It is to be noted here that these tests were performed independently and not in a combined manner. The combined effect of two or more ageing mechanisms is a topic of future investigation.

Cycle Steps
The consecutive cycle steps at which measurements of stone properties were designated by the following sequence: C_0, C_1, C_x, C_y, C_w, C_z, C_k that denote essentially number of lab cycles, for artificial ageing in laboratory.

The same type of AA test has been applied to all rock categories but the sequence and the number of cycles applied was established, for each AA tests, as a function of the RC (rock category) in order to achieve six (6) weathering steps for all of them (Table 1).

The complete set of each RC has been contemporarily artificially and naturally weathered (Fig. 2). At each step applied an established number (5 for AA and 3 for NA tests) of specimens were taken out and dried (70 °C) before the EDP (see 2.6) determinations. Those coming from SM AA test have been firstly desalinated and then dried.

The exposure sites for the NA tests were the following:

North European = BRE premises (Garston, UK)
Central European = Birkenfield Monastery (Bamberg, D)
South European T = Politecnico di Torino (Turin, IT)
South European F = Florence Cathedral (Florence, IT)

Figure 2: Exposure rack for RCs at the Test site SEF (Florence's Cathedral)

Time steps
The time steps (in months after the initial exposure) in which periodic measurements for detecting possible damage were considered, both for RC and monumental stone slabs, are:

$T_0 – T_{12} – T_{24} – T_{36}$ (for 0, 12, 24, 36 months respectively)

Table 1: Correspondence within test cycles sequence and effective cycle number for each AA tests

AA – TEST	TF	F/T	SC MC-MG-PW	SC SC-SV-VA	SM
C_0	0	0	1	1	0
C_1	6	20	5	3	10
C_x	12	40	10	5	25
C_y	24	60	15	7	50
C_w	48	80	20	9	75
C_z	96	100	25	11	125
C_K	192	120			

2.6 Event Dependent Parameteres (EDPs)

In order to evaluate the effect of the Weathering Factor (*WF*) characteristic for each AA test some *EDPs* (Event Dependent Parameters) have been measured, starting from sound condition (*quarry)*. The *Parameters* chosen are correlated with the mechanical features of the stone material (hardness, elasticity, cohesion, microstructure and thermal conductivity) which would have had be affected by the Event.

2.7 NDT methods for assessing stone damage

On four (4) specimens the EDPs were determined by using the *NDT Integrated System* and transformed into *Numerical Indexes* (NI_S), see Fig. 1. The 5th specimen was used for standard mechanical tests. After the determinations of EDPs the upper half side of two of these specimens were cut for the *Sequential Image Analysis* (SIA) measurements.

The main *NDT* methods for determining the EDPs adopted and applied in sequence were:

Ultrasonic Pulse Velocity (UPV)
Schmidt Hammer (SH)
Drilling Resistance (DR)
Stone Microstructure (SM)

After the integration with the Acoutherm project two more EDPs were employed but only on some RCs (Marbles and Sander Sandstone) and submitted to only F/T test:

Thermal Conductivity (TC)
Surface Waves Velocity (SSV)

2.8 Numerical Indexes derived from EDPs

In Table 2 the most suitable EDPs are indicated as a function of the Numerical Indexes (NI) to be evaluated for each AA test [3].

Table 2: Classification list for appropriateness of each damage detection method depending on the type of the ageing test

– = not tested *= little appropriate ** = pertinent *** = highly suitable

EDP	UPVt	UPVs	RB	DR	SIA	SSV	TC
NI	SEI	SEI	SHI	SCI	PSI	SEI	STI
Salt mist	*	-	*	*	*	**	-
Thermal Fatigue	***	***	**	**	***	-	-
Freeze-Thaw		***			***	***	***
Salt Crystallization	*	*	-	-	**	-	-

UPVt & UPVs (Ultrasound and Surface Waves pulse velocity)
RB (Schmidt Rebound Hammer)
DR (Drilling Resistance)
SIA (Sequential Image Analysis)
TC (Transient Thermal analysis)
SSV (Surface waves velocity)

SEI – Stone Elastic Index
SHI – Stone Hardness Index
SCI – Stone Cohesion Index
PSI – Polished Surface Index
STI – Stone Thermal Index
SEI – Stone Elastic Index

3 Considerations

3.1 Influence of type of ageing tests (AA)

Different stones react in a different way to the same weathering agent; therefore each RC reacts differently to a certain type of ageing test as a function of its mineralogical composition, structure / texture, porosity, and cohesion [4].

Calcitic marbles, due to the thermal anisotropy and the high modulus of elasticity of the calcite crystals, are strongly affected by thermal variations, while the action of the salt has little influence on them. The reason for this is probably the relatively high strength and low porosity of marbles compared with other stones. On the contrary, limestones and sandstone are very poorly affected by thermal variation but far more by salt crystallization.

These results clearly indicate that in order to verify the durability of a stone it must be established in advance what kind of weathering action (i.e. type of external stress or strain, for example mechanical stress, thermal stress or strain, chemical stress or strain due to crystal growth, etc.) should be applied and at which magnitude. As a consequence the most appropriate AA test must be selected as a function of the rock type and the natural exposure conditions (Table 3).

Table 3: Relative influence of the type of artificial ageing on the type of stone

Artificial Ageing	Cervaiole Marble	Gioia Marble	Vicenza Limestone	Portland Limestone	Sander Sandstone
Salt mist	*	*	***	***	***
Thermal Fatigue	***	***	*	*	*
Freeze-Thaw	***	***	*	*	*
Salt Crystallization	*	*	***	***	***

* = little influence   *** = high influence

In general the AA test should be performed according to Standardized Test Methods but the magnitude of external stresses of the cycle must be verified, preliminarily, if this gets over the ‘fatigue limit’ for the rock material under test. This limit is defined as the percentage of the maximum load at failure of the stone under a monotonic mode of load application below which the load does not produce deterioration of the material within a reasonable number of cycles (reasonable means the number of cycles in order that the test might be characterized as ‘accelerated’). Otherwise, the most appropriate boundary conditions shall be set up at the outset of the experimental programme in order to obtain detectable stone damages in reasonable time lag (or number of cycles). This essentially means a fatigue approach to study the durability of stones, that is to say production of S-N curves for each stone type similar to that shown in Fig. 3, with S to be the applied external stress (expressed as a percentage of the maximum load at failure in one cycle) and N the number of cycles which produce failure of the stone. Low-cycle fatigue is performed when the external stress S is a high percentage of stone strength in monotonic loading and high-cycle fatigue when we approach the fatigue limit. Normally, accelerated tests are in the low-cycle regime.

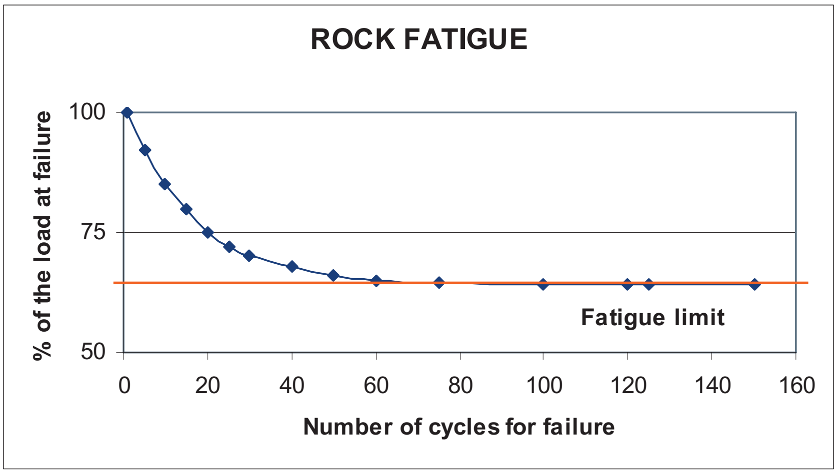


Figure 3: General relationship established between the applied load and the number of cycles required for the final failure

The AA tests impose damage to the stones, which is manifested with the growth of microcracks that eventually coalesce to form visible macrocracks, due to the development of mechanical strains (principally volumetric) inside the pore system of the stone. For example:

- heating or cooling of specimens produces dilatation or contracting volumetric strains depending on the temperature gradient, that are proportional to the product of the coefficient of thermal linear expansion of the stone with the difference in temperature.
- freezing-thawing produces volumetric strains due to the expansion of formed ice crystals inside the pore system of the rock, whose magnitude depends on pore size distribution of the stone.
- salt-crystallization and salt mist produce 'chemical' volumetric strains due to salt crystallization inside the pore system of rock essentially as a result of chemical reaction driven by the difference in the chemical potential of the crystal and the solution. These dilatational strains may be set proportional equal to the product of the 'chemical linear expansion coefficient' with the concentration of the salt in the water. These strains depend on the concentration gradient of the salt, the pore size distribution of the stone, and the surface tension of salt crystal-rock pore wall system. Most important, if the contact angle between the crystal and the pore wall is low, then the stress can be small; if $\theta < 90°$, crystallization could even create cohesive forces in the body. This suggests a method for protecting structures against crystallization damage: apply a coating to the pores that reduces θ. The crystallization pressure is also small if the pore size is large; that is why frost heave is more severe in fine-grained soils, which have small pores.

Therefore, by properly setting the boundary conditions and other specific conditions of each type of test or a combination of these tests (for example thermal fatigue initially and then salt crystallization or other), one can achieve few cycles to failure or large cycles until failure of a given stone (Fig. 4).

Rocks as many other engineering materials subjected to unfavorable mechanical and environmental conditions in general show a decrease in the elasticity modulus and strength due to accumulation of micro structural changes.

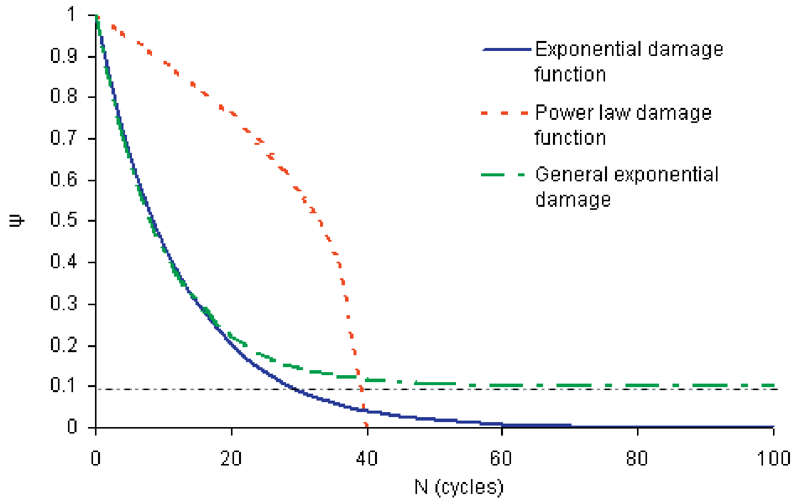


Figure 4: Evolution of rock integrity with number of cycles

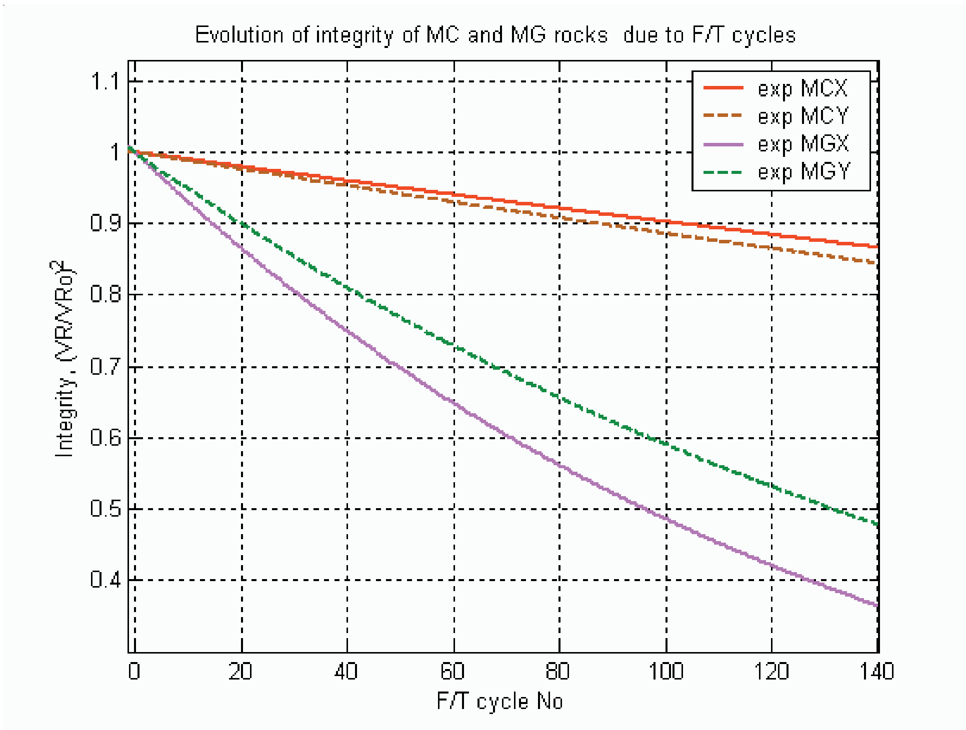
The concept of rock integrity involves properties such as elasticity or deformability, hardness, strength and structural wholeness of the rock. Consequently, as it is illustrated in Table 5, various parameters, determined by means of micro (MDT) or not destructive test (NDT) methods developed in the project can be used as measures for rock integrity (Fig. 5 and 6).

Table 5: Recommended Micro Destructive (MD) and Non-Destructive-Tests (NDT) for the assessment of rock properties decay

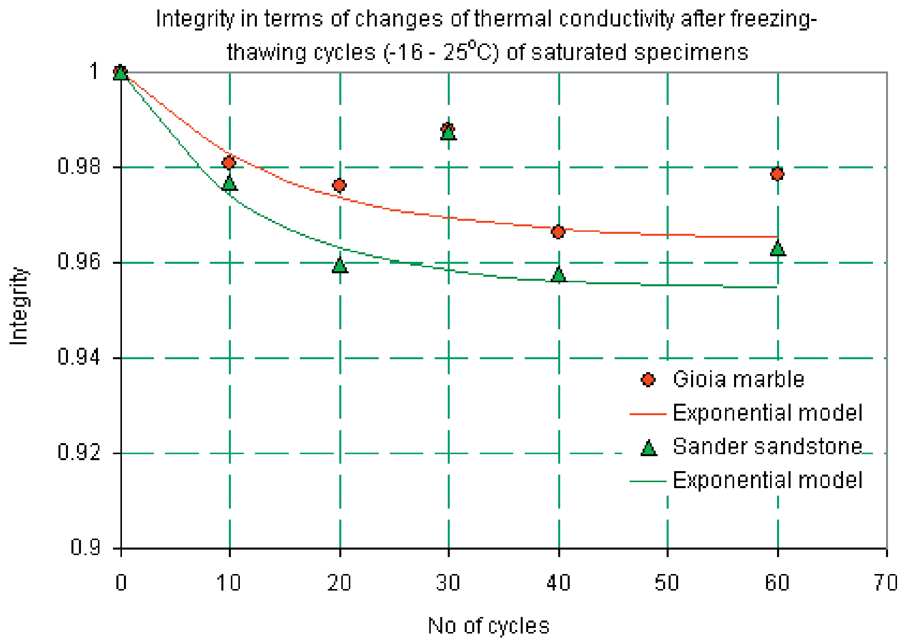
Rock property	MD/NDT
Hardness index	Indentation, Schmidt hammer, Drilling
Dynamic elasticity modulus	Ultrasonic, Indentation
Static elasticity modulus	Indentation
Tensile strength	Drilling resistance
Uniaxial compressive strength	Drilling resistance
Mass loss	Weighting
Porosity (as percentage of intergranular area)	Image analysis
Thermal conductivity	Hot-ball sensor
Water absorption/porosity	Weighting

3.2 Weathering resistance indices for stones

Frost resistance of rocks is a property to resist crack or pore opening forces created by the pressure generated inside the pores and cracks due to density change of water and thus its volume during its transformation to ice. Stone durability in F-T and in salt crystallization depends heavily on both strength and pore structure properties. Moreover, for calcitic stones overall for marbles, that have well developed calcite crystals (with very high thermal dilatation coefficient), the F-T cycles act also as a thermal loading.



(a)



(b)

Figure 5: a) Integrity of Cervaiole and Gioia Marbles after F-T ageing treatment by the surface wave method (data from IFTR:), b) Integrity of Gioia Marbles and Sander sandstone after F-T ageing treatment by the thermal conductivity method (data from IPTL)

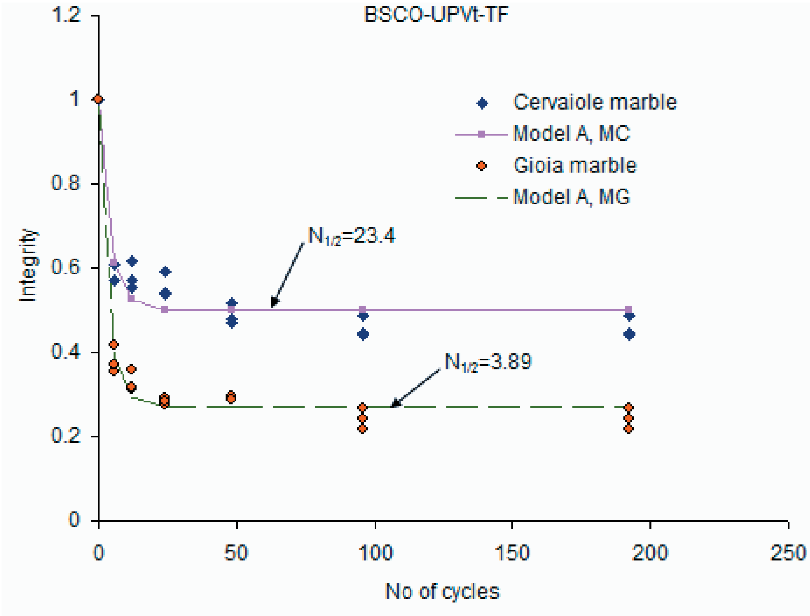


Figure 6: Thermal Fatigue test. Comparison of durability of Gioia and Cervaiole marbles measured with ultrasonic wave velocity (data from BLFD)

Salt crystallization resistance of rocks is their property to resist crack or pore opening forces created by the pressure generation inside the pores and cracks due to change of expansion of salts (sodium chloride, gypsum and other). Essentially, the expression for the resistance coefficient is similar to that defined for Freezing-Thawing as both require resistance to expansion forces within the material. There are however many differences between the two mechanisms. For example freezing proceeds from the larger pore spaces to the smaller but salt solution is evaporated from the larger pore spaces which then concentrates the salts in the smaller pore spaces where crystallisation eventually occurs.

The following considerations can be derived from the results of the AA test applied on selected RCs:

- Marbles are most susceptible both to freezing-thawing and thermal fatigue cycles than limestone and sandstones. Limestone is more resistant than sandstone.
- Cervaiole marble is more resistant than Gioia marble, in accordance with the experimental observations (see Fig. 5a and 6).
- Sandstone is more susceptible to Salt Ageing than limestone, while marbles are little affected.

4 Focal points

4.1 Accelerated Ageing tests

Given the present situation in the field of natural stone testing the McDUR-Acoutherm project had to start with standardised accelerated ageing tests to assess the behaviour as well as the resistance of the selected natural stones. The results obtained from the project, however, clearly demonstrate that standardised tests with respect to their design as well to the evaluation methods are not appropriate to give deeper insight into the question of how stone properties are correlated to the test results. In fact, mineralogical composition, porosity, moisture transport properties and thermal properties affect thermal fatigue and freezing-thawing seriously, but also the chemical properties of stones since the stone reacts with salt solutions, and finally rock fabric (i.e. grain shape / size and inherent microfracturing). Standardised test are mainly designed as merely destructive tests to obtain some data; accordingly to them, stones can be classified as resistant or not resistant to a specific weathering attack, like frost or salt. The prescriptions of the test rather deal with the correct execution of the test than with the scientific background of the deteriorating process. There is not a single so called accelerated ageing test for which the acceleration factor related to natural environmental conditions is known. Acceleration factors which can be sometimes found in the literature are always based on specific boundary conditions. They therefore are rather speculative and lack clear scientific evidence. It has been therefore found that natural stone testing must be put on a real scientific basis including mathematical modelling of test curves as well as introducing the concept of material fatigue into the assessment of natural stone quality.

For what concerns the correlation of the AA data with the results obtained for Natural Ageing tests (NA) we can derive that the same RCs exposed at the 4 monumental test sites have been very little influenced by natural weathering factors. Most probably the time steps of 3 years are too short or the induced alterations are too little to be determined with our NDT integrated system.

4.2 Ultrasonic pulse velocity

Pulse velocity tests can be carried out on both laboratory-sized specimens and stone structures. Pulse velocity readings are higher for compact materials and, in general, the degree of damage is related to a reduction in pulse velocity [5]. As stone ages, the rate of change of pulse velocity slows down much more rapidly than the rate of change of strength, so that beyond strength values of 13.6 to 20.4 MPa the accuracy in determining strength is less than ± 20%. Accuracy depends on careful calibration and use of the same stone in the test samples and for calibration. The determination of ultrasonic velocities can be used to measure the modulus of elasticity of materials. To reliably distinguish any changes in the 'fabric' of the material then both the compressive and shear wave velocity need to be measured (Vp & Vs) or surface wave velocity can be used as an approximation of Vs.

The following two arrangements for the transducers for velocity determination were used:

- *direct transmission* – the transducers are located directly opposite each other. This is the most sensitive arrangement;
- *indirect transmission* – the transducers are located to the same side surface This is the least sensitive arrangement.

