- System monitors movement – controlling recorded if thought a likely risk.
- System capable of people localisation, classification history and statistics; warning and alarms and simulations in visitor monitoring role.

The people localisation system can show:

- where are the people

- how far they are from exits
- the location of missing people
- the demographic group profile
- the duration of stay in specific areas
- the most visited rooms
- any problems that exist

Smart Sensors: self learning
It is virtually impossible to specify a priority of all the potential unsafe conditions and harmful actions that can occur, but the data to be transmitted can expand in scale, whilst the sensors must be capable of autonomous computations.

Visitor Monitoring Issues:
- Where are they now /how far from the exits
- Is someone missing, where is he/she?
- What kind of people are they (school groups, elderly people, handicapped people, people with special needs)
- How long did they stay, and where did they stay
- What have been the most visited rooms
- Is there any problem, and are they too great
- -

RFID functioning principles involves a host PC-signal to RF Module/Reader to aim to register with people using SMDT tags. In future it will be possible to put a smart tag inside the admission ticket. The Project been achieved in collaboration with others to consider the:
- Structure
- Simulation and validation.
- Real time documentation.

Future developments will include:
- Further implementation.
- Exchange experiences and best practices to integrate simulation data
- Going on with the implementation of the whole Security System
- Gather money
- Start international co-operation
- Exchange experiences and best practices
- Integrate more advanced simulation abilities (pollutants diffusion, spatial distribution of materials, what if recovery plans)

Summary:
- The system provide accurate statistics
- Simulations and Validation on the field
- Real-Time documentation of rooms occupancy
- History and Dynamic Behaviour Analysis
- Communications with the outside environment in case of danger
- Support to Evacuation Plans
- Assessment of the evacuation state (e.g. no more people inside!!)

Santa Maria della Scala: Results of an Emergency Evacuation Exercise

Mr Pietro Foderà, Commandant, Siena Fire Services

Presented the results of an emergency drill carried out on 21 February 2005 under the joint agreement with Santa Maria della Scala. The Civil defence drill exercise activities – concentrated on working conditions and management, the aim of the exercise was:

- Need to carefully analyse the working conditions that are operating.
- Emergency Master Plan must be clear and precise to identifying who does what.

Civil Protection in Italy: State body responsibility for protecting people from nuclear, radiation and biological attacks (NRBA) and other threats

- Assume fire incident and workers inhaled vapours (chlorine oxide?)
- Staff implemented building emergency plan to initiate exercise.
- Need to protect museum contents.
- Evacuation created a 100m zone around source, colour coded to extent of risk.
- Rescue and decontamination.
- Analysis of chemical substances.

It is critical to have full co-ordination of all participants to avoid panic and over alarm. On alert emergency team put system into action so that, in 12 minutes, the entire complex was evacuated to pre-established meeting points outside the building – offer details of where they were at point of alarm – 48 people were involved in exercise.

- Contamination systems brought into play to de-contaminate participants in exercise.
- Operators' protection is critical but suits are physically awkward to move in – Need to decontaminate operatives – Positioning of equipment relevant to allow decontamination.
- The outcome of the exercise was shown to be a need to improve evacuation times (to reduce the total number of people that was contaminated).
- Resources need to be provided by appropriate equipment/protection.
- Santa Maria della Scala was subdivided into 5 separate sectors.
- - Necessary to have homogenous information using media to inform the population (in real time).
- Crucial finding therefore left an unsolved question on what was the best way and how to decontaminate the contaminated building and works of art.

Fire in the Windsor Building, Madrid, Spain: 12 February 2005

Ms. Llinares-Cervera, Architect, and *Mr. Miguel Gómez-Heras*, Geologist, jointly presented a paper that considered the effects and consequences of the fire in the high-rise Windsor Building, in central Madrid, Spain on 12 February 2005:

(The case is currently sub judice due to the prevailing circumstances, so the paper was presented on the basis of publicly available information from press reports).

Built 1973-79, the 106 metre high Windsor Tower building was the 8th tallest building in Madrid with 32 storeys above ground and 5 storeys underground. It was one of the first intelligent buildings. It had two technical floors which housed plant and services: one in the second level, and the other in the 17th level. These helped in the compartmentation function.