The pulse velocity method is an ideal tool for establishing whether stone is uniform. But there must be a smooth contact with the surface under test and therefore a coupling medium such as a thin film of oil is mandatory. Dry-coupling indirect measurements have been applied only for the surface wave's determinations (very high frequency). The ultrasonic velocities were greater in the in-plane direction than in the through-thickness direction. Consequently, the in-plane longitudinal moduli were greater than the through-thickness moduli. Porosity had a greater effect in reducing ultrasonic velocity in the through-thickness direction than in the in-plane direction. Furthermore, increased porosity significantly decreased both in-plane and through-thickness moduli. Fairly good correlation can be obtained between cube compressive strength and pulse velocity. These relations enable the strength of stone material to be predicted within ± 20 per cent but this can be improved under strict laboratory conditions with well established calibration curves. Effective prediction of stone strength is more limited, owing to the large number of variables affecting the relation between strength and pulse velocity. The method is completely not destructive and can be applied "in situ".

In particular the indirect method is more sensitive to record the variation induce by the weathering action, instead the direct method can be influenced by several factors (a decayed layer too little respect to the specimen dimensions, or the specimen dimensions shorter than the ultrasonic pulse wave length) that prevent to evaluate the velocity variation with accuracy.

The ultrasonic velocity resulted to be a quite sensitive method for evaluating the salt crystallization damage because this test introduces strong changes in the whole mass of the specimen under test while for salt mist this method is less effective to detect damage because the damage mechanism only affects the specimens' external most layer.

In fact, the UPV data coming from salt crystallization test show an initial increase as material accumulates in the stone increasing the density and then a reduction as the salts disrupt the internal structure of the stone. The UPV changes are of the same order as the errors in the measurement (200 m/s) and repeated measurements were required to detect the change.

In particular ultrasonic velocity is appropriate for marble whose velocities varies from around 6 km/s for sound specimen down to less than 1 km/s for very deteriorated ones. The variation for sandstone is much less covering a range between around 3 km/s and 2 km/s. The variation of limestone depends on the primary porosity. Very dense limestones can exhibit the same ultrasonic velocity values as marbles, however, they do not exhibit the same type and degree of weathering consequently the drop of the ultrasonic velocity is much lower. The behaviour of porous limestones is similar to that of sandstones, even if the reading of the first arrival time can be very difficult in stone structure characterized by the presence of macropores (as in VA or PW).

With respect to the specimen dimension, the frequency of 1000-2000 kHz seems to be the best for laboratory use (transmission mode), while that of 45-54 kHz is suitable for in situ applications (refraction mode). The measurement accuracy is for transmission mode ± 50 m/s at best, while for refraction mode is ~ 100 m/s.

4.3 Drilling resistance

The determination of the drilling resistance (DR) is based on the measurement of the thrust (in Newton) necessary to perform a hole with specific operative conditions referring to rotational speed and penetration rate. The evaluation of the stone hardness is related to the drill penetration force measured during the hole machining. The system measures continuously both the penetration force and the actual drill position [6]. The measurement accuracy is ± 1 N, thus the DRMS method is able to resolve even slight changes in strength or to detect cracks of less than 1 mm size. A linear relation between the specific energy E and the drilling strength J exists for the types of stones considered. The UCS of rocks is exhibiting a linear relation with the thrust specific energy consumed during rotary drilling for several types of rocks. A key factor for successfully applying DRMS is the choice of recommended high quality polycrystalline diamond end mills type. Results on abrasive rocks have to be corrected [7]. It is strongly recommended to regularly calibrate the drill bit on a reference material, e.g. special low baked ceramic or homogeneous synthetic material (Macor, Corning). The durability of a drill bit depends on the stone type drilled; for calcareous material about 100 holes can be done using the same drill bit without observe meaningful changes in the cohesion profiles.

The test is essentially micro-destructive, since stones can be tested, with only minor patching of holes (Ø 5 mm) on exposed faces and can be applied "in situ". The Drilling Resistance is appropriate for monitoring the tests that promote significant decrease of cohesion, but, when concomitant mass loss occurs, it is of better to integrate the drilling resistance with the values of mass loss. Similarly the slight changes in the drilling resistance (5-10 N) indicated that there were some internal changes. As the changes were about the same size as one would expect for weathered stone, it would seem to indicate that the salts whilst disrupting the internal structure did not greatly affect the strength. It was not possible to remove the salts as in the later stages of the test as the susceptible stone disintegrated.

The determination of drilling resistance can be a useful methodology, if supported by an accurate analysis of all data obtained during the test.

The interpretation of data can be very difficult in the case of stone characterized by great grain dimension heterogeneity, as in VA or even in PW.

4.4 Sclerometer rebound hardness

The Sclerometer, better known as Schmidt Hammer, measures the surfaces hardness of materials by means of a plunger. The plunger of the Schmidt hammer is placed against the specimen and depressed into the device by pushing the hammer against the test specimen. Energy is stored in a spring, which automatically releases at a prescribed energy level (0.74 J), and impacts a mass against the plunger. The height of rebound of the mass is measured on a scale and it is taken as the measure of hardness.

The specimen holder consisting of a steel “cradle” fixed on a steel base drives the hammer in a perpendicular direction against the specimen. Prior to each testing sequence the Schmidt hammer shall be calibrated carrying out 10 impacts on the calibration anvil, supplied by the manufacturer. The average of the ten readings shall be obtained and used to calculate the correction factor.

The test surface shall be smooth and flat over the area covered by the plunger. This area and the rock material beneath shall be free from cracks, or any localised discontinuity. On each point of measurement three impacts should be made and only the third of them should be registered. Each impact has to be at least 10 mm far for the other. The hardness value obtained will be affected by the orientation of the hammer. In the laboratory tests the hammer shall be used vertically downwards.

The Schmidt Hammer has given good results in the measurements performed in situ on monumental stones, while in laboratory and to evaluate RCs exposed at the same sites the device is influenced by the small dimension of the specimen and the data obtained have a very high dispersion, that doesn’t permit to properly evaluate the real effect of weathering on stones.
The limits of this methodology can also be connected with the methodology used that assures to have coherent data and repeatable measurements, but, on the other hand, don’t allow to evaluate the presence of the weathered layer.

4.5 Sequential image analysis

This methodology aims to define quantifiable parameters based on geometrical features observed in a two-dimensional array (thin or polished stone section). The specific variables measured are intergranular space, grain size dimension and shape. The analysis is based upon the assumption that the measured variables provide a characterisation which is irrespective of the position of the thin section within a marble specimen. This is approximately true for marble which display a granoblastic microstructure, but generally the fabric observed can strongly depend on its orientation within the specimen. From grain boundary network, area, major and minor axes and perimeter are computed for each grain. From these measurements the axial difference and the factor perimeter / area and other mathematical correlations (roundness, axis ratio, length ratio and perimeter invariant are calculated and grain distribution (mean and skewness) within a given thin section can be determined. Generally, the values measured for these variables do not display symmetrical distributions.

The dedicated SIA software has been used to study the microfabric evolution as a function of the successive weathering stresses applied on the selected rock categories. The sequential images taken from the series of thin sections (for AA and NA tests) can be considered as a three dimensional x-y-t stack with two length dimensions (x,y) parallel to the image plane and one time dimension (t) perpendicular to it. This stack has been evaluated as a function of Event Dependent Parameters (EDPs). In fact, on these polished or thin sections the horizontal dimension are the NIs determined for grain structures and boundaries, while the vertical dimension represent the time steps or the cycles of the successive NA and AA test respectively. In this way we could visually follow the evolution, on weathering, of stone microstructure (SMI). All stone sections were made with the same direction in oriented samples, and the procedure for their preparation and image acquisition has been standardized. This is a typical laboratory diagnostic tool.

The analysis of polished stone sections resulted a good system for evaluate the effect of all weathering factors on all RCs. The Stone Durability Abacus derived by the integration of the NIs for all the AA indicates the Cervaiole Marble is the most durable RC while the less is the Sander Sandstone (contro). For the NA tests the durability sequence is completely different even if the starting point is the same (Cervaiole Marble).

4.6 Surface waves

Surface Rayleigh waves can be used themselves as a diagnostic tool or in combination with longitudinal waves to calculate moduli of elasticity of stones [8]. Surface waves intrinsic property is very shallow penetration into a material subsurface. This penetration depth is equal approximately to one wave-length, which means that a skin layer of 1-3 mm of the stone boundary can be tested using surface wave measurements. The other important surface wave's property is high attenuation which does not allow using a large measurement base between transmitting and receiving probes. This means that application field of Rayleigh waves can be local testing of outer skin layer of stones. So called edge probes were used for measurements. The probes frequency was 1-2 MHz and developed portable system allowed to take measurements both in laboratory and on-site. All the results were recorded with simultaneous checking of the frequency range of the received wave. Calculated accuracy of measurements is better than 50 m/s and observed scattering of the results is due to local variations of specimens' homogeneity.

In laboratory tests it was expected to measure changes of surface wave velocity due to the action of the unique artificial ageing factor: the Freezing and Thawing (FT). This has been applied only on oriented specimens made with Gioia Marble and Cervaiole Marble. Successful measurements showed decrease of surface wave velocity with increasing number of weathering cycles. The results elaborated as the appropriate Stone Elasticity Index (SEI) showed decrease of elastic properties of Cervaiole Marble down to 90% of original value while for Gioia Marble decrease of SEI down to 50% was observed after the same number of 120 FT cycles (Fig. 5a).

On-site measurements were the first surface Rayleigh wave measurements with edge probes done on historical construction materials outside laboratory. Measurement session made at the Florence's Cathedral on naturally aged stone blocks confirms that elastic properties of homeoblastic marble were lower than that of xenoblastic one.

4.7 Thermal conductivity

Methodology of the thermophysical analysis (with the RTB 1.01 instrument) [9] has been used for determination of the specific heat, thermal diffusivity and thermal conductivity of a specimen that is conditioned (drying, moist) or submitted to freeze / thaw cycling. The specimen 50 × 50 × 70 mm is cut into three pieces (a piece in dimension 50 × 50 × 25 mm). A plane heat source is put between first and a thermometer between second cut surfaces. A heat pulse is generated and the temperature response is measured. Then thermophysical parameters are calculated from the energy of the heat pulse and from parameters of the temperature response. Thermophysical properties are highly sensitive to temperature, pore structure and the content of the water.

The specimen temperature was controlled in a programmable way during experiment thus detailed information was obtained on processes during freezing or thawing. The shape of anomalies is highly sensitive to pore structure and the content of the water. Specific heat anomalies of the two rocks were analysed, namely Marble Cervaiole and Sander Sandstone. A small anomaly was found for Marble Cervaiole while complicated anomalies correspond to freeze process for Sander Sandstone. This is connected with the content of water or to the porosity. Thus microscopical picture on developing of the microstresses around pores of different sizes is a complicated process. Degradation of the Marble Cervaiole and the Sander Sandstone was analysed by the measuring thermophysical properties. A clear lowering of the thermal conductivity for Sander Sandstone was found (5%) within 20 freeze / thaw cycles (Fig. 5b). Degradation of the rocks corresponds to the content of the water that damages rock skeleton during freeze / thaw cycle.

Methodology of monitoring of the thermal conductivity changes "in situ" is based on the Hot Ball method. The RTM monitoring system works in a mode of data logger. The sensor has up to 3 mm in diameter and determines thermal conductivity of a material volume having diameter up to 40 mm around sensor. Sensor can be used in surface configuration when it is fixed at the surface using an auxiliary block of the same material or in a hole configuration when an appropriate hole is made into tested material in which the Hot Ball sensor is fixed. Fixing the sensor in real environment (wall, monument, etc.) a long time changes in moisture can be monitored.
The instrument was applied for monitoring one marble slab at the external wall of the Florence's Cathedral for 35 days. Large variations of the thermal conductivity were found when moisture has grown due to rain. Experiments proved that rocks exposed in environmental conditions are strongly affected by moisture and temperature in a dynamic regime.

4.8 McDUR Stone Resistance Sequence

The McDUR laboratory and field experiments results give a sequence of durability of the tested stones which seems to contradict "obvious or generally accepted" experiences. In particular, the good rank of Sander Sandstone in Natural Ageing tests is disturbing for German experts because stones of this type are known to be very fast weathering when exposed to German climate. On a first glance, the results therefore seem to contradict general observations. One has; however, to take into account several aspects which may put the results in a different light.

In a strict sense, the laboratory and field tests just demonstrate the power of resistance of the individual stones against the test conditions. A correlation to whatever general observation in the nature is not necessarily possible and may lead to contradicting results.

In neither of the participating countries all stone lithotypes chosen for the experiments are used for buildings or monuments. Therefore it is impossible to directly compare the behaviour of the stone types in the particular climate of the countries.

In Germany Vicenza Stone and certain grades of Portland Stone are not used for some locations and particular purposes because it is know that they are not resistant to German climate conditions which are characterised by frequent freezing – thawing cycles. Also marble is not allowed for cladding building facades because of insufficient frost resistant. On the other hand, Sander Sandstone is well used as building stone for modern buildings and cladding material if it is not exposed to very severe driving rain. Carrara Marble tombstones from the late 19th or from the early 20th century in Germany show very severe damage due to frost and acid rain attack.

It therefore seems reasonable that the durability sequence obtained from the McDUR tests reflects the factual power of resistance of the investigated stone types to the specific tests.

4.9 European database on durability of stones

One of the results of McDUR has been the construction of an interactive Web-Driven user-friendly *Data Bank* (for storing and easily retrieving all experimental data obtained within the Project.

5 Recommendation

Based on our experience gained from this project, the following recommendations are herein proposed for the above type of analysis:

- Performance of good quality stone damage detection measurements (for example, regarding ultrasonic wave measurements, the calibration of the instrument and the appropriate frequency, shape and stone transducers coupling, etc.).
- Sufficient analysis before each series of artificial ageing testing in the lab in order to set-up appropriate boundary conditions for achieving detectable damage in the lab after reasonable number of cycles.
- Adequate monitoring of artificial or natural ageing tests (for example temperature measurements during thermal cyclic tests and repeated freezing-thawing tests etc). It has been shown that only by proper monitoring of results useful numerical simulators of stone weathering can be achieved.
- Sufficient time of outdoor exposure of slabs from the same stone material accompanied with microclimate data for the exposure site.
- Use of accurate non-destructive and micro-destructive measurement techniques for repeated measurements amenable to statistical analysis. Needless to say, that the sample size must be also adequate for acceptably low uncertainty in the measurement data. Maybe, the calculations with mean values is not appropriate but rather with the lower extreme values, since damage and failure of stones obey the 'weakest link' concept, that is to say, damage and failure initiates from the weakest part of the stone.
- Application of the appropriate integrity function that is based on sound principles of mechanics.
- Use of Databank for easy storage and retrieval of *testing* and *associated microclimatic* data for subsequent statistical and numerical analyses.
- Adequate sampling procedure inside the quarry to derive the structure of spatial variability of stone physical-mechanical properties which are relevant to its durability.

6 Conclusion

In order EU to be competitive in the Stone Industry the problem of stone weathering should be carefully placed in a framework that will allow accurate quantitative short- and long-term predictions regarding stone durability in a specific climate. To achieve this objective the European dimension has been fundamental, together with the complementarities of the partnership and the innovative approach for the improvement of laboratory and field measurement techniques in order to study the effects of degradation of brittle monumental and building stones under cyclic loads and to develop suitable theoretical models, supported by experimental tests. The main application of the outcome of the project is in the field of the *Quarry modelling* in order to assess variations of stone physico-mechanical properties and structural properties within a quarry. The evaluation of this variation is necessary to ensure that the proper material is used in the optimal situation to enhance the efficiency of quarry operations. Another interesting application of McDUR results is faced towards a computer-aided deposit modelling methodology, based on geostatistics, for the establishment of zones of *lithostratigraphic* (for sendimentary and metamorphic stones) and *tectonic uniformity* (which means variability in certain range) of extracted natural building stones for subsequent *Stone Sampling Strategy (SSS)* and *Quality Control (QC)* of the quarried stone blocks during quarry development.

7 European project details

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How to assess the efficiency of a stone consolidant – the example of the Bologna Cocktail

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1 Introduction

The Bologna Cocktail consists of a solvent mixture of Paraloid B72 (acrylic resin) and DF104 (silicon resin). It was introduced by Ottorino Nonfarmale in the 1970's, for the conservation of the facade of San Petronio in Bologna, Italy. According to Nonfarmale [1], the acrylic resin brings the adhesive properties, while the silicone resin gives the water-repellency to the treatment, allowing consolidation of the stone, adhesion of flaking or disintegrating parts and prevention against future deterioration. Besides it was established in situ that the resin still remained soluble in solvent after four years, concluding that the treatment is totally reversible [2]. Initially applied for consolidation of marbles and limestones, it is later also used for sandstone's consolidation, as well as for the conservation of polychromy, and becomes widely used on historical buildings in Europe, mainly in Italy.

Because of its wide use BC has been subjected to careful laboratory studies, in the 80's. ESEM analyses showed that the prepolymerised resin was deposited on the grains surface without clear adhesion, confirming the possibility of removing the resin with solvents [3]. Nonetheless, after artificial weathering by acid rain, it was found that the silicon resin polymerised inside the stone, forming a three-dimensional network, that could possibly interfere with the reversibility of the treatment [4]. However, the in-situ polymerisation of the silicone resin occurred on the exposed surface, restricting the treatment's irreversibility to the uppermost layer [5].

In 2002, three international institutes, which conduct research in the field of conservation (The Laboratoire de Recherche des Monuments Historiques (France), the Istituto di Chimica Inorganica e delle Superfici (Italy) and the Getty Conservation Institute (USA)), undertook a collaborative study with the aim of evaluating well-documented Bologna Cocktail conservation treatments from the early 1980's until the 1990's. In-situ investigations were performed on BC-treated stones of two European objects: the central arch of the Portail Royal of the Cathedral in Chartres (France) and the San Clemente arch of the Basilica San Marco in Venice (Italy). The preliminary results showed that no evidence for secondary damage could be derived, but it became obvious that the Bologna Cocktail acted rather as a water-repellent than as a consolidant, and that it scarcely penetrated the stones [6].

As it is claimed that the success of Bologna Cocktail treatments highly depends on its application technology [7], a laboratory study, following the in-situ investigations, was initiated to investigate the influence of the application techniques on the penetration depth. The treatment's penetration depth and distribution are studied on Proconnesian marble. Various direct and indirect scientific methods are used to determine the presence and efficiency of the consolidation treatment. The subsequent modification of the physico-chemical properties is assessed.

2 Materials and Methods

2.1 Materials

The stone selected for this study is Proconnesian marble, resembling the material used in the construction of the San Clemente Arch of the Basilica San Marco, in Venice, which has been treated with the Bologna Cocktail by Nonfarmale's team in 1996-98. The marble samples (5 × 5 × 4 cm) are artificially aged, being heated up to 500 °C. The altered marble, obtained this way, is commonly called Marmo Cotto. The alteration of the stone is assessed on 15 cubes, by ultrasonic velocity measurements (Figure 1). The velocity drop from 6 $km.s^{-1}$ to 2 $km.s^{-1}$ which confirms the marble alteration. Indeed the artificial ageing induces microfractures and loosening of intergranular contacts, corresponding to an increase of porosity and decrease of mechanical strength, thus it reduces the ultrasonic velocity [8].

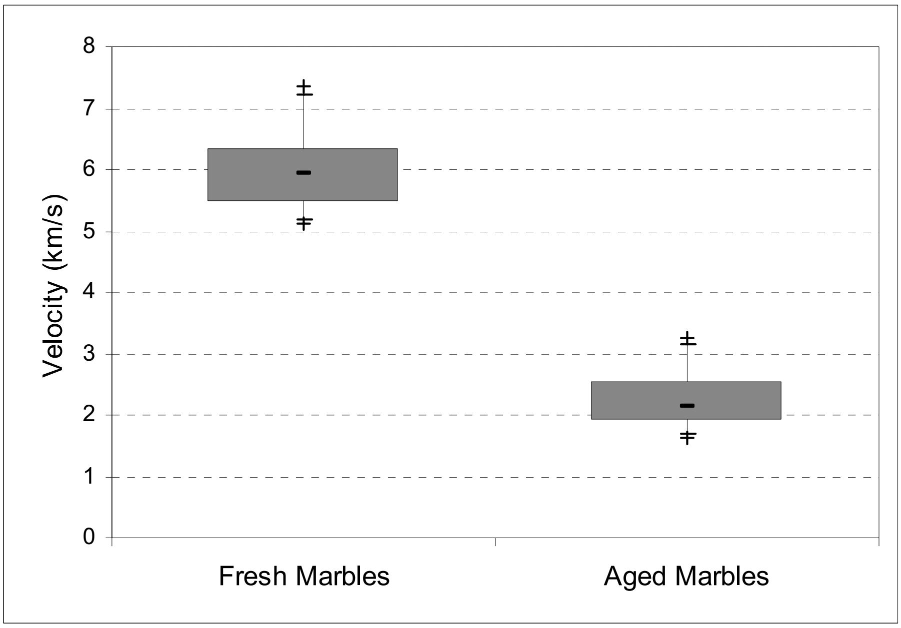

Figure 1: Ultrasonic velocity before and after artificial thermal ageing

The cubes are treated with the Bologna Cocktail (BC), whose published recipes vary in their solvent composition. In this study, the BC, which contains Dri Film 104 and Paraloid B72 in solvents, is based on the recipe of the commercial product Acrisil 201/O.N. distributed by the firm CTS (Italy), following the current safety standard. Table 1 explains its composition.

Table 1: "Bologna Cocktail" composition (according to CTS Material Safety Data Sheet)

Components	Composition	Amount (%)	% of active matter
Dri Film	30% in Toluene:Xylene 1:1	5	1.5
Paraloid B72	70% in White Spirit	15	10.5
Solvents mixture	Butanone (37.5%), Acetone (37%), Toluene (4.5%), Butanol (1%)	80	89

The artificially aged stones are treated with BC following different techniques of application:

- by capillary rise for one hour (BCC)
- by brush, one time (BC1)

- by brush one time, followed by rinsing with the Bologna Cocktail solvent mixture (BC1+SV)
- by brush five times, each time followed by rinsing with the Bologna Cocktail solvent mixture, with at least two days between each application (BC5+SV) (method used and recommended by Nonfarmale [1]).

For comparative purpose, an elastified ethyl silicate (SAE) (Remmers Funcosil Steinfestiger 300E) is applied by capillary rise for one hour.

2.2 Methods

2.2.1 Iodine staining

Iodine staining is performed on the samples following a method developed by Kumar and Ginell [9], to visualise the location of organic consolidants in limestone. Crystalline iodine, that sublimates at room temperature, has the property, in vapour, to adsorb on many organic compounds, forming a coloured yellow to dark brown stain. The process is reversible, as there is no chemical reaction between the organic component and the iodine vapour, but just physisorption.

2.2.2 Microprobe technique

For the analysis by means of Environmental Scanning Electron Microscope (ESEM), as well as by Electron Microprobe, the treated stone samples are embedded, cross-sectioned and polished. The consolidants are first detected by ESEM analyses. The elemental distribution of Si is used to indicate the presence of consolidant, as both products, BC and Remmers Funcosil 300E, contain silicon components in different concentrations. For a higher resolution, the stone samples are secondly analysed for elemental distribution using a CAMECA SX-100 Electron Microprobe. The observations are made with the following conditions: 20 nA beam current at 10 Kv accelerating voltage. A series of X-ray maps for Si, Ca, Fe, and O are acquired using WDS spectrometers at a size of 256 × 192 pixels and a dwell time of 100 ms in order to map consolidant distributions with depth.

2.2.3 Microdrop absorption (modified after RILEM II.8.a)

Microdrop absorption is used to determine the penetration depth of the consolidant into the stone, by showing the water-repellency. The rate of absorption by capillary decreases in treated stone, due to the water repellency effect of the consolidant and, also to a minor extent, due to the reduced pore size and distribution. Drops of 5 µl are deposited at regular distances on the side of drill cores taken from treated stone cubes. The time necessary for its complete absorption / evaporation is registered.

2.2.4 Drilling Resistance Measurement System

The Drilling Resistance Measurement System (DRMS), a micro-destructive method [10], has been applied to determine the stone hardness. The evaluation of the hardness is related to the drilling penetration force: the force necessary to drill a hole under specific operative conditions such as the Penetration Rate (PR) and the Rotational Speed (RS), which remain constant during the test. The DRMS developed by SINT Technology (Florence, Italy) consists of a precision drilling machine equipped with two precisions motors (to keep PR and RS constant), controlled by a computer. The profiles of drilling resistance provides information about the consolidating effect and the penetration depth of a product.

According to the operative conditions, the drilling resistance is recorded on the treated marble cubes for 5 mm/min and 1200 rpm. Then the values are corrected according to the formula [11]:

$$DR_c = DR\frac{20 \times RS}{PR \times 600}$$

DR_c: Corrected drilling resistance (N)
DR: Drilling resistance (N)
In this study diamond drill bits with 5mm diameter are used.

2.2.5 Bi-axial Flexural Strength

The efficiency and the penetration depth of the consolidation treatment are determined by evaluating the bi-axial flexural strength of stone slices collected at successive depths in a drill core taken from a treated marble cubes [12].

A slice of stone is placed between two steel rings. A load (F) is applied on the sample. First an elastic deformation occurs, which allowed determining the static E-modulus (E_{stat}). By increasing the load until the sample's break, the bi-axial flexural strength (σ_{fb}) is calculated.

3 Results

3.1 Direct detection of consolidant

Figure 2 displays Si-mappings for BCC, BC5+SV and SAE treatments. The mapping of BCC, Bologna Cocktail applied by capillary rise, shows clearly that a film was formed on the surface of the sample; the product concentrated close to the surface without penetrating in depth. No film occurrence is observed on BC5+SV's mapping. The application by brush followed by rinsing seems to eliminate successfully the film-formation. For all samples treated with the Bologna Cocktail, the concentration of silicon in the pore space decreases quickly below the surface and falls below detection limits before reaching a depth of 5 mm (Table 2). Nonfarmale's method of solvent rinsing is obviously efficient in reducing the film formation on the surface of the stone, but does not increase the penetration depth.

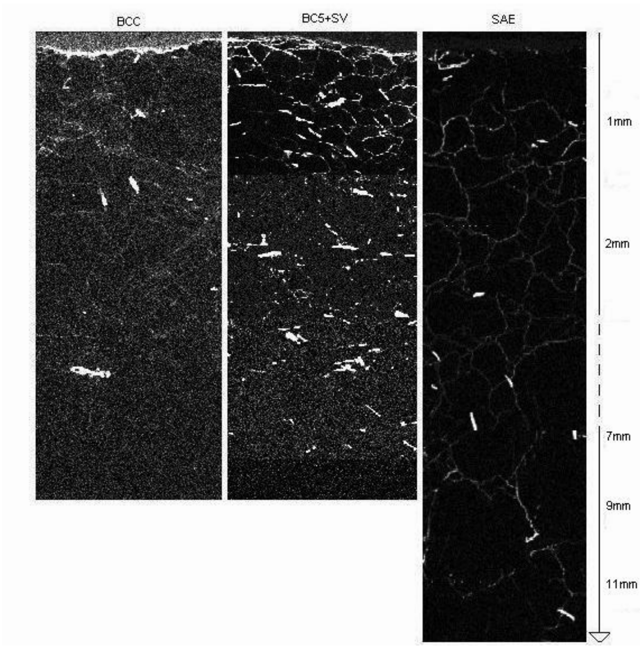

Figure 2: WDS X-Ray map for Silicon (left: BCC, middle: BC5+SV, right: SAE)

In comparison, the SAE shows a significantly higher penetration than the Bologna Cocktail. Here, Silicon is observed in depths until 9-11 mm.

The results of iodine staining are summarized in Table 2. The penetration depth measured for the different samples of BC ranges between 0 and 3.6 mm, while SAE reaches a depth of 12.5 mm. These results confirm those obtained by microprobe.

Table 2: Results of penetration depth detection with the microprobe and iodine staining

Treatments	Microprobe mm	Iodine staining mm
BCC	1-2	3.6
BC1	<0.5	2.7
BC1+SV	-	-
BC5+SV	1-2	1.5
SAE	9-11	12.5

The application technique by capillary rise results in better penetration than the application by brush. However the rinsing with solvents after the application of the BC by brush, as propagated by Nonfarmale does not have the desired effect on the penetration depth. On the contrary for the one-time application by brush followed by rinsing, no Silicon is found, suggesting the rinsing operation removes the active matter of the consolidant.

The microprobe analysis, as well as the iodine staining, both allow to detect the consolidant itself, by showing the presence of one of its constituents. By ESEM, the inorganic phase is able to be distinguished, through the mapping of the elemental distribution of Silicon, while the iodine vapour is adsorbed on the organic phase to form brown stains. A slight difference is obtained between the two exerted methods of analysis. Iodine staining tends to show a higher penetration depth than the microprobe analysis for the application of the Bologna Cocktail without rinsing (BCC and BC1). This can be due to a slight chromatographic effect, with a better penetration of the organic matter than of the silicon part. This effect would be eliminated by rinsing.

The presence of the consolidant is proved by direct detection, but it is important to underline that the presence of the consolidant itself gives no direct evidence for the consolidation performance. The product may be present but have a poor or no consolidating effect. Hence it is insufficient to notice the presence of the product, but to also to observe its consolidating effect, as it is done in this study by measuring the bi-axial flexural strength.

3.2 Hydrophobicity

There are three distinct profiles of hydrophobicity detected by the microdrop test, as shown in Figure 3. The samples of BC1, BC1+SV and BC5+SV first show very high values of absorption time on the treated surfaces, but then the values along the core drop fast down to a constant low range, showing that water-repellent properties are limited to the first 3 mm. For BCC, the absorption time on the treated part is similar to the other treatments with Bologna Cocktail (around 5000 s), but the evaporation / absorption times at a depth of 3 mm and 7.5 mm are still higher than the values of the untreated marble, indicating the presence of water-repellent properties in depth. In the case of treatment with SAE, the absorption time on the treated surface is significantly lower (less than 3000 s) in relation with the hydrophilic properties of the compound. Deeper along the drill core, the absorption time decreases slowly until 15 mm, where it reaches the range of the untreated marbles.

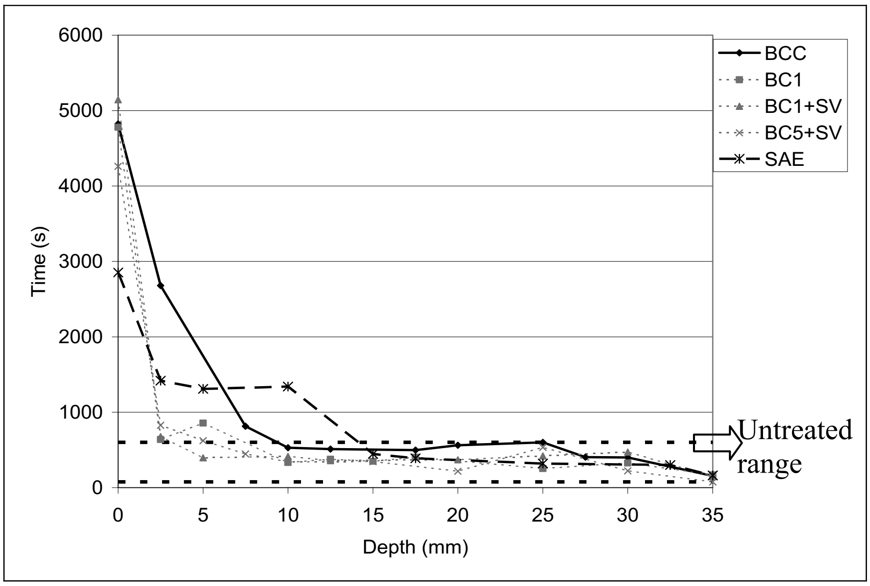

Figure 3: Profiles of Microdrop test

As the Bologna Cocktail treatment noticeably modifies the properties related to water transport, due to its hydrophobic effect, the microdrop test also acts as an indirect way to measure the penetration of this consolidant into the stone.

3.3 Strength detection

3.3.1 Drilling resistance measurements

Proconnesian marble, being a homogeneous stone, allows to compare the drilling profiles directly from one sample to the other. Figure 4 shows three profiles of drilling resistance: an untreated aged marble as reference, SAE and BCC. BCC's profile is homogeneous, varying around 300 N along the entire depth. Although the DR_c is slightly higher than the DR_c of the untreated stones, there is no proof of a consolidating effect.

In case of SAE, the drilling resistance is generally a little higher and begins to decrease at 9-10 mm. It is important to notice that it decreases slowly: there is no zone of strong discordance between a superficial consolidated layer and interior untreated zones. The consolidation seems to perform very well until around 10 mm depth.

3.3.2 Bi-axial flexural strength

The range of values of bi-axial flexural strength of the untreated samples of Preconnesian marble is determined first: it lays between 3.0 and 5.5 N/mm^2. The values, shown in Table 3, allows to compare the range of the bi-axial flexural strength of the samples treated with BC, against the mean-value of the strength for SAE samples.

The first slice, coming from the treated surface of the core, has a higher strength, when treated with the Bologna Cocktail, as seen in Table 3, except for BC1+SV, which has a homogeneous profile of strength versus depth. Nevertheless, the bi-axial flexural strength of BC1 is much lower, 7.2 N/mm^2, while for the others, the strength ranges from 10.1 to 11.0 N/mm^2. Owing to these facts, the consolidation of the first slice is very important for BCC and BC5+SV, less noticeable for BC1 and not visible for BC1+SV.

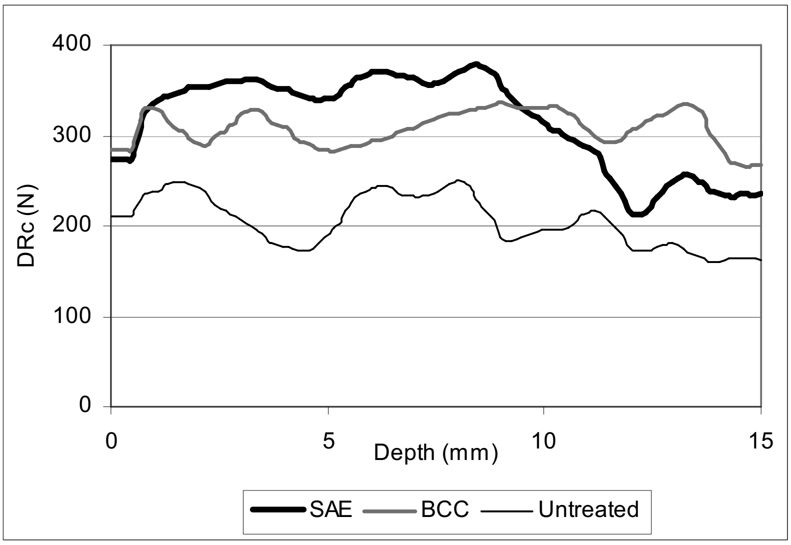

Figure 4: Drilling resistance measurements (BCC, SAE)

For the cores treated with ethyl silicate, the values show a higher strength for the first free slices, assuming that the product penetrates until 12 mm.

Table 3: Results of the bi-axial flexural strength

Depth mm	BC σbz (N/mm²)	SAE σbz (N/mm²)
0-4	7.2-11.0	9.6
4-8	5.4-6.2	6.6
8-12	3.5-5.0	7.4
12-16	3.0-4.5	4.7
16-20	3.1-5.5	3.0

Figure 5 shows the bi-axial flexural strength as a function of the static modulus of elasticity, for Proconnesian marble.

For one substrate, both properties, the bi-axial flexural strength and the static modulus of elasticity, are following a linear correlation: higher strength corresponds to a higher modulus of elasticity. When a consolidation treatment is applied, the aim is to increase the strength, but a consolidation treatment also modifies other linked mechanical properties. Thus by increasing the strength, the modulus of elasticity will also increase. A disproportionately large increase of the modulus of elasticity compared to the bi-axial flexural strength should be avoided. Ideally the increase should follow the correlation line established for the untreated stone, like it is observed in the case of the treatment with the elastified ethyl silicate, as seen in Figure 5. But some treatments like the Bologna Cocktail applied by capillarity substantially increase the E-modulus beyond the desired values, inducing discordance in the mechanical properties between the treated and untreated stone. If stress is applied, the two parts of the treated stone will react differently, which is supposed to increase the risk of decay.

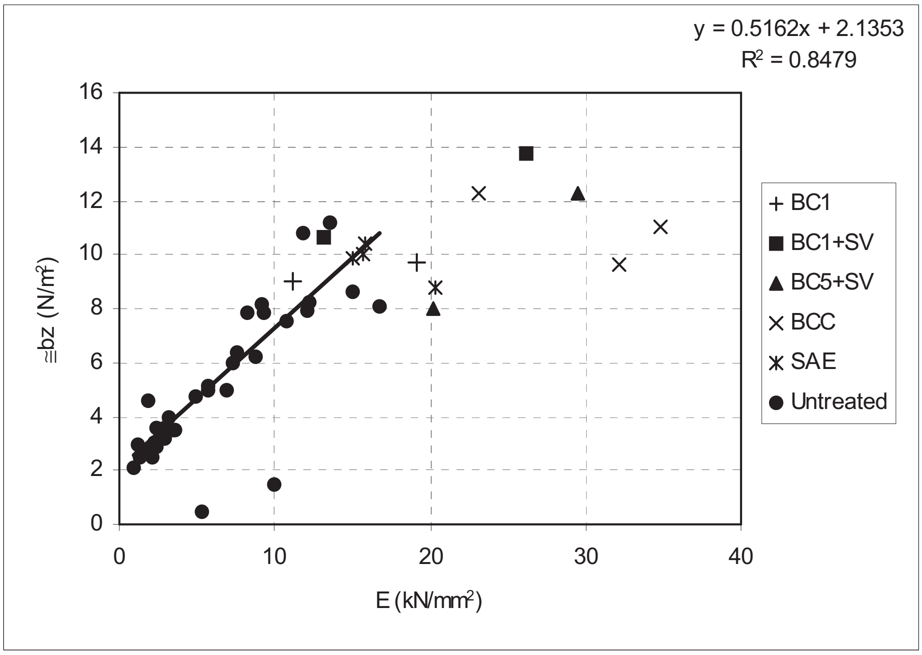

Figure 5: Bi-axial Flexural Strength vs. E-modulus

4 Conclusion

In this study, the presence of consolidant is put in evidence by diverse techniques: direct and indirect detection of the product itself or direct and indirect detection of its consolidating effect. There is a good correlation between the values of penetration or efficiency depths for the ethyl silicate, which has a good penetration depth. However, for the Bologna Cocktail, the scattering of the results probably comes from the difficult detection of a product that has a low penetration. Indeed, in this case, methods related to strength measurements seem less reliable. It is still clearly visible that the Bologna Cocktail is restricted to the first millimeters, regardless of the application technique. This does not fit the requirement for a stone consolidant to penetrate deeper than the zone of maximum mean moisture [13]. Moreover, it modifies noticeably the intrinsic properties of the stone and induces abrupt changes between the treated and untreated parts, revealing possible risks of discordance, when reacting to stress.

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BIODAM – Practicability studies, application experience and succes control of polyphasic approaches to inhibit subaerial biofilm growth and damage on buildings including spin-off to end-users

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Sub-aerial biofilms – a term introduced by Gorbushina (1997) – considerably differ in characteristics and detrimental aspects from subaquatic ones. Biofilms of varying compositions have been found to largely influence the aesthetical outlook and durability of building surfaces worldwide (Krumbein, 2003). Damage and protection from biofilm growth are of enormous scientific, applied and commercial potential. The “Neue Pinakothek” Munich (Germany) for example rapidly developed green and black detrimental biofilm growth and was cleaned and restored at extremely high costs only 25 years after inauguration. Similar effects occur on very ancient buildings. The Primatiale of St. Trophime at Arles (France) or the pock-scarred Colonna Traiana in Rome (Italy) are examples of permanent cleaning experiments with new growth occurring shortly after treatment. Restoration and conservation attempts often failed or were lead “ad absurdum” by new biofilm growth emerging as fast as three months after cleaning and conservation. The project BIODAM of the EU has initiated new techniques and new ways of polyphasic anti-biofilm-treatments by combining skill of biologists, chemists, geologists, engineers, physicists, and restoration / conservation experts (Alakomi et al., 2004). BIODAM also involved consulting experts (BIOGEMA) and governmental authorities (Historic Scotland) in order to include environmental aspects as well as art history case studies into new approaches to bioremediation and safeguarding. This contribution depicts (1) the technology developed (2) the techniques applied and potentially applicable in the future and, (3) the strategies of transferring the scientific and technological progress into the policies and strategies of end-users. Multiple techniques as well as success control methods are described briefly using examples from laboratory, field test sites, and modern and ancient buildings. Last not least a brief analysis is given on misinterpretations of damaging colour changes and destructive elements reported on building surfaces. Air pollution, aerial dust deposition and biofilm growth as complex interactive factors in architectural damage are evaluated.

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Biotechnologies and cultural heritage

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Sulphates, nitrates and organic compounds are commonly found as alterations of works of art. This presentation describes the use of viable bacteria for the cleaning of cultural heritage as an alternative method to both organic solvents and mechanical treatments. Sulphates are transformed into H_2S by sulphate-reducing bacteria, nitrates into N_2 by nitrate-reducing bacteria, and organic matter into CO_2 by organic degrader bacteria. H_2S, N_2 and CO_2 are gases that are liberated into the air.

Four *in-situ* bioapplications are presented. The biotreatments of the Cathedral of Milan and the Cathedral of Matera altered by sulphates and nitrates respectively (EU funded BIOBRUSH project); the biological removal of the insoluble glue of the frescoes of the Monumental Camposanto in Pisa; and, finally, the bioremediation of the base of Michelangelo's Pietà Rondanini altered by gypsum and calcite.

Tools for assessment of corrosion and soiling in the multi-pollutant situation

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Key words: corrosion; soiling; dose-response function, pollution, cultural heritage

1 Background

The cost for deterioration and soiling of different materials due to air pollution are huge and the damage to culture targets endangers seriously the rich European cultural heritage. Effective policy making requires environmental impact assessment, cost benefit analysis and risk management. An important effort to create management tools based on quantification of detrimental effects of pollution on materials has been the MULTI-ASSESS (Model for multi-pollutant impact and assessment of threshold levels for cultural heritage) project within EU 5FP [1].

The decreasing sulphur dioxide (SO_2) levels in most parts of Europe and the increasing car traffic causing elevated levels of nitrogen compounds, ozone and particulates has created a new multi-pollutant situation. This has been acknowledged *i.a.* in the activities within the UN/ECE Convention on long-range transboundary air pollution (CLRTAP), where a multi-pollutant, multi-effect protocol has been adopted. This changed pollution situation must be taken into account in the development of an improved model for the effects of pollutants on the deterioration of important material groups. Existing dose-response and damage functions, prior to the MULTI-ASSESS project, reflect in principle a pollution situation dominated by sulphur dioxide emissions. The decreasing trend of SO_2 levels in Europe has resulted in decreasing corrosion rates for most materials, Fig.1. For some materials, however, the corrosion in the last years is no longer decreasing despite the still decreasing levels of SO_2. Thus special interest in the MULTI-ASSESS was devoted to important parameters such as the corrosive and soiling effects of particulate matter and the effect of nitric acid (HNO_3). Both parameters are of special interest in urban areas with dense traffic and HNO_3 is of special interest in warmer regions such as in the Mediterranean countries.

The performance of this ambitious and innovative project was possible as MULTI-ASSESS completes and extends the CLRTAP International Co-operative Programme on Effects of Materials including Historic and Cultural Monuments (ICP Materials) and there has been an important synergism between the two projects.

The main objectives of the MULTI-ASSESS project have been:

- To *develop* multi-pollutant deterioration and soiling models of wet and dry deposition of gases and particulates and to obtain DRF:s quantifying the corrosion and soiling.
- To *use* the DRF:s for assessment of tolerable levels of pollution and to recommend target levels to be implemented in the future development of EU Directives on urban air quality in order to minimise the pollution effects on historic and cultural objects.
- To demonstrate the approach by mapping areas exceeding tolerable levels in Europe.
- To adapt and validate passive samplers for measuring concentrations of HNO3 and particles.