Ms. Llinares-Cervera reported on the building construction as follows:

- The vertical structure in the inner part consisted of rectangular columns and a rigid central core housing the vertical communications of the building, both made of reinforced concrete. In the perimeter there was a steel frame which also supported a curtain wall, supplemented by concrete columns in north and south facades below 17th floor level.
- Floor construction consisted of reinforced concrete bidirectional ribbed slabs on composite steel beams in the east-west direction.
- A twenty metres high crane was installed on the top of the building, supported by the central core, for the works carried out to adapt the building to the regulations in force and to renovate the facades.
- Windsor building was approved according to the 1970's standards. Only smoke detection and fire hoses systems were installed.
- It was being refurbished at the time of the fire with a building-permit obtained in 2003.
- New buildings in the Region of Madrid must fulfil both national regulations (dating back to 1996) and its own regional regulations (dating back to 2003).
- Similarly to most European codes, active measures don't play an important role in Spanish codes. As an example, the regional code of Madrid does not require sprinkler protection for buildings with an evacuation height of less than 100m, so active measures in the Windsor building were limited to fire hoses, a dry riser system, and automatic detection and alarm.

The state of the refurbishment works was as follows:

- A new exterior staircase was being constructed for emergency evacuation. It was also useful to carry vertical cables of electrical wiring through it, which was being renovated.
- Fire resisting materials to protect metallic structure in the facades during 3 hours were already placed in floors 4 to 14.
- Vertical shafts and cavities were being sealed to avoid fire spread through them. Also completed in floors 4 to 14.
- Vertical fire protection was being placed along the perimeter slab edge to avoid fire spread through facades. This work had just started.
- Smoke detectors were obsolete and they were being renovated floor to floor.
- A new sprinkler system was being also installed. So far, the pipe network was finished but the heads were not yet installed, so they had no choice to work.

Ms. Llinares-Cervera reported the fire event as follows:

- During the night of 12th February 2005 the fire was detected in the 21st floor by security guards at about 5 minutes past 11, when the building was supposedly empty.
- The origin of the fire is still unknown.
- A time of 16 minutes passed between this moment and the call to the fire brigade.
- They arrived at 25 minutes past 11, and they started fighting about ten to 15 minutes later.

- Firemen tried to extinguish it from the interior. But the fire spread very quickly, so at midnight they ordered to leave the building, fighting only from outside.
- At one o'clock in the morning four storeys of the building were already on fire, and gases spread through other two floors.
- Materials kept falling from the burnt facades. Firemen tried to avoid the fire affecting the neighbouring buildings.
- At 2 o'clock in the morning the flames covered almost the whole building. Principal seats of fire were close to north and east facades.
- A huge smoke column could be seen from far away.
- At half past 3 in the morning part of the curtain walls of the facades collapsed for the first time.
- Fire revived and it spread both upwards and downwards.
- The fast propagation of fire in the upper section of the building lead to the breaking of the curtain wall and strongly damaged metallic columns in the facades, causing their deformation and collapse.
- Some of the floors were dragged down, and part of the structure rested on the upper technical floor.
- Unexpectedly, fire spread downwards to the lower section of the building. Maybe first through wiring shafts, or through slab edge or other openings with a subsequent interior horizontal spread.
- Early in the morning, flames already affected the first floors of the building. Firemen shot water-jets from adjacent buildings. They reached all the storeys up to 13th floor.
- During the first 14 hours of fire fighting, between five and six million litres of water were needed.
- In all, 300 people worked to control the fire and to make sure the surroundings were safe.
- The fire was extinguished after eighteen hours of fire fighting.
- No casualties occurred, except for a few firemen affected by smoke.
- 48 hours after extinction works were finished, the building was examined by several experts.
- Some bays adjacent to the facades in the lower section of the building were in very bad conditions and risked to collapse. Steel columns were strongly deformed due to a long and direct exposure to fire.
- Next bays parallel to the north facade were also badly damaged: concrete slabs had lost much of their load bearing capacity.
- In other areas of this section of the building, concrete columns show different kinds of damage: from concrete spalling to signs of cracking.
- Damages in the central core were not so important.
- In the upper section of Windsor building, bays adjacent to the facades almost totally disappeared.
- The debris accumulated on the upper technical floor.
- Metallic frames hang over the perimeter.
- Next floors and concrete columns parallel to north facade had also collapsed over the technical floor.
- Some adjacent buildings got damaged because of the impact of facade elements.

Windsor Building during the fire

Photo source:
(http://www.whatreallyhappened.com/spain_fire_2005.html)

Summary:

The alarm was raised too late fire spread downwards. The fact that 30 to 35 minutes elapsed from the initial alarm in the control room to the first fire attack played an important role in allowing the unsprinklered fire to grow out of control. Fire spread downwards through service or other penetrations, but in a more gradual way.

Events have shown that the core in the upper floors and the rest of concrete structure performed an outstanding rating of about 18 hours of fire.