- To *propose a kit* for rapid low cost assessment of the deterioration risk to objects of cultural heritage, consisting of selected material specimens and passive samplers for pollutants.

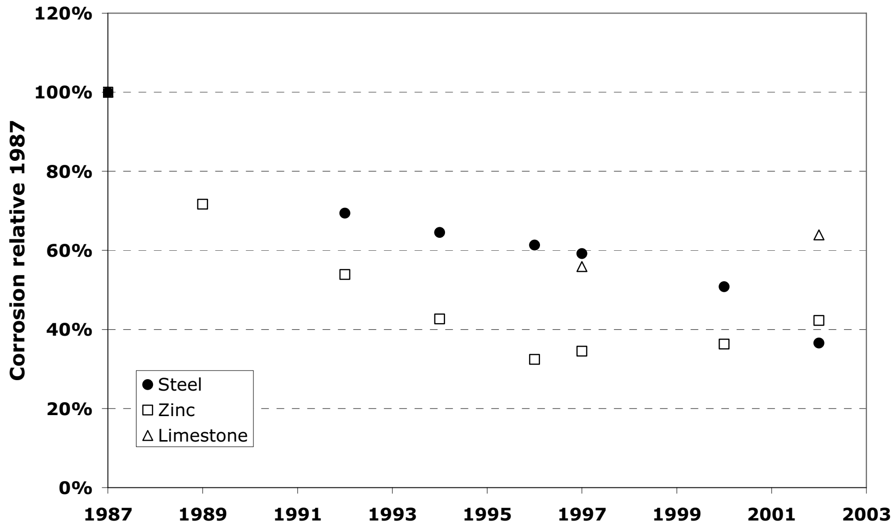

Figure 1: Average trends in corrosion based on data from ICP Materials sites

2 Passive samplers for pollutants

To the advantages of passive samplers belongs that they do not need electricity, are small, and noiseless. Besides they measure concentration *in-situ,* they are cost-effective and can be used for long-term sampling and their measuring range is very large. These characteristics are very important especially for measurements of pollution in microclimates on or close to monuments. Within the project new concepts of passive samplers were validated for HNO_3 and for particles. The successful development is illustrated in the sequel.

The sampler for HNO_3 has been used in an extensive network of ICP Materials. The annual average concentrations at the European sites are shown in Fig. 2. As can be seen from the map the concentrations are low in northern Europe and high in Southern. The HNO_3 concentrations are unfortunately higher in the cities, where most of our cultural heritage is situated, see Fig. 2.

The sampler for particles consists of a surrogate surface of a cylindrical shape covered with a Teflon filter wind-exposed vertically under a rain shelter. It was used to measure two months average particle deposition at 35 test sites during one year. The particle mass, light reflectance (soiling) and its chemical content (nitrate, ammonium, sulphate, calcium, sodium, chloride, magnesium and potassium) were analysed. Additionally PM_{10} concentrations were obtained from 14 sites. Surprisingly, the deposited masses correlated very well with the PM_{10} concentration at 11 of these, see Fig. 3. The slope of the regression line corresponds to a deposition velocity of 2.3 mm s^{-1}. The other three sites were all close traffic and gave a higher deposition velocity. This correlation makes it possible to establish a relation between PM_{10} and particulate deposition and has been used in order to replace the PM deposition values in the DRF:s with the today available concentration of PM_{10}. This is a necessary requirement in order to define practically useful target levels for corrosion and soiling.

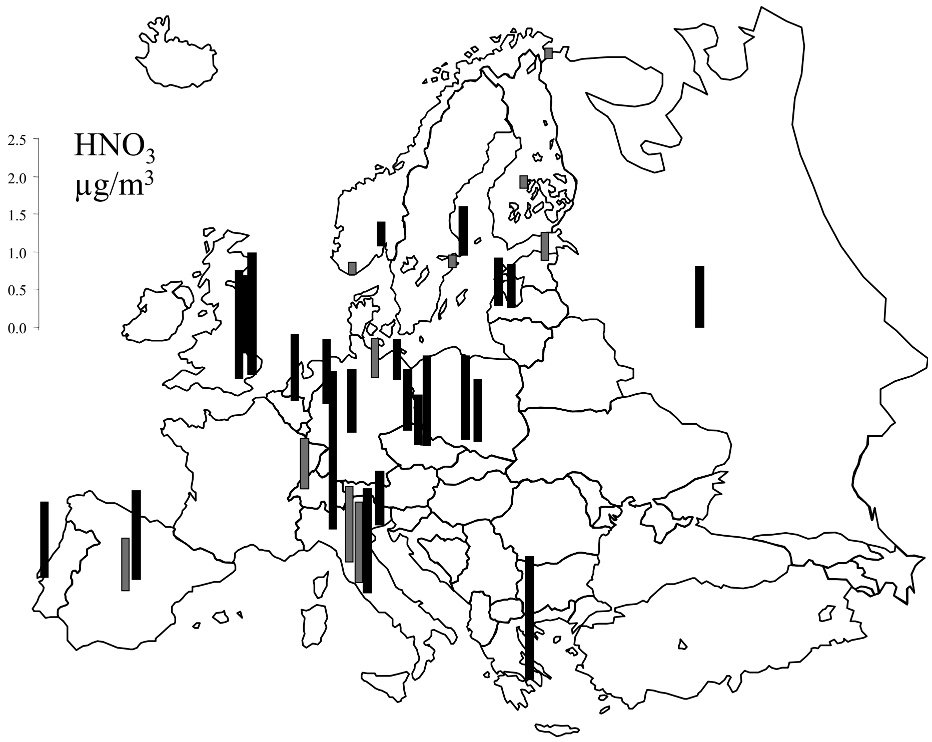

Figure 2: Annual HNO_3 (December 2002 to November 2003) concentration at the ICP Materials / MULTI-ASSESS test sites. Grey and black bars indicate rural and urban sites respectively

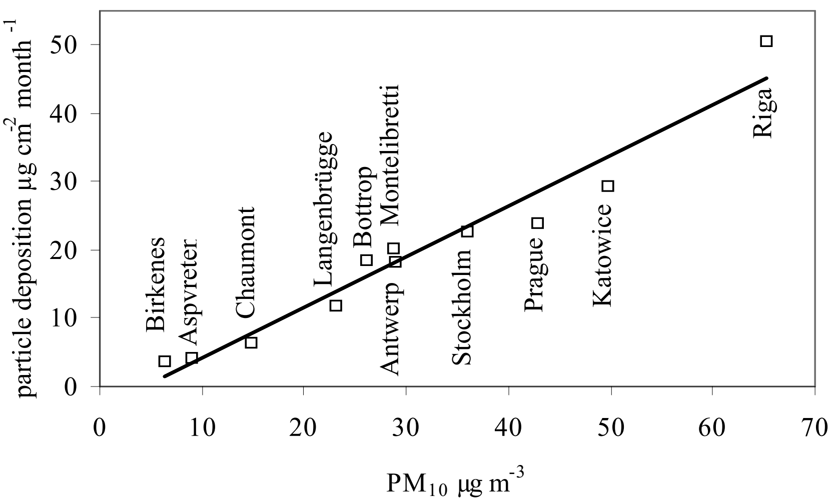

Figure 3: Particle deposition to the passive sampler in rain sheltered wind-exposed position as a function of PM_{10} concentration

3 Dose-response functions

3.1 Corrosion

The statistical analysis has been a combination of linear/non-linear regression based on corrosion values of carbon steel, zinc, copper, bronze and limestone after 1, 2 and 4 years of exposure in the ICP Materials multi-pollutant programme (1997-2001) [2]. The environmental characterisation has then been complemented with data on HNO_3 and particulate matter from the MULTI-ASSESS exposure.

One important criterion for the developed DRF:s is that they should be suitable for mapping areas with increased risk of corrosion. Therefore the environmental parameters have been restricted to those that are easily available or can be related/calculated from other easily available parameters. These are given in table 1 including used abbreviations and units. A list of the DRF:s for steel, zinc, copper, cast bronze (expressed as ML in g m^{-2}) and Portland limestone (expressed as surface recession, R, in µm) is given in table 2. However the PM_{dep} that is not easily available has been substituted by the PM_{10} concentration using the relation

$$PM_{dep} = 72.6 \times PM_{10}$$

Table 1: Environmental parameters used in the statistical evaluation

Parameter description	Abbreviation	Unit
Temperature	T	°C
Relative humidity	Rh	%
Amount of precipitation	Rain	mm $year^{-1}$
pH of precipitation	pH	decades (dimensionless)
Acidity of precipitation#	$[H^+]$	mg l^{-1}
SO_2 concentration	$[SO_2]$	µg m^{-3}
NO_2 concentration	$[NO_2]$	µg m^{-3}
O_3 concentration	$[O_3]$	µg m^{-3}
HNO_3 concentration	$[HNO_3]$	µg m^{-3}
Total PM deposition	PM_{dep}	g m^{-2} $year^{-1}$

Calculated directly from pH

Table 2. List of MULTI-ASSESS dose-response functions, including the temperature function for unsheltered materials

Material Dose-response function Temperature function
Carbon steel $ML = 29.1 + \{21.7 + 1.39[SO_2]^{0.6}Rh_{60}e^{f(T)} + 1.29Rain[H^+] + 0.593PM_{10}\}t^{0.6}$ $f(T) = 0.15(T-10)$ when $T < 10$ °C, $-0.054(T-10)$ otherwise
Zinc $ML = 1.82 + \{1.71 + 0.471[SO_2]^{0.22}e^{0.018Rh+f(T)} + 0.041Rain[H^+] + 1.37[HNO_3]\}\ t$ $f(T) = 0.062(T-10)$ when $T < 10$ °C, $-0.021(T-10)$ otherwise
Copper $ML = 3.12 + \{1.09 + 0.00201[SO_2]^{0.4}[O_3]Rh_{60}\cdot e^{f(T)} + 0.0878Rain[H^+]\}t$ $f(T) = 0.083(T-10)$ when $T < 10$ °C, $-0.032(T-10)$ otherwise
Cast Bronze $ML = 1.33 + \{0.00876[SO_2]Rh_{60}\cdot e^{f(T)} + 0.0409Rain[H^+] + 0.0380PM_{10}\}t$ $f(T) = 0.060(T-11)$ when $T < 11$ °C, $-0.067(T-11)$ otherwise
Portland limestone $R = 3.1 + \{0.85 + 0.0059[SO_2]RH_{60} + 0.054Rain[H^+] + 0.078[HNO_3]Rh_{60} + 0.0258PM_{10}\}\ t$

Also the HNO_3 concentration is today not easily available and therefore the following equation was developed, based on environmental data obtained in the project, It may be used for calculating annual HNO_3 concentrations where measured values are not available:

$$HNO_3 = 516 \bullet e^{-3400/(T+273)}([NO_2] \bullet [O_3] \bullet Rh)^{0.5}$$

The SO_2 concentration was the single most important parameter in previously developed DRF:s from ICP Materials. These functions were, prior to the newly developed ones given in table 2, considered to be the best available DRF:s suitable for mapping and calculation of costs. SO_2 is also a very important parameter in the multi-pollutant situation for all materials. Both the previously developed and the new DRF:s are useful but for different purposes:

The previously developed ICP Materials DRF:s are valid for the *SO_2– dominating situation*, and are preferable especially when the SO_2 concentration is high.

The new DRF:s given in table 2 are valid for the *multi-pollutant situation*, and are preferable especially when contributions from N pollutants and/or particulate matter is expected to be high, often in urban areas dominated by traffic.

This is illustrated in figure 3. In the interval with moderate SO_2 concentrations (0-20 µg m^{-3}) the difference between the two functions is not significant. The main difference between the two functions is at higher SO_2 concentrations (60-80 µg m^{-3}) where the linear function wrongly predicts higher values.

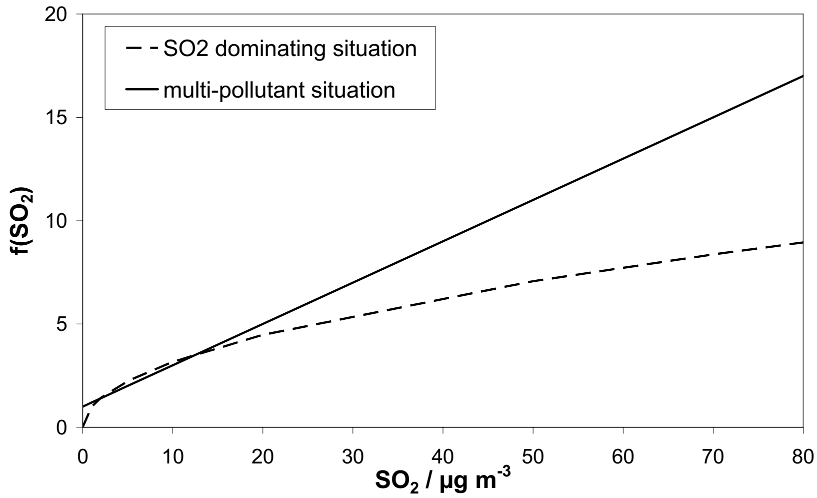

Figure 3: Illustration of the difference between the SO_2 dependence in dose-response functions for the SO_2 dominating situation and for the multi-pollutant situation

3.2 Soiling

For a model to be useful in policy terms, it should have a physical basis because this permits soiling rates to be described in terms of atmospheric pollution (especially particulate matter). The exponential model is the one which has been most commonly used in soiling studies because it meets this criterion

$$R = R_0 \exp\{- K \times t\}$$

Where R is the reflectance, R_0 is the reflectance at time zero, K is a constant and t is the exposure time. This is the relationship (often called the basic exponential relationship) which has been most frequently used in soiling studies.

For this reason, the DRF:s used in the development of tolerable levels are based on the exponential model while further research is being carried out on other models. The developed DRF:s are:

Painted Steel: $\Delta R = Ro\ [1\text{-}\exp(- C_{PM10} \times t \times 5.9 \times 10^{-6})]$

White Plastic: $\Delta R = Ro\ [1\text{-}\exp(-C_{PM10} \times t \times 5.3 \times 10^{-6})]$

Polycarbonate Membrane: $\Delta R = Ro\,[1\text{-}\exp(-C_{PM10} \times t \times 2.4 \times 10^{-6})]$
Limestone: $\Delta R = Ro\,[1\text{-}\exp(-C_{PM10} \times t \times 6.5 \times 10^{-6})]$

where C_{PM10} is in µg m^{-3} ; t is in days

While an exponential model (basic or asymptotic) gives a fit to experimental data which is generally satisfactory for metal, plastic and stone, it does not give a sufficiently good fit for glass and therefore an alternative approach has been developed to describe the soiling of modern glass.

4 Tolerable pollution and deterioration levels

4.1 Corrosion

Because atmospheric deterioration of materials is a cumulative, irreversible process, which proceeds even in the absence of pollutants, threshold levels and critical levels are not applicable as for some natural ecosystems. Instead, the term acceptable level has been introduced and is currently used in the UN/ECE LRTAP Mapping Manual [3]. In this presentation instead the term tolerable level is used specifically for cultural heritage objects since the use of the word "acceptable" may give the impression that the loss of our cultural heritage is acceptable. In principle, however, the same framework developed for acceptable levels and described in the mapping manual can be applied also for tolerable levels.

Material corrosion is affected both by the climatic as well as the pollution situation. The climate impact will change with the geographical situation and can not be controlled outdoors. Several pollutants will increase the corrosion rate and the relation between tolerable corrosion and tolerable pollution is illustrated schematically in Figure 4.

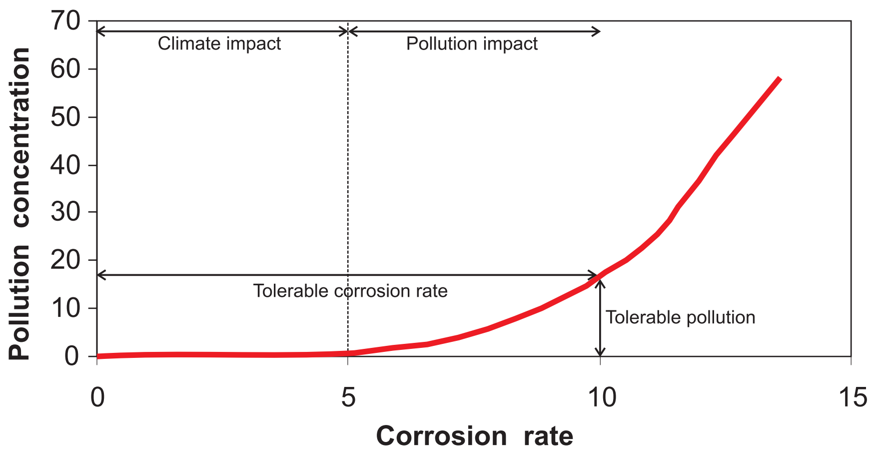

Figure 4: Schematic illustration of the relation between tolerable corrosion and tolerable pollution

The tolerable corrosion rate has to be based on experiences from restoration work and can be calculated from two important components:

– The "tolerable corrosion before action", based on the stage of deterioration when the restoration must start
– The "tolerable time between maintenance", based on how often it is acceptable to restore the object.

The recommended values of these two parameters will be different for old cultural heritage materials compared to new monuments or replaced materials. However, it turns out that the resulting tolerable corrosion rate is relatively independent on these factors. When assessing target levels for policy purposes the status of the object can not be a parameter and a more uniform approach is needed. If the approach in the UN/ECE Mapping Manual for acceptable levels is applied to tolerable levels the tolerable corrosion rate (K_{tol}) can be calculated as

$$K_{tol} = n \times K_b$$

Where n is a factor and K_b is the background corrosion level for Europe. In Table 3 the tolerable corrosion rate for the most common materials are shown for n = 2.5. The background corrosion rates are taken from the UN/ECE Mapping Manual.

Table 3: Tolerable corrosion rate based on background corrosion rates and n = 2.5

Material	Background corrosion rate	Tolerable corrosion rate
Limestone	3.2 µm year^{-1}	8 µm year^{-1}
Sandstone	2.8 µm year^{-1}	7 µm year^{-1}
Copper	0.34 µm year^{-1}	0.8 µm year^{-1}
Bronze	0.25 µm year^{-1}	0.6 µm year^{-1}
Zinc	0.46 µm year^{-1}	1.1 µm year^{-1}
Carbon steel	8.5 µm year^{-1}	20 µm year^{-1}

DRF:s for the materials were presented above and involve the effect of both climate and pollution (table 2). These functions together with the tolerable corrosion rates enable the specification of a tolerable climate / pollution situation. In the multi-pollutant situation several different options can be implemented in order to reach the same goal, i.e. to reach the tolerable climate / pollution situation, and a complete strategy should in principle involve all parameters included in the DRF:s. However, in order to assess the SO_2 concentration, which still is one of the most important parameters for corrosion, it is possible to fix the other parameters expressed as different scenarios. The consequence of using the tolerable corrosion rates from table 3 on selected materials in the ICP Materials network is given in table 4. Even though the corrosion rate has decreased substantially exceedances of tolerable levels of corrosion for materials included in objects of cultural heritage are still frequent.

Table 4: ICP Materials test sites with corrosion rates exceeding the tolerable corrosion rate in 1997 for carbon steel, zinc and limestone

No exceedances		Exceedances for 1-2 materials	Exceedances for all 3 materials
Ähtäri	Aspvreten	Prague-Letnany	Bottrop
Waldhof-Langenbrügge	Madrid	Kopisty	Milan
Casaccia	Toledo	Langenfeld-Reusrath	Lincoln Cathedral
Oslo	Lahemaa	Rome	Lisbon
Birkenes	Dorset	Venice	
		Stockholm South	
		Moscow	

4.2 Soiling

As for corrosion, the tolerable soiling rate has to be based on tolerable degradation and time intervals between actions. For soiling, however, these two factors have been assessed in a different way:

The “tolerable soiling before action”, based on the public attitudes to soiling and a perception of what constitutes tolerable degradation. The EU 5FP project CARAMEL has indicated that a 35% loss in reflectance triggers significant adverse public reaction. This value has been adopted also by MULTI-ASSESS.

The “tolerable time between cleaning”, based on an assessment of the period of time for which the building can remain without cleaning and an economic evaluation of the options. For cultural heritage objects a period of 10-15 years is appropriate.

These factors together with the DRF:s can be used to make an estimate of the maximum ambient air quality to which the building can be exposed to tolerable soiling (Table 5). Based on these data a tolerable PM_{10} level of 15 $\mu g\ m^{-3}$ is proposed.

Table 5: Tolerable PM_{10} levels for painted steel, white plastic and limestone based on dose-response functions and a tolerable loss of reflectance of 35%

Material	5 years	10 years between	15 years maintenance	20 years
Painted steel	40 $\mu g\ m^{-3}$	20 $\mu g\ m^{-3}$	13 $\mu g\ m^{-3}$	10 $\mu g\ m^{-3}$
White plastic	45 $\mu g\ m^{-3}$	22 $\mu g\ m^{-3}$	15 $\mu g\ m^{-3}$	11 $\mu g\ m^{-3}$
Limestone	36 $\mu g\ m^{-3}$	18 $\mu g\ m^{-3}$	12 $\mu g\ m^{-3}$	9 $\mu g\ m^{-3}$
Average	40 $\mu g\ m^{-3}$	20 $\mu g\ m^{-3}$	13 $\mu g\ m^{-3}$	10 $\mu g\ m^{-3}$

5 Kit for assessment of pollution and deterioration

The DRF:s developed in MULTI-ASSESS express the general level of corrosion attack in a particular area and can not, nor are they intended to, take into account possible effects of microclimate. However, people in heritage management are often interested in the level of corrosion attack on specific locations at their object of interest. To respond to this demand, the MULTI-ASSESS project has developed a Rapid Tool Kit, Figure 5.

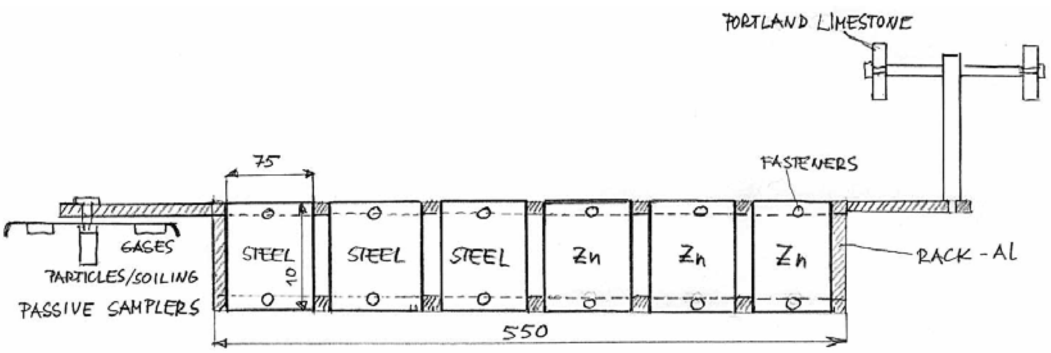

Figure 5: Rack for the Rapid tool kit – complete

The selected materials are representing metals (carbon steel and zinc) and porous materials (Portland limestone) and are selected because they have reliable DRF:s and sufficient degradation rate after one year of exposure. The material used for soiling (identical with the passive sampler for particular matter exposed in a rain sheltered position) has a good soiling correlation with the particle concentration in air. It will also be possible to expose 3 samples of one type of local stone on the rack (optional).

The Rapid Tool Kit is proposed in two versions: *Basic* and *Complete*. Both versions contains a rack with reference specimens for assessment of corrosion and soiling of materials or materials groups of interest and the *Complete* version also includes passive samplers of the relevant pollution parameters (SO_2, NO_2, HNO_3 and O_3). The exposure period for both kits shall be one year in total in order to even out the effect of seasonal variation and to get reliable data for comparison with the tolerable corrosion levels.

Data from the tool kits will show if tolerable pollution levels are exceeded and how the environment is affecting deterioration and soiling of the relevant materials. If the exposures are repeated, for example each third year, the results will give trends of pollution and deterioration, which could be used as control of the effectiveness of strategies and measures for reduction of pollution and as an early warning of unexpected increase of corrosion due to new sources or combinations of pollutants.

6 Conclusions

The project has been performed in co-operation of partners from 8 European countries and used a network of 30 test sites. This exceptional resource could not has been achieved in a national or bilateral co-operation both due to the necessary financial resources and to the variability of pollution and climatic parameters in the concerned European region.

The main achievements of the highly innovative project are the development of new DRF:s for corrosion and soiling in the multipollutant situation, their use for assessment of tolerable deterioration rates and pollution levels, and the development of a kit for rapid determination of corrosion and soiling including passive samplers for HNO_3 and particles.

The DRF:s together with the tolerable corrosion and soiling rates enable the specification of an acceptable climate / pollution situation. For SO_2 a target level of 10 µg m^{-3} is proposed protecting 80% of the European territory at present HNO_3 levels. PM is not a crucial parameter for the corrosion of materials but its main effect is instead connected to soiling and a target level of 15 µg m^{-3} PM_{10} is proposed.

The pollution threshold levels for materials of cultural heritage objects, which were the ultimate aim of the present project, are intended to be used in future reviews of the European Air Quality Directive and thus directly contribute to an improvement of the legislation policy in this field.

The DRF:s describing corrosion in the multipollutant air environment experienced in Europe today can be coupled to risk mapping for cultural heritage objects and related to threshold values for air pollution in terms of time to needed maintenance. This should be valuable information for public authorities with responsibility for cultural assets as well as for local heritage managers.

The Rapid tool kit and the passive samplers for HNO_3 and particles will be important tools especially for people in heritage management often interested in the level of corrosion attack on specific locations.

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John Watt, Ron Hamilton and Samantha O'Hanlon, Middlesex University, UK.

8 European project details

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Coordinator: Vladimir Kucera, Corrosion and Metals Research Institute, Stockholm, Sweden.

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The change of atmospheric composition – new findings on its impact on immovable cultural heritage

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Key words: emission of pollutants, air quality, acid formation at surfaces, nitric acid, nitrous acid

Abstract
Numerous emissions from natural and anthropogenic sources lead to an atmospheric composition, which can have adverse affects on nature, human health and buildings, in particular on monuments of cultural importance. The impacts are related to the deposition of primary trace substances, of secondary products of primary emissions and to the impact of emissions on climate, which may change the temperature and the precipitation. The amount, chemical composition and spatial distribution of the emissions on regional and global scales are steadily changing. Today the long lasting accumulation of sulphur deposition resulting in the destruction of stone surfaces is still visible, but at present the ongoing detrimental processes should originate predominantly from VOC and NO_x, and in part from aerosols and heavy metal depositions. In the last decades the SO_2 deposition has significantly decreased in Europe. Today NO_x together with NMVOC's have become of much greater importance. Although the NO_x emissions have been significantly reduced during the last years, the NO_2 concentration remained on a high level or even increased in European cities. In particular, nitrous and nitric acids are products of the NO_2 deposition. New analytical techniques enable in situ measurements of both acids, and this will be shown in more detail by reporting on measurements made inside and outside of the Cologne Cathedral.

The composition of the VOC and NO_x emissions together with their trends in Europe and because of long-range transport worldwide leads to the conclusion that nitrogen acids and the deposition of particles including heavy metals have to be carefully studied in Europe for possible surface damages on stone and glass surfaces with the aim to develop appropriate protection methods. The analysis of atmospheric change and the measurements around the Cologne Cathedral together with modelling on the basis of emission scenarios can help to develop a strategy of European cultural heritage protection for the coming decades.

1 Introduction

The influence of anthropogenic emissions of a variety of air pollutants in Europe on climate and air quality is regularly documented by institutions such as EMEP [1], IIASA [2], EEA [3] and other national agencies, e.g. the German Environmental Agency UBA [4]. In one of the most densely populated European regions, North Rhine-Westphalia / Germany, the actual data of air pollutants immediately can be received online [5]. EMEP and IIASA also take care about the global situation considering the long-range transport of air pollutants between different continents. As major pollutants SO_2 (sulphur dioxide), NO_x (nitrogen monoxide + nitrogen dioxide), NH_3 (ammonia), VOC's (Volatile Organic Compounds), POP's (Persistent Organic Pollutants) and particulate matter are considered, however, mainly by calculation of emissions and modelling the transport dispersion and chemical transformation. Results from field measurement are missing to a large extent. The products of chemical transformations of primary pollutants are also documented, e.g. O_3 (ozone), acids, SOA (Secondary Organic Aerosols) etc., however, many of the input parameters for CT (Chemistry and Transport) models and also measurements exhibit large uncertainties. The knowledge of atmospheric chemical processes in the gas phase is well developed, but much lower for chemical processes in the aqueous phase and with relation to particles, for surface reactions and particle formation. With respect to the aim of the present paper the outline will concentrate on acid forming pollutants, not taking care about the complex subject of particles but including data on NH_3. The impact of VOC emissions is only mentioned on side. Apart from climate change, which takes place within the atmosphere and may have a great effect on changing temperature, water vapour and precipitation, all adverse impacts on human health, the ecosystems and the materials are caused by deposition of the primary and secondary pollutants, either by dry or wet deposition. Process analyses of surface reactions are mostly concerned with dry deposition. Wet deposition processes are being studied in the wide field of aqueous phase chemistry, the advances, e.g. for the oxidation of SO_2 can be found in textbooks. During the deposition processes complex chemical reactions are initiated, which are being influenced by the interaction of many pollutants and the surface material. Many details are not known at present. Organic films can have a large influence on the deposition rates, water uptake and chemical transformation on surfaces. On surfaces, which are permanently exposed to the atmosphere, also a variety of micro-organisms become active for which the deposition supplies nutrients. The final goal for legislation is the protection of human health and the ecosystem. The protection of material for buildings and monuments is not of major concern. All emission strategies are oriented to bring or keep the concentration of harmful pollutants under certain thresholds. However, the impacts to a target is dose (concentration × time) dependent, which has led to the definition of critical loads for controlling acidification and eutrophication of ecosystems, and in the case of O_3 to AOT40 values, see Directive 2002/3/EC [6]. Such dose values are also important parameters with respect to cultural heritage protection, however, this complex subject will not further discussed.

2 Emission of air pollutants

2.1 Global situation

Many new data for the global distribution of pollutants become available, in particular by satellite observations of SO_2, NO_2, carbon monoxide (CO), formaldehyde (HCHO) and particulates [7, 8]. The retrieval of the remote sensing data for column densities to concentration profiles and emission data from the surface is quite difficult, but very recent work is very promising. By both, satellite data and ground-based measurement new revised emission data for NO_x yield total global values in the range 130 [8] to 160 [9] million t/year (NO_x expressed as NO_2) for 2000 and 1997, respectively. Approx. 64% are being emitted from fossil fuel combustion, 16% from soil emission, 14% from biomass burning and 6% from lightening. The values for soil emissions show an upward trend, 50% can originate from fertilized soil in agriculture.

Presently, the US still are the world largest NO_x emitter, but in the meantime East Asia emits more than Europe, and the emissions from these areas will further increase. This is also shown by IIASA calculations [10], see figure 1, in particular from Asia a significant increase of SO_2 and NO_x emissions have to be expected. By long-range transport this development should also have an influence on European air quality.

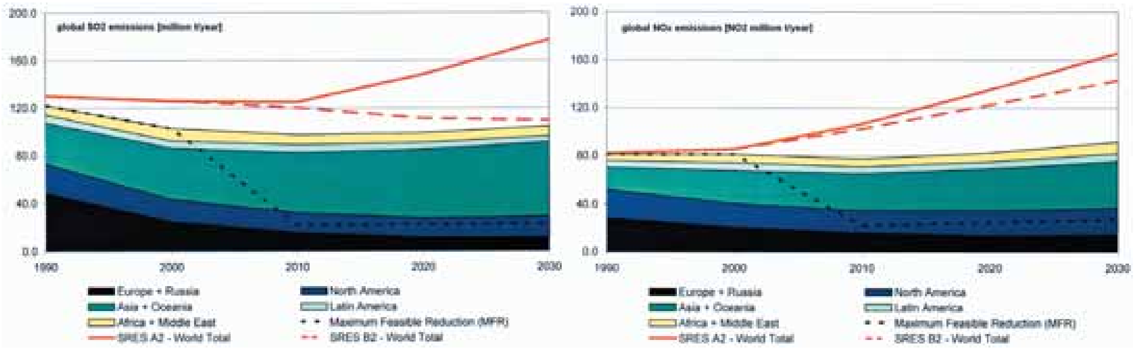

Figure 1: Global anthropogenic emission trends of SO_2 and NO_x between 1990 and 2030 (NO_x is given as NO_2) [10]

2.2 European situation. Emission and air quality

Because of trans-boundary long-range transport of air pollutants the model calculation of EMEP [11] includes also the countries adjacent to EU, here defined as wider Europe. Figure 2 shows the data between 1980 and 2020 as total anthropogenic emission values for SO_2, NO_x, NH_3 and VOC; for the 25 member states and particular countries the data can be seen in “emissions data by sector” at [12]. The rather high emission plateaus for SO_2 and NO_x, NMVOC (Non-Methane Volatile Organic Compound) and NH_3 during the next two decades are remarkable even with the strong European effort on emissions reductions. The importance of NO_x for the coming decades can also be recognized. It is also remarkable that SO_2 and NO_x emissions approach similar values in wider Europe whereas in Western Europe with reference to 2002, except for Spain, the SO_2 emissions are significantly smaller than the NO_x emissions. In Eastern Europe and in Turkey on the reverse, the SO_2 emissions are much higher than the NO_x emissions even during the next decades.

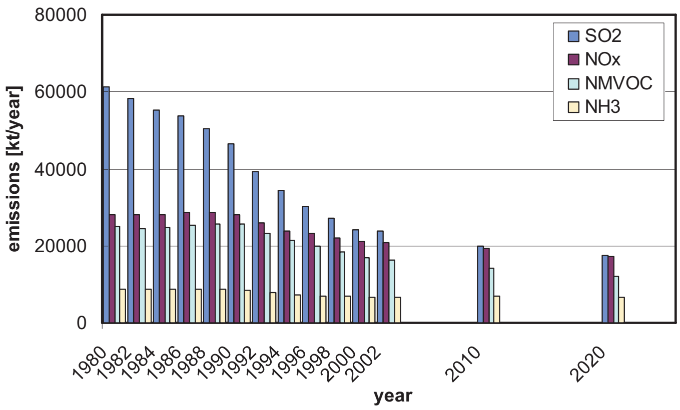

Figure 2: Trends of the anthropogenic SO_2, NO_x, NH_3 and NMVOC emissions between 1980 and 2020 for wider Europe [11]

The situation in ambient air determining the air quality is more difficult to identify, some judgement can be obtained from the data available in the member states, e.g. from Germany. As already previously discussed with respect to cultural heritage protection [13, 14], the SO_2 concentrations significantly went down parallel with the emission reduction, though, depending on wind directions, also slight increases have been observed at the meteorological observatory Hohenpeißenberg due to long-range transport from Eastern Europe [15]. For NO_x the behaviour is less obvious because the downward trend is much slower than for the calculated emission reduction [13, 14]. A trend analysis for NO_x concentration again at the meteorological observatory Hohenpeißenberg has not shown any trend between 1990 and 2001 [16], though, according to the German inventory [17], the NO_x emissions have decreased by 45% from 2.846 kt/y in 1990 to 1560 kt/y in 2001. At stations closer to urban areas a downward trend has been observed, but less than 45%. One explanation could be that growing NO emission from soils may compensate in the countryside the reduction of the emissions from combustion engines. For particulates the situation is even more complex and will not be discussed further. For NMVOC's a downward trend has been observed [14], but the apportionment to different source categories is far off from the reality. The apportionment of more than 50 % to solvent use given for the year 2003 in the German inventory [17] very likely is at least a factor of 2-3 higher than field measurements recently have shown [18]. The VOC fingerprint in German cities, but also in other European areas is still determined by emissions from traffic, which was shown by comparable measurements in a road traffic tunnel [19]. Remarkable is the relatively high content of aromatic hydrocarbons in the urban air mix, which can lead to a number of adverse effects. The photo-oxidant problem is also difficult. High O_3 concentrations certainly have decreased in Germany [13, 17], but the background values are still increasing [20] with the result that also the annual values at surface stations increase [17]. The increase is more pronounced in urban areas [21]. The subject of aerosols will not further be discussed here; a recent review on the organic aerosol is given by [22].

3 New findings in air quality

NO_x is assumed to be emitted predominately as NO from stationary and mobile combustion. However, since the last few years an increase of the $(NO_2)/(NO_x)$ emission ratio has been observed in larger cities, in London [23], see figure 3, and in Wuppertal [24].

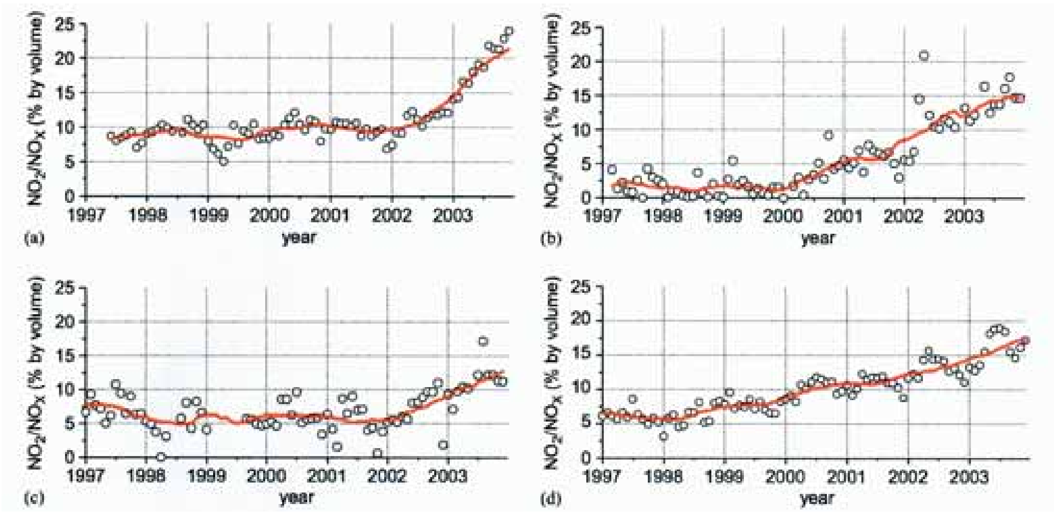

Figure 3: Monthly trends in the $(NO_2)/(NO_x)$ emissions ratio for different sites in London (1997-2003): (a) Marylebone Road, (b) A3 motorway, (c) Hillington and (d) mean of all 36 sites. The solid line in each case shows the 12 month adjacent average smoothing line [23]

Because of the titration effect $NO + O_3 \rightarrow NO_2 + O_2$ the trend of NO_2 emissions cannot be recognized directly. But during the day near a traffic road the simultaneous measurements of NO, NO_2 and O_3 can provide data, which are able to show the primary NO_2 emission, see figure 4. In this figure the volume mixing ratios $(O_x) = (O_3) + (NO_2)$ are plotted versus (NO_x). The slope of these plots gives the contribution of the primary $(NO_2)/(NO_x)$ emission ratio, which makes about 12% in Wuppertal at present, but the increase of the ratio has already been recognised since 1998 [25]. In London at Marylebone Road, which is used for intense public bus traffic, in the years 2002-2003 a relative increase of the $(NO_2)/(NO_x)$ ratio of 130% has been reported [23]. The increase in NO_2, also in absolute terms might be so large that the EU annual limit value of 40 µg/m^3 will be quite often violated in larger cities from January 1, 2010 on (Directive 1999/30/EC) [26].

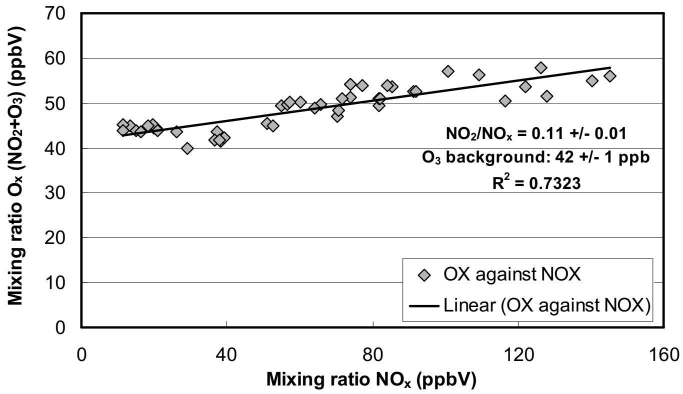

Figure 4: The plot of the volume mixing ratio $O_x = O_3 + NO_2$ against NO_x for data measured in the city centre of Wuppertal [24]

4 Consequences for deposition

NH_3 and NO_x are major depositions of reactive nitrogen during day and night. During the day also HNO_3 from ambient air will be deposited. During night N_2O_5 is an important substance, which reacts on the surface with water producing HNO_3 or directly reacts with the surface material to form nitrates and CO_2 [27]. As intermediate specie carbonic acid may be involved in this reaction [28]. N_2O_5 is formed by the following reaction and is only stable during the night because of rapid NO_3 photolysis in daylight:

$NO_2 + O_3$	→	$NO_3 + O_3$	(photolysis and reaction with NO destroys NO_3)
$NO_2 + NO_3 + M$	→	$N_2O_5 + M$	(N_2O_5 dissociation increases with temperature)
$N_2O_5 + H_2O_{(surface)}$	→	2 HNO_3	(during the night the major loss process of NO_x)
$N_2O_5 + CaCO_3[H_2O]_{ad}$	→	2 $HNO_3 + CaCO_3[H_2O]_{ad}$	
	→	$Ca(NO_3)_2[H_2O]_{ad} + CO_2$	
2 $HNO_3 + CaCO_3$	→	$Ca(NO_3)_2 + H_2O + CO_2$	

Recent wintertime field measurements of N_2O_5 were reported by [29]; according to this paper the production of HNO_3 during the night was a factor of nine greater than the HNO_3 production during the day. Organic films may influence the N_2O_5 reactivity at the surface [30]. Nitrous acid is formed at surfaces by heterogeneous NO_2 reaction yielding per HONO molecule also one HNO_3 molecule:

$$2\,NO_2 + H_2O \rightarrow HONO + HNO_3,$$

depending on the pH-value HONO evaporates whereas HNO_3 sticks to the wall [31]. Nitrous acid is generated mainly by the deposition of NO_2 during the night; during the day the gas phase reaction NO + OH also forms HONO, which is rapidly photolysed in daylight. However, very recent findings point to much larger daytime sources of HONO, which also may lead to the direct deposition of HONO during the day [32, 33]. The deposition of NMVOC is more complex, in particular in the presence of O_3. At the end oxygenated VOC's are being formed including many organic acids [34, 35]. The particle deposition may influence the deposition rates because of changes in the surface structure. The NH_3 deposition leads to ammonium formation, either to sulphates or nitrates. More important seems to be the nutrient effect, because micro-organisms transform NH_3 rapidly into nitrates and nitric acid [36, 37, 38]. But also VOC and NO_x depositions should accelerate the growth of micro-organisms, whereas H_2SO_4 may act as inhibitor [39, 40].

The low volatile compounds stick to surfaces where they are converted to oxidized species, e.g. carbonic acids. The production of organic acids is also enhanced by micro-organisms. The recently observed increasing attack of stone monuments by micro-organisms, might be explained by both, higher deposition of reactive nitrogen species and lower deposition of SO_2/H_2SO_4.

At present the observed nitrate concentrations on glass and stone surfaces are quite small [41, 42]. This might be due to a faster uptake by micro-organisms [43, 44]. A $(NO_x)/(SO_2)$ ratio of the ambient concentrations on a molar basis of at least 20 can be calculated in most urban areas of Western Europe. However, the deposition velocity could be much smaller for NO_x than for SO_2 and could compensate the large $(NO_x)/(SO_2)$ ratio during the day whereas in the night the deposition of N_2O_5 should lead to a fast HNO_3 and nitrate formation. Any HNO_3 from the formation in the gas phase, mainly during the day by the reaction NO_2 + OH, will certainly undergo rapid deposition. The involvement of nitric acid has been reported in several cases [14, 36, 38, 39].