A more robust structure and less severe fire conditions, as well as protected metallic structures in addition to the presence of concrete columns in north and south facades, contributed to a better behaviour of the lower storeys of the building. Furthermore, sealing of concealed spaces and fire-fighting reaching up to the 13th floor also improved the building behaviour to fire. In any event, there are still many unknown factors and the Police are still investigating the situation.

The Building behaviour was better in the lower storeys due to:
- More robust structure
- Less severe fire conditions
- Protected metallic structure
- Concrete columns on two facades
- Sealing of concealed spaces
- Fire fighting

Materials behaviour at the Windsor Building

Miguel Gomez Heras.

Concrete structure prevented total collapse but fire damage to columns occurred. Whilst steel melts under fire (e.g. WTC collapse), reinforced concrete resists higher temperatures without total loss of strength. Nevertheless fire damages concrete in a similar way to that found in stone materials.

Of particular importance are:

- Loss in compressive strength.
- Cracking and spalling.
- Destruction of the bond between the cement paste and the aggregates
- Gradual deterioration of the hardened cement paste.

On heating:

- Above 300ºC concrete discolours, depending mainly on iron content.
- At 300 ºC strength reduction would be in the range of 15–40%.
- At 550 ºC reduction in compressive strength would typically range from 55% to 70% of its original value
- At 550 ºC calcium hydroxide dehydration takes place. Calcium hydroxide is a hydration product of most Portland cement

(There is no official statement about temperatures reached in Windsor building. Different information sources give temperature data ranging from 800-1000 ºC.)

Microscopic effects of fire:

- Transformations of carbonate aggregate in concrete to CaO above 800-900 ºC (incomplete reaction)
- Gaps related with pulverization of the aggregates or the cement paste fragmentation
- Cracking in the cement paste–aggregates interface

Heritage value of the Building:

The fire in the Windsor building makes us think of the definition of historic buildings. Historic buildings are not only the "old buildings". Rather, any building which is a landmark in the architecture of a city, and has a value for the population, could be considered a historic building. Historic and heritage value is not a numerical concept, but the result of the peoples' perceptions. Skyscrapers are one of the highlights in 20th century architecture that tried to communicate values of modernity and power. Skyscrapers are landmarks that receive a lot of tourism in many world cities. They are, in the community view, the real heritage items of the last century.

Memorialisation of Disasters:

There are instances throughout Europe where decisions have been taken to retain at least a part of a structure damaged by fires as a material witness to the event. Following the Second World War, this approach includes the Victoria and Albert Museum in London, Royal Garrison Church in Portsmouth, Coventry Cathedral and the Kaiser Wilhelm Church in Berlin.

The Windsor building was subject of an unsuccessful initiative to be kept as a memorial; as a journalist said: *A monument to the spirit of our time, evocation of the insecurity feeling that permanently pester us, homage to the faint of all humans, its present state should be respected as the wake of our particular Titanic."*

Discussion Issues:

- Accuracy of regulations
- Who bears the responsibility
- Buildings unfriendly with fire extinguishing

Windsor Building during the fire
Photo source: (http://www.whatreallyhappened.com/spain_fire_2005.html)

Risk Analysis
Prof, Torbjorn Theedeen, Centre for Safety Analysis, KTH, Sweden

Prepare – create base for decision:
- effective for action – choice of safety measure.
- Evaluate the consequences of alternatives

Risk? Random/uncertain events with negative consequences for human health and life and the environment (and material/financial damages) and cultural values.
What can happen and how likely is it?
Causes: Nature/Material/Human factor/Malicious

Who will use data:

- Decision makers
- Benefit receivers
- Risk takers
- Coming generations

Risk analysis; Identification; Estimation; Perception and Valuation:

- What can happen?
- How likely is it?
- How are risks perceived, and evaluated in decision making?

Analysis of available Information:

- Case studies of catastrophic events
- Data on other cases
- Logical models based on real buildings
- Expert knowledge.

Risk Perception:

- By whom
- This generation or next
- The population of the country with specific risk objects or the EU community
- A “democratic perception” or “merit wants”?

From Data to Decisions:

- Judgement, data
- Risk identification, estimation
- Communication
- Perception, valuation
- Decision

Action:

Probabilities, Consequences Reconstruction

Risk Valuations:

- Limited issues
- Value of Historic Building’s
- 100% protection impossible
- Protection/Documentation/Reconstruction after catastrophe
- Time dimension
- International ‘twins’

Decision principles (not clear cut):

- Limited resources
- Cost benefit analysis
- Acceptable risk
- Maximum probable loss
- Distribution of risks.

Ingval Maxwell
Chairman COST Action C17

23 April 2005