5 Measurements in the Cologne Cathedral

Giving attention to the growing deposition of nitrogen compounds, the Institute of Physical Chemistry of the Wuppertal University developed a very sensitive in situ monitor for HONO (LOPAP) and recently also for HNO_3, both developments were supported by the "Deutsche Bundesstiftung Umwelt". The instruments have detection limits of 0.2-2 pptV and 2-30 pptV for time responses of 7-2 min and 6-2 min for HONO and HNO_3, respectively [45, 46, 47, 48].

In close cooperation with the "Dombauhütte" of the Cologne Cathedral, a pilot-project has been carried out in 2004 to simultaneously measure NO, NO_2, HONO, O_3, CO and CO_2 by time resolved in situ methods outside close to the roof in a height of 45 m, under the roof, and through an opening in the upper ceiling to the nave of the cathedral (height approx. 40 m). The objective was to test the methods in order to elucidate deposition processes of reactive nitrogen and the airflow within the cathedral under different conditions during day and night. For each component a characteristic diurnal variation has been observed. Outside the cathedral relatively high concentrations of nitrogen oxides were observed compared to other measurement stations in Cologne. From the rush hour peak a $(HONO)/(NO_x)$ emission ratio of 0.9 % was calculated, which is in good agreement with other measurements in urban areas [49]. Under the roof much higher $(HONO)/(NO_x)$ ratios were observed than from the outside measurements. From the estimated exchange time of the air mass under the roof an uptake-coefficient of NO_2 for the heterogeneous conversion into HONO and HNO_3 of $\gamma = 1 \times 10^{-6}$ was calculated in good agreement with measurements in a road traffic tunnel in Wuppertal [50]. By using this uptake coefficient a production rate of 10^{16} (HONO + HNO_3) molecules per m^2 and per h and per ppbV (NO_2) has been calculated. The values for NO and HONO inside the cathedral (figure 5) were remarkably high and could not be explained by the inflow of polluted air from outside. Inside the cathedral a diurnal variation was observed with maxima during the day, which correlated with the opening hours of the cathedral from 6:00-20:00 hours. These high values for NO reaching 80 ppb and HONO reaching 14 ppb could only be explained by sources inside the cathedral. By using the CO_2 data as reference it has been estimated that 80% of the observed

CO_2 increase originated from visitors and 20% from burned candles, which were lightened by the visitors with a rate of about 200 candles per hour. By complimentary laboratory work it has been approved that the candles were significant sources of NO_x (measured separately for NO and NO_2) with 1.2 g/kg (candle fuel) and in part, HONO was directly emitted. In the meantime the candle manufacturer has changed the paraffin fuel to palm oil, which emits at least 30% less NO_x.

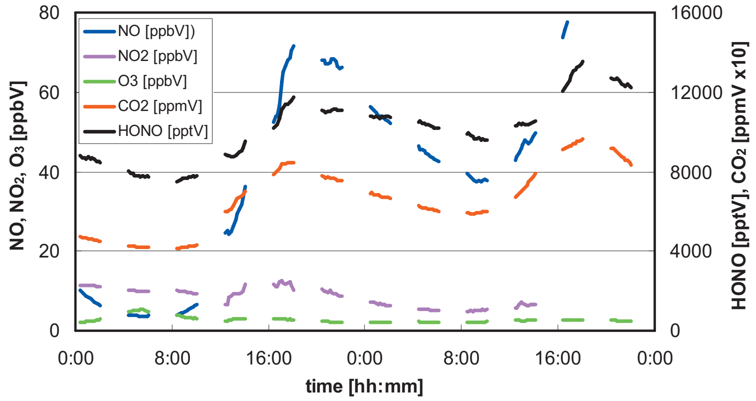

Figure 5: Measurements inside of Cologne Cathedral at a height of about 40 m in the ceiling above the nave; the diurnal variation of the mixing ratios NO, NO_2, HONO, O_3 and CO_2 were measured on May 8 (Saturday) and May 9 (Sunday), 2004

Further work is necessary to better quantify the depositions of different air pollutants and, in addition, time-resolved in situ measurements of HNO_3 have to be carried out. The findings can be compared with indoor measurement in museums, which have been carried out during recent years by researchers within several EU projects [50, 51, 52]. In these studies passive sampling and denuders were applied with low time resolution. Generally, the results have already shown the high HONO and HNO_3 concentrations, which built up inside museums by the heterogeneous conversion of NO_x, however, for tracking the different sources and pathways of transformation processes time-resolved measurement of the involved components were necessary even on the account of more expensive and sophisticated instrumentation. A combination of passive samplers and instruments with time-resolution would be suggested for future work. At low concentration levels the results of passive sampling might have larger uncertainties, which preliminary tests have shown for NO_2 measurements. On the other side, integrated values of reactive pollutants gained by passive sampling are very valuable for estimating the damage potential. However, searching for detailed processes, which are responsible for the deterioration of cultural heritage objects, high sensitive and time-resolved in situ measurement are indispensable. The candle case described above demonstrates this conclusion. The need to reveal the processes caused by the deposition of reactive nitrogen compounds, organic gases and particles and heavy metals would require the use of all available analytical methods in a combined effort of highly specialised research groups.

6 Conclusions and summary of key results

The pilot project has shown that the use of time resolved in situ measurement of interrelated chemical compounds can provide data by which the details of emission sources and the distribution of pollutants directly can be assessed. In many cases supplementary work using passive samplers as in the EU projects VIDRIO or MULTI-ASSESS would be very helpful.
Globally an upward trend of NO_x emissions has to be expected, particularly in Asia; SO_2 emissions probably also increase on a global scale:

- in wider Europe the SO_2 and NO_x emissions will after reduction to the present levels remain on a high plateau of about 20 million t/year each during the next decades with relatively large contributions from Eastern Europe and Turkey; because of the global trend this plateau might even increase,

- NH_3 emissions in Europe remain at a level of about 7 million t/year for the next decades,
- an increase of the $(NO_2)/(NO_x)$ emission ratio has recently been observed in larger Western European cities, most likely due to new technologies for cleaning diesel engines, but also due to an increase in the O_3 background concentration,
- deposition of NO_2 clearly has shown within a pilot project outside and inside the Cologne Cathedral the formation of HONO, which is released to the gas phase, and equal amounts of HNO_3, which stick to the surface,
- in addition, HNO_3 deposition from ambient air and by release from deposited N_2O_5, which hydrolyses into nitric acid at surfaces, has to be expected,
- together with other deposition like O_3, organic particles, NMVOC's, NH_3 and heavy metals, complex surface reactions will be initiated, which also involve micro-organisms.

7 Key question and outlook

Why have nitrates, and to a smaller extent also nitrites, such a low abundance at stone and glass surfaces though the deposition of NO_x is favoured by at least a factor of 20 of the concentration ratio $(NO_x)/(SO_2)$ in air of most Western European cities?

In future work new analytical equipment and state of the art simulation facilities in Europe are available [53] and would allow a much better inside look to the impact pathways at surfaces, which certainly could help to improve conservation methods. Moreover, there is urgent need to reveal the contra-productive European development with respect to emission reduction of certain source categories without taking care about side effects in the environment. The European dimensions clearly enforce an integrated view on such developments, particularly to the benefit of cultural heritage protection.

8 Acknowledgements

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Foundation re-use as a mechanism for the preservation of buried cultural heritage in urban centres: how new engineering research helps limit archaeological damage

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Key words: foundation re-use, archaeological deposits, preservation *in situ*

1 Introduction

This paper achieves the main aim of the conference, as it 'assesses the impacts of results achieved in previous EC research projects in relation to cultural heritage'. In particular it focuses on how archaeologists (cultural heritage managers) are exploiting the results of a project principally conceived with a much wider environmental sustainability agenda. This paper was presented in the session "Innovative Applications and New Ideas", which focused on the exploitation of EC-supported research results. The EC project is part of the 5th Framework Programme "cultural heritage and the city of tomorrow". The project is RuFUS (Re-use of Foundations for Urban Sites). This paper addresses the session themes as it 'highlights the complementary nature and synergy between cultural heritage and environmental issues' and is written jointly by an end-user (JW) and the RuFUS project manager (TB), who come from different disciplines, cultural heritage and civil engineering respectively.

To tackle this subject effectively, this paper will first outline the cultural heritage issues that exist in urban centres, before summarising the main findings from the project and how it benefits cultural heritage. Finally we will consider how the lessons learned in the project can be applied in practice, through reference to a case study and a spin-off project in the UK.

2 Managing below ground cultural heritage assets in urban centres

Many modern urban centres have a long history that reaches back hundreds and sometimes thousands of years. As towns and cities grow larger, the areas of previous habitation, industry and recreation are either retained as part of the evolving cultural landscape, or are removed and replaced with new buildings, This is not a modern phenomenon, and applies just as readily to the past two thousand years or so, as it does today. Before the last century, when buildings were replaced, little modification of below ground remains usually took place. Instead, new buildings were constructed on top of the demolition rubble and previous foundations of the old ones. This left a complex and often deep legacy at the heart of many urban cities. These archaeological remains when excavated yield information about the history of the area and its people. Such remains are also a cultural asset that need to be managed, sustainably.

Unlike previous centuries, redevelopment in the last fifty years has had a much greater impact on below ground deposits. As buildings grow taller and larger they need deeper, stronger and more numerous foundations. Requirements for services on a large scale (sewerage, electricity etc), and items such as lifts, as well as basements all impact on below ground sediments to a much greater degree than in the past. The rate of development has also quickened and this is particularly the case in major cities where the average life span for large offices is 30-40 years.

Set within this context one has to question what is the most sustainable way of managing these important cultural heritage assets.

Given the pace of development, there are a number of reasons why the total excavation of every single site before construction may not be appropriate. Firstly, large scale urban excavations are time consuming and expensive to carry out properly. Currently there are also probably not enough well trained staff to excavate, analyse or publish every single urban site that is redeveloped; or perhaps the capacity to curate all of the finds and make a reasonable selection of them accessible to the public. There is also the potential that future techniques will improve evidence recovery, and crucially for archaeologists, if it is all dug up now, there will be no work in the future! Finally, as archaeology is a finite resource, it is arrogant to assume that we as a society, or as archaeologists have the right to consume all of this resource and pass nothing onto future generations. A balance therefore has to be reached between investigation and preservation. However, preservation cannot, in most instances, take place to the exclusion of development, otherwise most of today's modern cities would become fossilised, with sites left undeveloped. One solution is to find a foundation design where one accepts a small proportion of the site will be lost, but the rest is preserved *in situ* beneath the development.

2.1 The policy context for preserving below ground cultural heritage

The rationale of *in situ* preservation is expressed in both European and national government policy. The European policy context is the "European Convention on the Protection of the Archaeological Heritage (revised)" [1]. This legislation was drawn up in Valletta, Malta in 1992 and is usually referred to simply as the Valletta Convention. It provides, in effect, a common European policy for archaeological protection. The most relevant sections are Article 4 ii, which requires states to make provision "for the conservation and maintenance of the archaeological heritage, preferably *in situ*" and Article 5 iv, which requires states "to undertake to make provision, when elements of the archaeological heritage have been found during development work, for their conservation *in situ* when feasible". This suggests that these sites should have a longevity beyond their current stage of redevelopment.

In England, this policy is similarly stated in the Government's Planning Policy Guidance note 16 – Archaeology and Planning [2], commonly referred to as PPG16. This places the onus for dealing with archaeological remains identified during the course of redevelopment with the developer, and more importantly, recommends that where nationally significant remains are encountered, there should be a presumption in favour of their physical preservation. This national policy is mirrored by local planning policies that promote preservation *in situ* of nationally important remains, see Leicester case study, below. When sites are encountered during development, these policies are used by local planning authority staff, and the developer's archaeological consultants to produce a strategy to retain as much as possible of the site's archaeological remains and deposits, whilst still ensuring that development can progress.

Most English planning authorities are provided with archaeological advice from internal or occasionally externally contracted staff. They will advise the planners on the potential for the presence of archaeological remains on any proposed development. In many instances, the developer will have discussions with these archaeological staff in advance of submitting any planning application, although in the absence of pre-determination discussions, planning conditions relating to archaeological works will be applied. The first stage of the process is to evaluate the potential of the site. This is carried out using both non-intrusive desktop and intrusive site evaluations, to help characterise the nature of the below ground deposits. At this point, decisions will be made as to the significance of the remains and the practicalities of their long-term preservation, resulting in a foundation design aimed to achieve the preservation of that largest possible amount of the archaeological remains, an excavation to record these remains, or the refusal of planning permission.

2.2 Development impacts on archaeological remains

It would be an oversimplification to suggest that one can simply engineer a foundation without causing damage to any archaeological deposits. In a paper to the 5th EC conference, Williams and Corfield [3] highlighted the potential impacts on archaeological sites and artefacts from construction activities. Such impacts can occur at four stages of the construction process, from pre-construction ground investigation, and site preparation activities, through to the construction work, and later remedial and maintenance work [4]. In this current paper, the development impacts covered relate to the construction stage only.

From the late 1980's onwards, developments in England began to utilise engineering methods to avoid other more expensive ways of dealing with archaeological material, such as total excavation. When the Government's planning guidance was published in 1990 this added further impetus to a move to excavate less, and preserve more *in situ*. At about the same time, the City of York had undertaken a study to look at the best way of managing their archaeological heritage [5]. One of its main recommendations was that an adequate balance between the needs of current development and the desire for preservation could be met through using piles, so long as their impact on the site was limited to 5%. Similar approaches were used throughout the country, but archaeologists began to question whether these methods really did provide adequate levels of preservation [6].

These concerns related to a number of issues. Firstly, where only limited pre-construction characterisation of the site has taken place, it is impossible to know what types of archaeological remains might be impacted by piling; it would not, for example be appropriate to pile through a cemetery [7]. Secondly, it is clear from the limited excavation carried out on previous foundations that some techniques are more damaging than others [4, 6, 8]. In some cases, more physical damage has clearly taken place than was anticipated [9, 10], and the assessment of chemical impacts, which may leave little physical trace, is difficult. Most evidence suggests that the impacts from driven (displacement) piles are greater than other techniques and their extent more difficult to predict. Excavations and laboratory analysis has so far shown that disturbance adjacent to driven piles can range from one to three pile diameters [9, 11, 12], covering an area up to nine times the size of the original pile. Thirdly, piles are rarely installed on their own, and impacts therefore accrue cumulatively from the placement of piles in groups (where deposits in between the piles become inaccessible for future evaluation), and from the construction of ground beams and other elements that connect the superstructure to the foundations. Finally, when sites with existing piles are re-developed, if more piles are used, then the proportion of the site that is subsequently left preserved will reduce.

3 A solution is RuFUS

Although the section above suggests that for the last fifteen years, archaeologists and developers have been preserving the majority of the archaeological remains of a given site through the use of piled foundations, it should be emphasised that this also occurred during the previous few decades. However at that time there was less awareness of cultural heritage issues, and no robust statutory framework for dealing with archaeological remains encountered during development. As a result, there are many sites within urban centres in England, and presumably other European countries where archaeological sites lie unintentionally buried beneath modern buildings. When these sites are made available for re-development, re-using the previous foundations would obviously reduce further potential impacts on the buried archaeological deposits. Equally, where sites are preserved *in situ* in the present, it is important that adequate documentation is made, so that these piles can be re-used in the future.

There are many reasons aside from the protection of cultural heritage why foundation re-use might be appropriate or necessary on a given site. These include environmental drivers supported by legislation, and the promotion of sustainability, as well as the changing economics of construction. Environmental issues include reductions in the use of new natural resources and the quantity of waste produced from demolition and construction, as well as concomitant reductions in vehicle and plant movements. Economic drivers include lower energy and natural resource costs, as well as the expected future increase in the costs of the disposal of demolition debris, including for example congestion charging and other transport costs. Some of the financial considerations of foundation re-use are shown in Table 1.

Table 1: Costs to be considered in re-use of foundations, from the RuFUS handbook [13]

Savings	Extra costs
Ground Investigation	Investigation of existing foundations
New foundation design	Remediation of existing / additional foundations
New foundation construction	Redesign / relocation of superstructure
Spoil disposal	Interfacing with new superstructure
Raw and processed materials	Environmental impact of operation of new building
New foundation construction time	
Environmental impact of new foundations	

The biggest driver for the re-use of foundations is ground congestion, and this will become an increasingly important issue in the coming centuries, particularly in large urban centres where below ground constraints can include services and transport, as well as previous foundations, as can be seen in Figure 1. Archaeological remains add yet another element to an already complex picture.

In many cases it is theoretically possible to re-use foundations. However, for this to work in practice, a number of technical considerations must be met. The locations where piles are needed must be compatible with the existing foundations, and they must have a sufficient capacity to carry the new load. Additionally, it will be important to verify that the old piles are in good condition, and would operate as effectively as new ones.

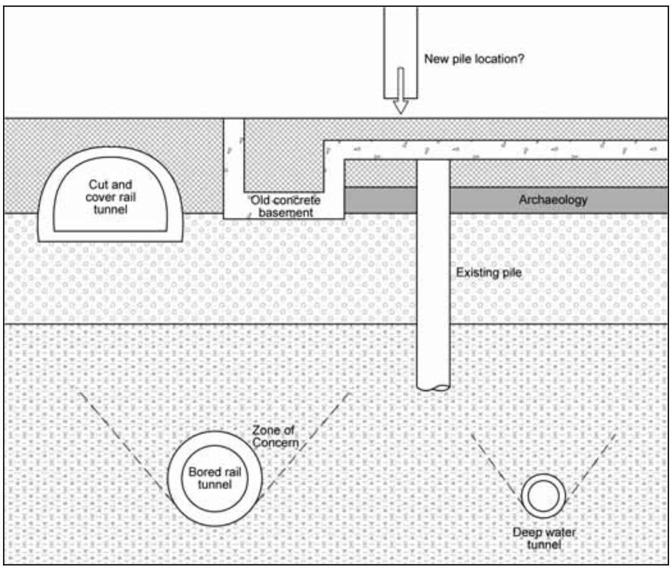

Figure 1: Problems of ground congestion are a key driver for the re-use of foundations. This image shows some of the potential below ground obstacles faced in urban centres. Image from the RuFUS handbook [13]

3.1 Major new research elements

The principal new research outputs from RuFUS include:

- advances in risk modelling and decision models
- advances in non destructive testing for integrity of foundation materials and foundation geometry and capacity
- Foundation capacity enhancement and the exploitation of under utilised capacity
- Future proofing new foundations

The re-use of foundations has many implications that need to be understood at the earliest stage of a re-development project. To assist in the consideration of these implications new decision models have been developed for use by clients / developers and their construction professional advisors. These decision models consider risk, economics, environmental impact and whole life costs and will help highlight both the benefits of a re-use of foundations strategy and its possible consequences.

The assessment of existing foundations is key to understanding their likely behaviour if re-used. Significant advances have been made in the detection of the geometry of foundation slabs and piles. The latest systems can now detect the thickness of foundation slabs up to over 1 m thick including two layers of reinforcing that in the past would not have allowed the full thickness of the slab to be determined. The detection of pile lengths using seismic waves has also been developed into a rapid and cost effective technique. In addition the understanding of rapid pile testing methods (under used in Europe), for capacity has been significantly improved by comparative testing.

The foundations that are currently assessed to be re-used were all designed typically over 30 years ago and the understanding of soil structure interaction and complex foundation systems has advanced considerably over that time. This situation allows for re-analysis of existing foundations that will frequently allow an upgrading of the foundation capacity. Furthermore, time dependent effects on foundation capacity are now better understood and can under certain circumstances also allow upgrading of foundation capacity. These advances, together with enhancement systems such as mini-pile groups that surround an existing pile, can enable the re-use of foundations with significantly less cost in time, economic and environmental impacts than the installation of new foundations and particularly the removal of existing foundations before replacement by new foundations.

The future re-use of foundations should be considered both when installing new foundations or re-using existing foundations. To future-proof these foundations they need to be documented and an understanding of their behaviour gathered. The RuFUS project developed a documentation system to record all the necessary data to enable a foundation to be re-used and new 'smart' instrumentation that can monitor a building's behaviour during its life thereby demonstrating the foundation behaviour and its potential for re-use.

All of these project elements will be reported within a best practice handbook [13] (the RuFUS handbook), which will provide an easy to use guide to foundation re-use for clients and developers, as well as engineers and other construction professionals.

3.2 How foundation re-use benefits cultural heritage

There are many sites in England, and presumably Europe where piles have been installed into archaeological deposits, inadvertently preserving the majority of these sites *in situ*. Re-using these foundations when the sites are redeveloped will allow this *in situ* preservation to continue. It may not always be possible to re-use all of the foundations, and even if total re-use is achieved, some new piles may still be needed. This would still represent a reduction in the total number of new foundation elements used, allowing a greater proportion to be preserved than if only new piles were used [14]. As well as sites which have been accidentally preserved *in situ*, in England there are those (post-1990) where a piled mitigation strategy has been used. On these sites, piles have deliberately been installed to leave the rest of the site preserved. In order to continue to preserve this site the next time it is redeveloped, these piles should be re-used.

Unfortunately, the archaeological community has only lately, with notable exceptions [5], come to realise the potential for foundation re-use, and no coherent strategies are in place for the long-term curation of either basic information such as which sites have been preserved *in situ*, or more complex engineering data that would allow future re-use. This is a problem that exists across the board, and the lack of records for currently standing buildings and their foundations is one of the biggest problems that is faced by those wishing to undertake a pile re-use programme. Therefore as part of RuFUS, a list of the types of information that should be curated from each new construction project has been drawn up, see Table 2. Whilst this has wider implications outside the sphere of cultural heritage management, for sites where archaeological remains are preserved *in situ*, it is essential that this information is retained, perhaps with the archive from the site, so that future re-use can be more easily achieved.

Table 2: Information relating to new piles that should be stored to ensure that pile re-use can take place the next time the building is developed, from the RuFUS handbook [13]

Program stage	Design stage	Construction stage	Building operation
Geological info Geotechnical info Groundwater level Groundwater quality Contaminated soil Site conditions	Design philosophy Design codes Design calculations Necessary bearing capacity Force combinations applied on each pile Pile data Settlement limitations Protocol for foundation records	As-built documents Non conformance reports Construction documents Programme of piling works Plant and equipment Test piling Working documents Site records Pile installation records Effects on nearby foundations and structures Results from monitoring	As-built drawings Maintenance records Environmental changes Inspections Pile behaviour Service life measurements Structural alterations

4 Applying RuFUS in practice

Buildings are usually designed first by architects, who then engage civil engineers to design the foundations around that structure. In particularly congested locations, this may be a significant challenge for the engineers, see for example Figure 2. For foundation re-use to be more readily acceptable and regularly used, this way of working needs to change. For large and complex urban sites, the design of any new building should start with a thorough below ground characterisation, and consideration of whether foundation re-use would be technically feasible. Once those parameters are set, they can be introduced to the architectural design team as a starting point for the design.

Intriguingly, it is often the potential costs of dealing with archaeological deposits, rather than the potential complexity of previous foundations, or the other environment costs that has led developers to re-use foundations, as is demonstrated by the following two case studies. Aside from these two examples, there have been at least two other sites where foundations have been used to reduce damage to archaeological remains. These were at 22-24 High Street, Colchester, Essex [15, 16] and The Collection, Lincoln [14, 15].

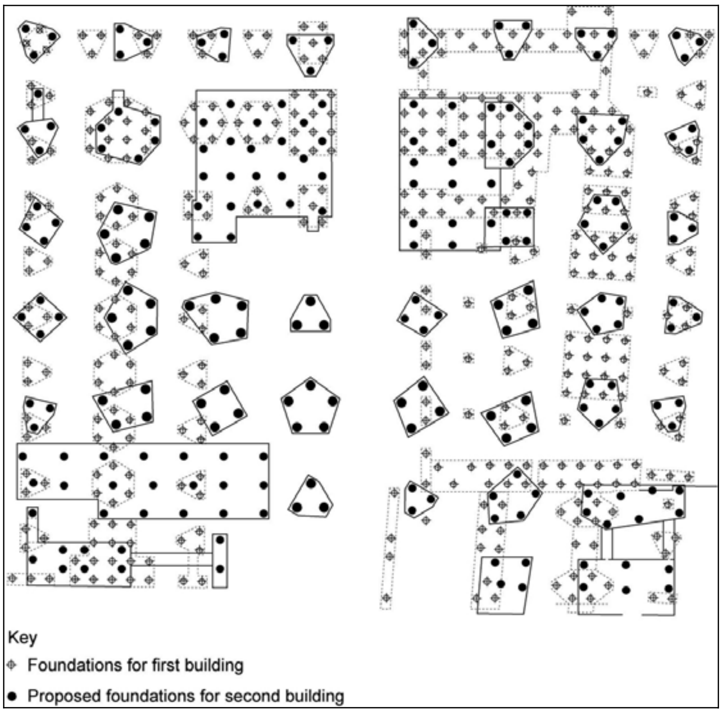

Figure 2: Ground congestion from a first set of piles limiting locations for a second set of piled foundations. This will become an increasingly common occurrence on large urban sites. Image from RuFUS handbook [13]

4.1 York

A study carried out for the City of York in 1991 [5] and adopted as planning policy makes recommendations about how best to achieve preservation *in situ*. One of its recommendations is that good record keeping is essential for the future re-use of foundations installed to preserve archaeological deposits. Since this report was produced, there have been a number of sites where the potential to re-use foundations has been considered, and for the redevelopment of any building constructed from the 1960's onwards, the City Archaeologist always suggests to the developer that they consider the potential for pile re-use. So far, four sites that fall into this time period have been considered (J. Oxley, pers. comm.). Of these, two of the developers were reluctant to go ahead with re-use schemes because of issues of insurance / liability, and questions over the validation of pile integrity. A further scheme also did not come to fruition.

The fourth site is the former Victoria House Co-op building, on Micklegate, which is now the Ramada Encore Hotel. The original building on the site was owned by and housed the Yorkshire Co-operative society, and was constructed in the 1960's. It was a fairly simple design, with internal columns that transferred the load of the structure directly to the foundations below, which were set out in a regular grid. In the late 1990's the site was purchased by George Houlton and Sons Limited, for development into a hotel. In early consultation discussions with the City Archaeologist the developers were alerted to the likely archaeological constraints of the site, which lies within the medieval city walls, in an area where well preserved and potentially waterlogged archaeological remains were likely to be present. To reduce the financial costs of dealing with the archaeology, the developers themselves suggested that they could build off the existing foundation slab, thereby protecting any archaeology *in situ*. In one location, the piles were broken out and a pile test was carried out, which demonstrated that the piles would be suitable for re-use. A limited number of new piles were needed for additional building elements, but these were kept to a minimum, and were only located in two small areas of the site, and were a small proportion of the total foundation elements on the site

(13% of the total 127 piles). The areas where these piles and their caps were inserted were subject to a watching brief, as were a small number of service trenches, but these only impacted on post-medieval deposits, that in this case were not of any particular significance [17].

Having opted for a scheme that included the re-use of foundations, this decision then affected the rest of the design programme of the hotel, which had to fit around the existing foundation plan, and therefore to a large degree the former building shape. The ground floor area now contains two separate retail units (unrelated to the hotel) and a large, and open hotel lobby. The upper floors contain the 104 bedrooms of the hotel, and a restaurant. Because of the constraints of the site, the architects had to move away from the standard 'Ramada Hotel' specification, and design the hotel to fit around the existing space (D. Padden, pers. comm.), which they have done very successfully (J. Williams personal observation.).

4.2 Leicester

The City of Leicester, UK, is currently undergoing substantial regeneration, in many cases in areas containing deeply stratified and complex archaeological deposits. Much of the development is planned for an area that has until recently been somewhat peripheral to the current city centre, but was in fact the location of the walled medieval, and before that Roman town of Leicester, and is identified as an archaeological alert area in the Local Plan [18]. It has been estimated that the current redevelopment programme covers an area of about 12% of the walled town (R. Buckley, pers. comm.). A number of the buildings that have been re-developed or are earmarked for re-development were constructed at some point from the 1950's to the 1970's and are therefore likely to be founded on piles, that maybe suitable for re-use. Given the potential presence of significant archaeological remains, and the costs that would have to be expended in adequately dealing with them, the developers have already carried out pile re-use feasibility studies at two locations in recent years. Unfortunately, neither could be used, due in part to the constraints of the pre-existing design of the new development.

Given the pace of regeneration, and the importance of the archaeology, the City Council has recently commissioned a project to raise awareness of foundation re-use and provide guidance to encourage developers to consider it on all relevant sites, but also to ensure that on sites where archaeological deposits are preserved *in situ* through the use of piles, that an appropriate record is kept so that these piles can be re-used in the future. The project is being carried out by the Building Research Establishment, drawing on experience gained from RuFUS, and will result in the production of a short guidance leaflet aimed at developers in the city. It will highlight the benefits of foundation re-use, in particular the lower foundation construction costs, and most importantly, reduced costs for dealing with archaeological remains. It will link clearly into the City's existing Local Plan policy relating to archaeology, 'BE01 – preservation of the City's archaeological heritage'. This policy states that 'the City's archaeological heritage will be preserved where appropriate by ….. c) negotiating amendments to submitted schemes to preserve archaeological remains *in situ*, and generally minimise the impact by appropriate siting, foundation design and location of services and associated landscaping' [18].

The project will also emphasise the need to curate recent and future foundation information, as described in Table 2. Some of this information is currently already required by the City Archaeologist in order to enable the archaeological assessment of the site. This is detailed in a standard planning condition that reads:

'Before the development is begun, a detailed design and methods statement and archaeological impact assessment including existing and proposed ground levels showing the layout and depths of all foundations, services, trenches, drains and other ground works, and all revisions of such, shall be submitted to and agreed in writing with the City Council as local planning authority. No development shall take place except in accordance with the agreed details….' (C. Wardle, pers. comm.).

This guidance note will be used by the Leicester Regeneration Company to target future developers, to encourage them to consider foundation re-use, and also by the City Archaeologist to encourage developers to adhere to the standard condition on archiving information so that future re-use may be achieved. It will be a clear and demonstrable spin-off from the RuFUS project that will hopefully work at a local level to drive forward foundation re-use as a viable option, and one that helps to ensure that suitable documentation is available so that sites preserved *in situ* in this phase of re-development, can be considered for further preservation through foundation re-use in the future.

5 Conclusions

Currently no published single source of information exists in the format that will be produced for the RuFUS handbook [13], and this has had major implications for the past uptake of foundation re-use schemes. The work carried out in project RuFUS has made significant progress in providing mechanisms that will help to promote foundation re-use in the future. These include decision models for project management of foundation re-use projects, and risk models to investigate associated financial risks. Equally, innovative approaches have been made in relation to non-destructive testing of piles to assess integrity and geometry. Recommendations have also been produced for ways in which the 'in service' history of piles can be measured, giving an even more accurate quantification of their future re-use potential.

It is likely that a general upsurge in foundation re-use and improved acceptance of it as a viable technique will increase the numbers of archaeological sites where these issues are considered, and the detailed sections on archaeology within the RuFUS handbook will give greater emphasis to this topic. This is not to say that this is by any means, a problem solved. Although most EU countries are signatories to the Valletta Convention [1], the ways in which this legislation is reflected in national and local planning documents will doubtless be different from the English examples given here. However, the principal results and methods of this project are applicable and transferable to any country, as are the main problems. Currently the most pressing need in England is to ensure that where archaeological remains are preserved *in situ* using piles, that the information listed in Table 2 above is collated and curated so that these piles can be re-used in the future.

In the introduction we highlighted the fact that this paper would assess the impact of an EC research project in relation to cultural heritage. It is clear from the information presented that the research carried out in RuFUS will greatly enhance our understanding of foundation re-use, and in particular its application on sites containing preserved archaeological remains. The results of the study are not restricted to England, or the other project partner countries, and will provide benefits to all wishing to find sustainable ways in which to preserve cultural heritage.

6 European project details

RUFUS, EVK4 – 2001 – 00289, Re-Use of Foundations for Urban Sites, Antony Butcher, BRE; The project is managed by the Building Research Establishment (UK). The other partners are ARUP (UK), Cementation Foundations Skanska (UK), BAM [Federal Institute for Materials Research and Testing] (Germany), Institute and Laboratory for Geotechnics at the Technical University Darmstadt (Germany), Stamopolous and Associates Architects (Greece), Solentanche Bachy (France), Swedish Geotechnical Institute (Sweden). There is a project web site (www.webforum.com/rufus), where information relating to the project can be found.

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Session III

Innovative applications and new ideas: cities, villages and landscapes (including archaeology)

Risk based approach to cultural heritage buildings

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Key words: fire safety, cultural heritage, fire protection, optimisation methods

1 Background

Fire is probably the largest threat to cultural heritage buildings in Europe. Europe loses one cultural heritage building a day!

In most countries fire safety of cultural heritage buildings does not receive the appropriate level of consideration neither in view of their significance, nor in terms of their unique and irreplaceable cultural, social and economic value.

To introduce fire risk reducing measures in cultural heritage is often expensive and in many cases leads to conflicts between the respect of the original aspects of the cultural heritage buildings and the application of fire protection techniques.

Cultural heritage buildings often do not meet the prescriptive regulations. These are often inefficient and cannot be met. However, in many cases alternative protection measures can be proposed, which can provide an equal level of safety.

These considerations constituted the background to set up the FIRE-TECH project ‘Fire Risk Evaluation to European Cultural Heritage’. The outcome of the work is a risk based ‘FIRE-TECH Decision Supporting Procedure’. The project was financed by the European Commission under the Fifth Framework Programme: Environment and sustainable development.

Partners in the project are AUTH – Greece; CSTB – France; IBMB – Germany; IST – Portugal – TNO – The Netherlands; Ghent University – Belgium; WFR – United Kingdom; EMI – Hungary, FSN – Sweden; IUAV – Italy; University Innsbruck – Austria.

2 The project

The first phase of the project was mainly devoted to the collection of useful information on regulatory systems in various European countries, on statistics of fires in culture heritage, on the behaviour of ancient materials and on existing fire protection technology.

The second phase was devoted to the development of a risk based decision supporting procedure. The first step in this process is the evaluation of the fire risk of a given cultural heritage object. In this respect 16 existing fire risk assessment methods have been evaluated on their suitability for use in cultural heritage buildings. The second step was then to develop a method in order to allow decision-makers to select protection systems that will have the greatest impact on fire safety, thereby optimising the selection process with regard to the reliability, acceptability and cost of individual fire protection measures.

3 Collection of information

Information on four topics is collected.

The existing regulations and practices concerning fire safety in cultural heritage buildings have been identified and the motivation behind them was decoded. An analysis has been carried out on the current state of the EU-wide legislation as it applies to cultural heritage. Information on fires affecting cultural heritage buildings all over Europe was collected. Information on the fire performance of ancient materials and assemblies was collected. And last but not least the existing fire safety technologies and products were analysed on their applicability and acceptability in cultural heritage buildings, their reliability and cost.

3.1 Existing regulations and practices

Only a few countries address cultural heritage in specific fire regulations: Italy, Portugal, Switzerland. In most of the countries cultural heritage is addressed by other parts of the regulatory system: Austria, Italy, the Netherlands, Belgium, Germany, Switzerland, England and Wales, Sweden, Scotland. In some countries fire safety aspects are included in cultural heritage legislation.

In a few countries important guidance documents are applied. Eminent examples are documents from Historic Scotland, English Heritage, Guidance for the fire protection of windmills in the Netherlands.

3.2 Analysis of fires affecting cultural heritage

Although no systematic statistical information is available for cultural heritage buildings, from the information collected, the main causes of fire appear to be arson, renovation works, old or deficient electrical and gas installations, late detection …

3.3 Fire behaviour of ancient material

Available information from literature was collected.

3.4 Fire protection technologies and products

The state of the art of fire prevention techniques and products for the use in cultural heritage application was analysed. Qualitative and quantitative information is given. Both passive and active or engineered systems have been evaluated in terms of suitability, acceptability, reliability and cost. Suggestions on how these systems and products may be improved have also been included.

4 The risk based approach

First an analysis of different fire risk assessment methods was made and out of that suitable methods were selected.

Than a quantitative decision method, an optimisation procedure, was developed to allow decision makers to choose systems that will have the greatest impact on the fire risk at the lowest cost, taking into account reliability and acceptability of individual fire protection measures.

4.1 Fire risk assessment methods

Nine ranking methods and seven quantitative methods have been examined.
The ranking methods are:

- Risk Value Method;
- Fire Safety Evaluation System;

- Specific Commercial Property Evaluation Schedule;
- Dow Fire and Explosion Index;
- XPS FIRE;
- Hierarchical Approach;
- SIA 81 – Gretener Method;
- Fire Risk Assessment Method for Engineering;
- The Fire Risk Index Method.

Seven quantitative methods have been analysed:
- Computation of Risk Indices by Simulation Procedures;
- Risk-Cost Assessment Model (FIRECAM – Fire Risk Evaluation and Cost Assessment Model) ;
- The Building Fire Safety Engineering Method;
- Fire Evaluation and Risk Assessment System;
- Petri net to Fire Safety Measures;
- Event Tree Analysis as a Risk Analysis Method;
- Fire Risk Assessment with Reliability Index β.

The conclusion of the analysis of the different methods is that the Event Tree Analysis, the Fire Risk Index Method and the Fire Risk Assessment Method of Engineering are the most suitable for the purpose of risk analysis of cultural heritage buildings.

Twelve case studies in total have been carried out.
The event tree analysis is illustrated amongst others in the case study of De Nieuwe Kerk Delft (The Netherlands), the Chiado fire (Portugal), Saint Mary of Consolation in Este (Italy).

The Fire Risk Index Method is applied on the Hoffburg Schönbrunn, and the Fire Risk Assessment Method for Engineering was used to evaluate. "Het Pand", a former convent belonging to the Ghent University, with a multipurpose use, offices, conference center, restaurant, library etc.

4.2 Application of Event Tree Analysis

As an example the present situation of the Saint Mary of Consolation in Este (Italy) is examined on the risk of fire with the Event Tree Analysis Method.
The buildings contain laboratories and a computer room.

Firstly objectives and acceptance criteria are put forward. The most important objective is the "life safety of people in the building". The objective "safety of property" means that in case of fire, the building should have the minimum, and overall not irreversible damage.

Acceptance criteria are:
- No persons more than slightly injured in case of fire.
- The probability of having irreversible damage to more than the complete room of origin of the fire should be less than 10%.

The following events are selected:
developing fire > fire location > time of day > fire detected > extinguished by staff > sprinkler control the fire > fire brigade control the fire.

The following fire scenario's are selected: The fire could start either in one of the laboratories or in the computer room. It is assumed that the probability of the fire to start in the laboratory (60%) could be slightly bigger than in the computer room (40%).

The probabilities for the other events where determined with the help of fire safety engineering methods.

The elaborated Event Tree is given in fig. 1.

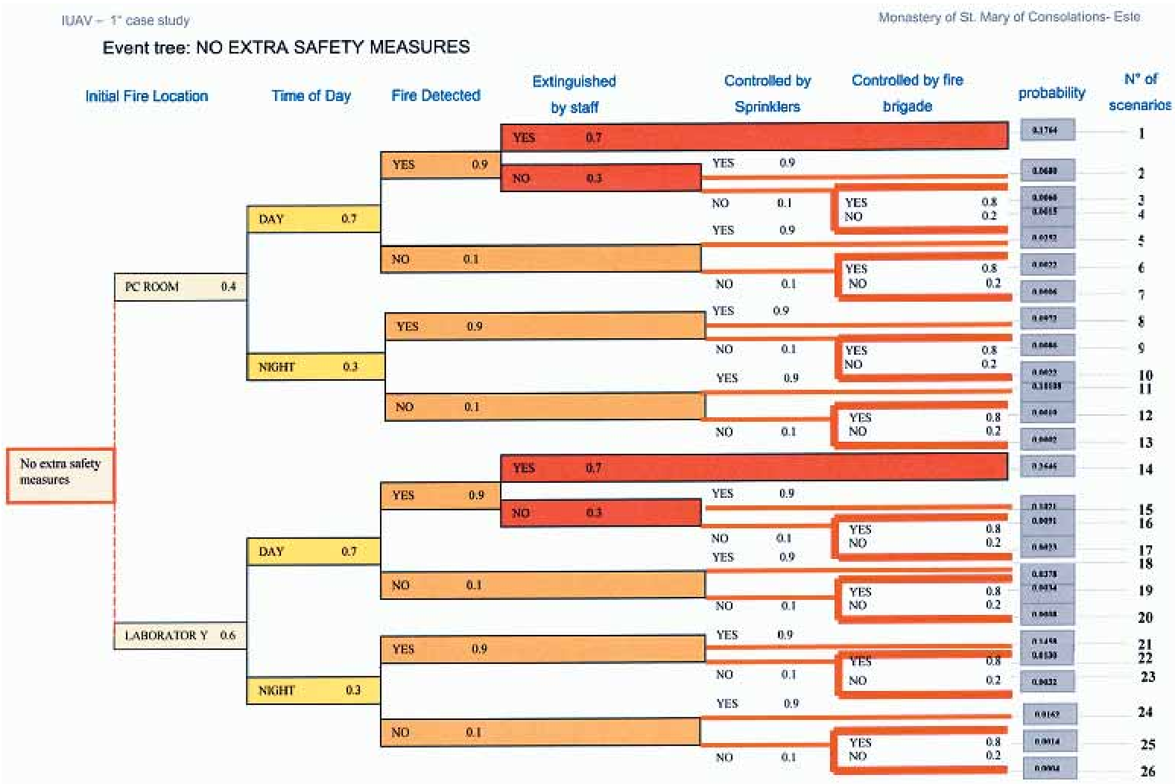

Figure 1

5 A quantitative decision supporting procedure

5.1 The method

The FIRE-TECH Decision Supporting Procedure comprises six steps (fig. 2):

- The first step deals with the objectives and boundary conditions, to be agreed by the stakeholders.
- The second step consists of the gathering of data, which are needed for the application of the procedure. A risk assessment method is applied to evaluate the present situation.
- In the third step an overview is made of the potential fire safety measures, their acceptability in the heritage building, their reliability and cost.
- The fourth step constitutes the core of the method in which an optimisation method is applied in order to rank the potential fire safety measures according their efficiency and also according their cost-efficiency. Two alternative calculation techniques are offered, based on the same fundamental principles.
- In a fifth step the results are critically analysed and the application of the risk analysis method can demonstrate the contribution of the proposed fire safety measures.
- Ultimately, the recommendations and conclusions are formulated and presented to the stakeholders.

The procedure is very flexible and can be applied as well on the basis of rough approximations and expert judgement, as on the application of (quantitative) fire safety engineering methods. The reliability of the results depends of course on the precision of the input data.

For the fourth step, in order to optimise the use of fire safety measures also in terms of cost-efficiency, a quantitative decision method has been developed.

The analytical hierarchical process method was selected and adapted for this purpose. The method defines:

A general policy (P)
Objectives (OB)
Strategies (ST)
Measures (M)

The general policy is to provide fire safety of cultural heritage: P1

The proposed objectives which are specifically selected for the purpose of cultural heritage buildings are:

OB 1 – protect the occupants
OB 2 – protect the firemen
OB 3 – protect the building
OB 4 – protect the contents
OB 5 – safeguard the continuity of activity
OB 6 – protect the environment

The strategies are:

ST 1 – Reduce the probability of fire start
ST 2 – Facilitate fire fighting
ST 3 – Facilitate egress
ST 4 – Limit the fire development / propagation
ST 5 – Limit the effects of fire

Nineteen possible measures are identified:

M1 – Reaction to fire
M2 – Fire resistance of structure
M3 – Fire resistance of partitions
M4 – Size of fire compartments
M5 – Characteristics and location of openings on the facades
M6 – Distance between buildings
M7 – Geometry of egress paths
M8 – Access for the firemen
M9 – Means of fire detection
M10 – Means for fire suppression
M11 – Smoke control
M12 – Emergency and alarm signs
M13 – On site firemen
M14 – Fire brigade
M15 – Maintenance of fire safety systems
M16 – Education for fire safety
M17 – Emergency planning + training
M18 – Salvage operation management
M19 – Periodic inspection of the building

Two numerical tools where developed:

- The first is ALADIN a FORTRAN computer programme that was designed by CSTB and which is limited to the comparison of six measures.

– The second is the IST Cost / Effectiveness sheet, an excel sheet. This sheet is designed for the evaluation of up to 19 measures.

Decision Supporting Procedure comprises six steps (fig. 2).

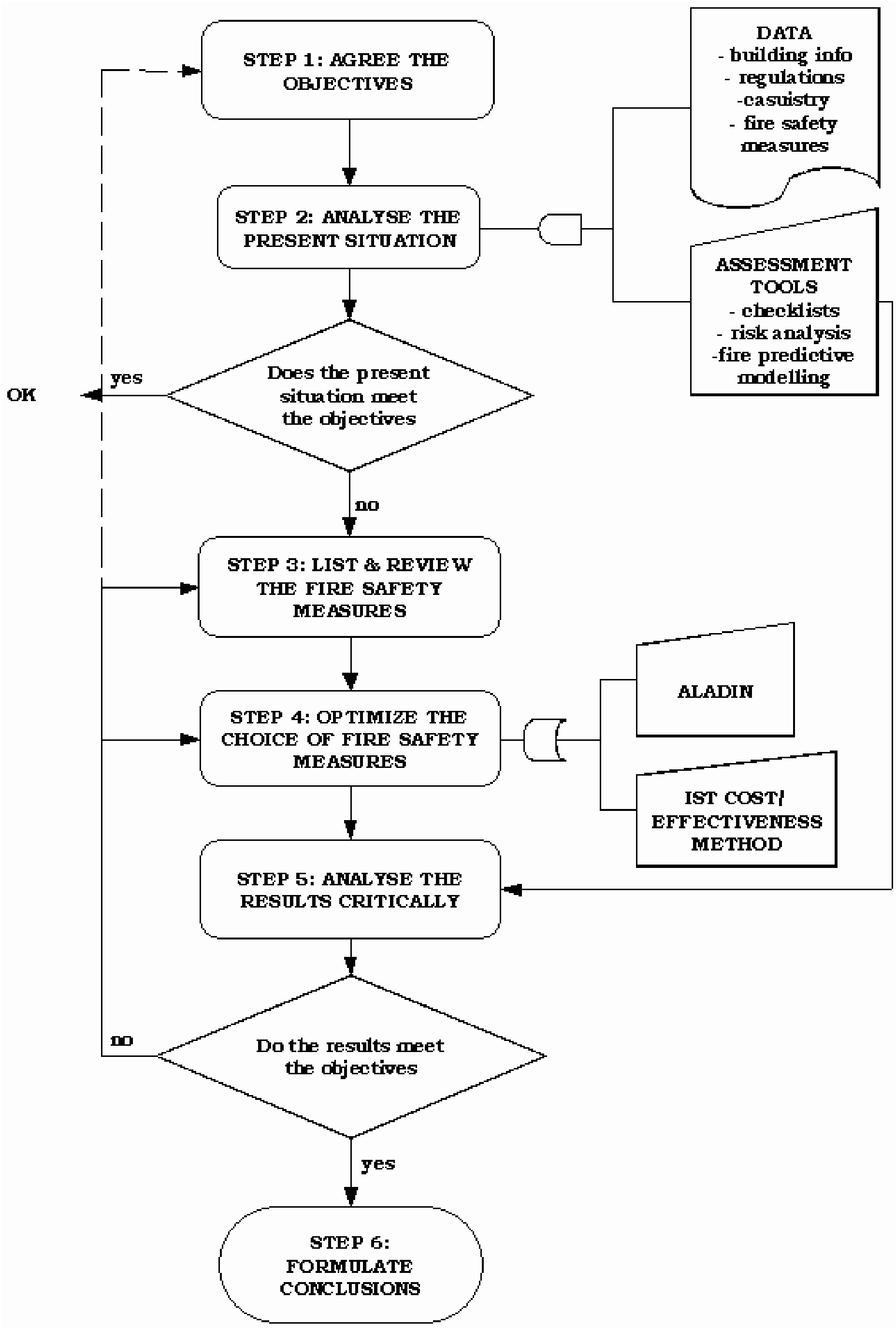

Figure 2

5.2 An example: De Nieuwe Kerk in Delft (the Netherlands)

De Nieuwe Kerk is a church with annex shop for gadgets, souvenirs and candles. The surface is approximately 2000 m², including a 25 m² shop. It has a tower of 100 m high.

A risk analysis via event tree method was effectuated. In the present situation there is a 35% chance that people can be evacuated from the tower by special means. There is a 22% chance that more than 4% of the building will be destroyed. This doesn't meet the acceptance criteria set forward, which means that extra measures are needed for both tower and church.

Fifteen potential specific fire safety measures P have been identified. Their costs have been calculated and their influence on the fire risk quantified.

The model ranks the different measures in order of efficiency. It gives the increase in Effectiveness Index in function of costs.

This gives a ranking as follows:

1. P13 – The presence of fire guards during large events gives an improvement of the Effectiveness Index of 0.11%/kEuro
2. P15 – Control of electrical installations improves the EI of 0.089%/kEuro
3. P2 – First aid fire fighting equipment gives an improvement of the EI of 0.062%/kEuro
4. P3 – Automatic fire detection
5. P5 – Visual signals and evacuation plans
6. P4 – Alarm systems
7. P14 – Guides accompanying visitors to tower
8. P8 – Inert insulating materials
9. P9 – Intumescent materials
10. P10 – CCTV
11. P1 – Sprinklers

Fig. 3 shows that with a budget of 200 k Euro an improvement of the effectiveness index of 14% is obtained (from 66,5 till 80,5) whilst for a further improvement of ± 10%, another 600 Euro is required.

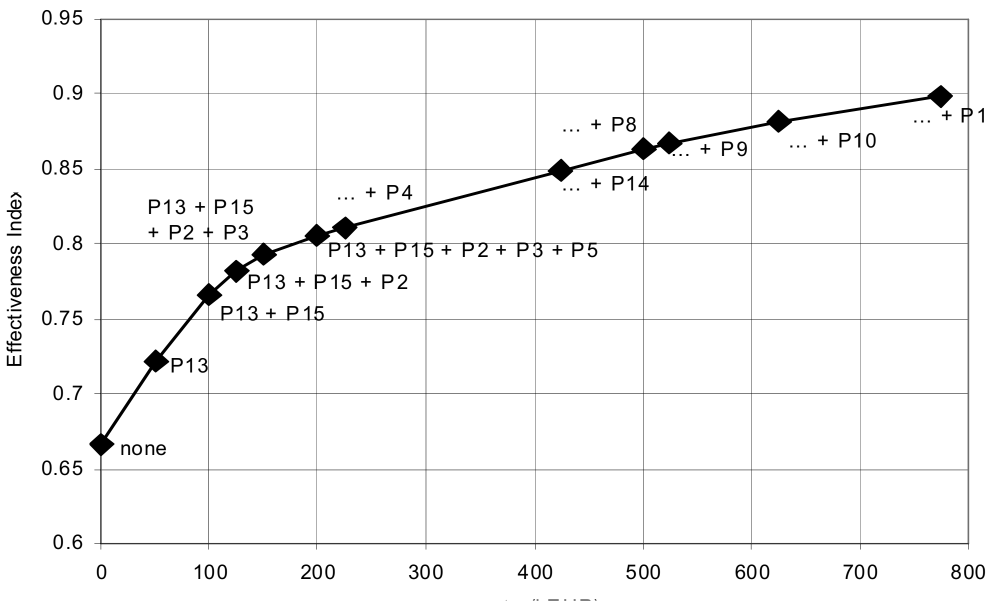

Figure 3

6 Conclusions

Considering that on the one hand fire appears to be the largest threat to cultural heritage in Europe and that on the other hand the financial resources to protect cultural heritage against fire are scarce, the available means need to be utilized in the most cost efficient way.

The FIRETECH project has developed a quantitive decision supporting procedure allowing the most cost effective measures to be identified.

The procedure makes use of existing fire risk evaluation methods and is very flexible in its application. It allows the use of expert judgement as well as quantitative fire engineering methods.

Reducing the seismic vulnerability of cultural heritage buildings

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Key words: immovable heritage, seismic protection, simplified methods, case study, dissemination

1 Introduction

Due to the effects of aggressive environment (earthquakes, soil settlements, traffic vibrations, air pollution, etc.) and to the fact that many old buildings and historic centres were not subject to continuous maintenance, a large part of this heritage is affected by structural problems that menace the safety of buildings and people.

European countries have developed a valuable experience in conservation and restoration. In recent years, large investments have been concentrated in this field, leading to impressive developments in the areas of inspection, non-destructive testing, monitoring and structural analysis of historical constructions. These developments, and the recent guidelines for future reuse and conservation projects, allow for safer, economical and more adequate remedial measures.

Being earthquakes a major source of destruction of cultural heritage buildings, this paper focus on a research project funded under the EU-India Economic Cross Cultural Programme from the European Commission. The partners involved in the project are University of Minho (coordinating institution), Portugal, Technical University of Catalonia, Spain, Central Building Research Institute, India, and University of Padova, Italy.

2 Objectives and activities

The main objective of the project is the development of a social and economic argument, at Indian-European level, to support an earthquake protection innovative program for cultural heritage masonry buildings at risk. This will consider cultural heritage buildings / monuments in an earthquake prone area in India, identify seismic input scenarios and specific vulnerability features, and study advanced upgrading and strengthening techniques, based on four case studies (see Figure 1). The Plan of Action is based on a multidisciplinary approach, entailing aspects of risk analysis, in situ survey and monitoring, numerical analyses and the design/application of innovative strengthening strategies. The objective is to devise strengthening strategies that, based on thorough knowledge of the traditional craft and material, can use modern materials and techniques to prevent vibration borne damage to the structures and to the decorative apparatus.

The proposal mainly focuses on:

– The identification of preventative measures that can be implemented to improve the earthquake resistance of historic masonry Cultural/Historical Buildings (CHBs) and Cultural Heritage in general;

- Definition and application of optimal modelling strategies for determining the load bearing capacity of historic structures before and after repair;
- Cost / benefit analysis of the proposed procedures taking into account the different levels of complexity and of disposable budget;
- Set up of a comprehensive database of traditional local technologies for construction and repair;
- Full conservation design for three case studies selected in Europe and India;
- The interchange of knowledge between European and Indian experts.

This implies a better understanding and enhancement of the inherent earthquake-resistant characteristics of CHBs achieved through compared vulnerability analysis, in situ monitoring of real cases and numerical simulation.

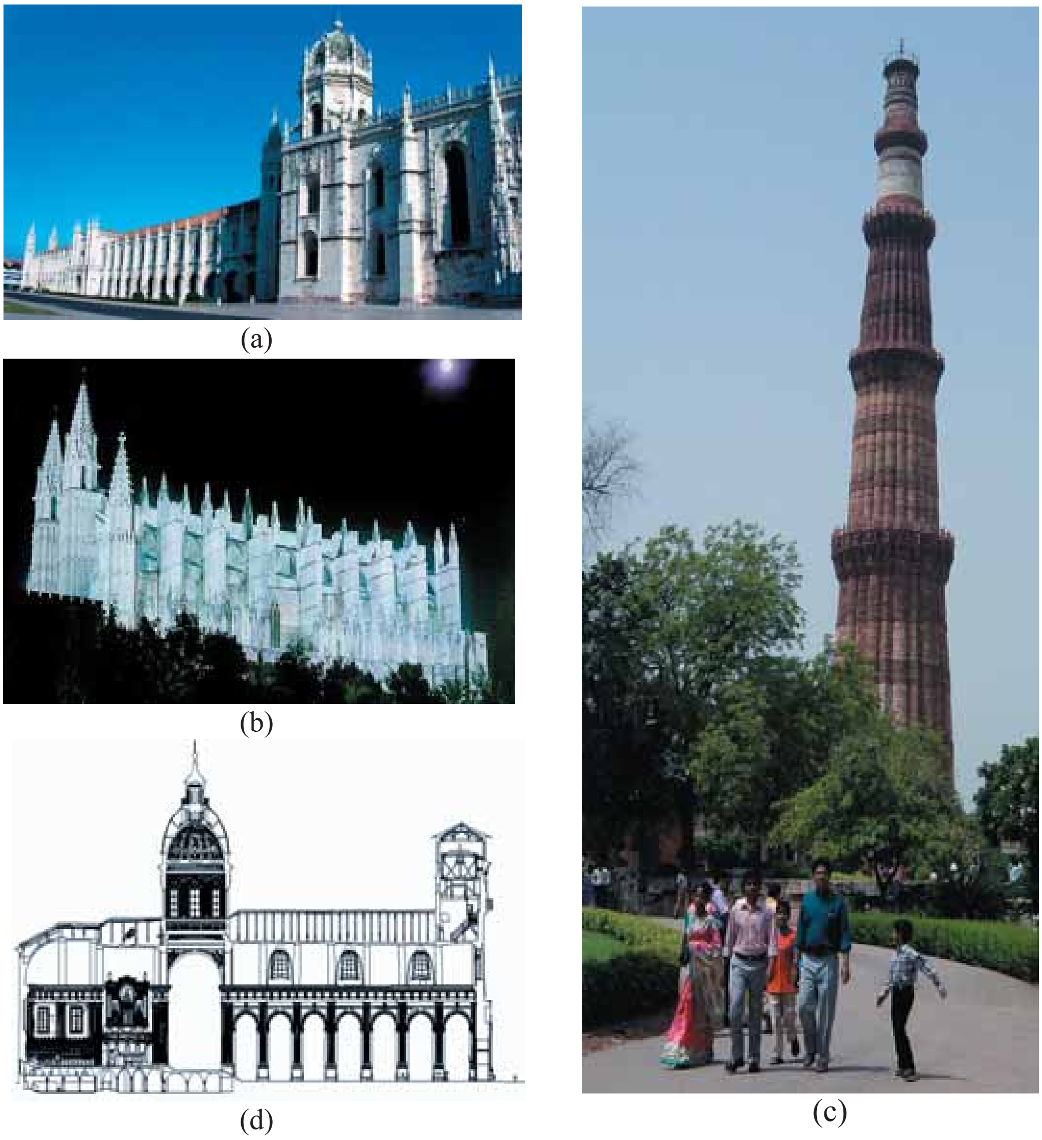


Figure 1: Case studies: (a) Monastery of Jerónimos, Lisbon, Portugal – World Heritage Monument; (b) Cathedral of Majorca, Spain; (c) Qutub Minar, New Delhi, India – World Heritage Site; (d) Cathedral of Reggio Emilia

The activities included in the project are:

- Activity 1: Inventory of monuments at risk. The aim of this activity of to develop, at a European-Indian level, the social and economic argument to support an earthquake protection program for monuments at risk and to collect existing background information on the three case studies. This activity includes the creation of an inventory of monuments at risk from earthquakes in Portugal, Spain, Italy and India. From the inventory, a selection of about 40 monuments (10 per country) were selected on the basis of available geometrical data, historic and architectural significance, importance to local visitor economy, seismicity of the area and seismic vulnerability according to simplified methods (ratio between walls area and total area; ratio between weight and total area; shear base action).
- Activity 2: Seismic activity evaluation and site effects. The aim of this activity is to evaluate the seismic hazard and the site effects associated with each church of a selected collection. For the hazard evaluation, information will be gathered on hazard studies, in the various countries where the monuments are located. The information is to be analyzed, in order to homogenize the different patterns in the data treatment and establish comparisons among different sites and categories the situations in terms of high, medium and low hazard.
- Activity 3: Conference in Padova, Italy. The fourth international conference on structural analysis of historical constructions – possibilities of experimental and numerical techniques was carried out during November 2004, with the participation of 350 delegates.
- Activity 4: In situ tests and monitoring. The objectives of this activity are: (a) To develop a monitoring system suitable for the identification of dynamic properties of monuments; (b) To identify, by means of long term vibration monitoring, the dynamic response of the four case studies to natural vibrations caused by traffic, wind and minor earthquakes occurring during the monitoring period; (c) To carry out a set of NDT tests to identify in situ the mechanic properties of the materials. In general the activity includes the design and production of a long-term monitoring system based on the use of fixed measurement devices placed at meaningful points of the structure, with continuous remote logging. The integrated monitoring system will include displacement transducers, crackmeters, tiltmeters, accelerometers, seismometers and wind and temperature transducers. The systems were installed in the four case studies.
- Activity 5: Evaluation and design of strengthening. The objective of the activity is to simulate the static and dynamic responses of the selected three ancient constructions, including degradation processes and repeated shaking. This will allow to: (a) Identify limit thresholds associated with accumulated permanent deformation; (b) Identify the role of performance-related overall properties: dissipation, monolithism, ductility, and the extent to which they should be considered in the design of the strengthening strategies; (c) Assess the sensitivity to material parameters. In addition, a European-Indian database of current strengthening strategies for monuments will be established, together with a measure of the efficiency of strengthening strategies in terms of reduced vulnerability with respect to the target limit state, but also in terms of respect of the conservation criteria. The activity includes the usage of methods for the analysis of large masonry buildings available at the partners, for the simulation of the actual condition of the structures analyzed and determine their main weak points, as well as their main needs of repair and retrofitting. In addition, different strengthening strategies for the case studies will be analyzed.
- Activity 6: Definition of guidelines. The objective of the activity is to provide guidelines for end users and professionals on the methodological approach to conservation of historic structures in seismic areas. These will include the general concepts and specifications, which must lead to adequate strengthening design. The

guidelines will include the definition of alternative strengthening techniques with respect of quantity and quality of implementation, alternative materials, and alternative implementation procedures.

- Activity 7: Dissemination. The objectives of this activity are the following: (a) To develop and maintain a web site with progress update of the project; (b) To set and update a database on multi-media support of structural information on historic buildings at risk in Europe and on strengthening techniques; (c) To organize a round robin for assessment of strengthening strategy; (d) To prepare a 3D virtual model. The findings will be presented and discussed with practitioners at purposely-organized workshops in the countries of each workshop. For one of the case studies and one specific strengthening strategy a 3D virtual model will be developed, with the following objectives: (a) Showing the building process and the structural changes through the centuries; (b) Explaining the flow of forces within the structure and link to a demo on the basic principles of structural behaviour of old structures; (c) Showing the collapse of the structure; (d) Showing how strengthening changes the flow of forces and that the new structure survives. The target audience will be visitors of the considered monument and the aim is to raise the profile of the problem and its possible solutions at European-Indian level.
- Activity 8: Conference in New Delhi, India. The fifth international conference on structural analysis of historical constructions – possibilities of experimental and numerical techniques is to be carried out in New Delhi, India, during 6-8 November 2006. This will provide a forum for discussion of the results of the project and for full knowledge transfer for practitioners worldwide and, specifically, in India.

3 Highlights of present results

3.1 Simplified methods of analysis

An analysis of the damage survey of historical masonry buildings for the Umbria-Marche earthquake [1] shows that the problem of earthquake damage is generalized and that structural typologies, as well as associated types and distribution of damage, are fairly recurring. Seismic protection actions requires the knowledge of seismic site response, the definition of the seismic load (a rather challenging issue) and the knowledge of the characteristics of existing buildings. This is a gigantic task, requiring large funds and considerable large time-span, but efforts have been made to create damage scenarios and to prioritize retrofitting works, see Barbat et al. [2] and Langa and Bachmanna [3].

The approach adopted in the present project aims at a much more simple, fast and low cost procedure, being based on a simplified geometric approach for immediate screening of the large number of buildings at risk, see [4] for more details. The objective is to evaluate the possibility to adopt simple indexes related to geometrical data as a first (very fast) screening technique to define priority of further studies with respect to seismic vulnerability. These fast techniques are to be used without actually visiting the buildings, being therefore not accurate. It is expected that the geometrical indexes could detect cases in serious risk and, thus, define priority of additional studies in countries / locations without recent moderate or severe earthquakes The historical buildings considered at possible risk may deserve more detailed studies using advanced computer simulations, together with adequate material and structural characterization, see Lourenço [5] and ICOMOS [6] for recommendations. In case of urban areas, and in spite of the diversity, a common matrix can usually be established for the seismic areas, more structural than technological. This consists of low building height (up to three stories), moderate spans (maximum of four or five meters) and large thickness of the walls (less than 1/7 of the height), see Giuffrè [7].

The work carried out in this paper is focused in European churches, given: (a) Their intrinsic greater structural vulnerability due to open plan, greater height to width ratio and, often, the presence of thrusting horizontal structures from vaulted ceilings and timber roofs; (b) The ample geometry survey drawings and documentation available. Moreover, in earthquake prone countries, churches and monuments have already been subjected to earthquakes, and sometimes survived them, meaning that they are testimonies and they represent full-scale testing data. This fact, permits to discuss and, generally, to accept that these ancient structures have been adjusted to local seismicity. Forty-four churches from Portugal, Spain and Italy have been selected and analyzed considering three in-plane indexes and three out-of-plane indexes. The proposed indexes of monuments located in different seismic areas are compared with the respective seismic hazard, i.e. the peak ground acceleration (PGA), defined for a 10% probability of exceedance in 50 years for a rock-like soil, corresponding to a return period of 475 years. The recognition of the likely existence of a correlation between structural characteristics and seismic hazard is, therefore, sought.

The usage of simplified methods of analysis usually requires that the structure is regular and symmetric, that the floors act as rigid diaphragms and that the dominant collapse mode is in-plane shear failure of the walls. In general, these last two conditions are not verified by ancient masonry structures, meaning that simplified methods should not be understood as quantitative safety assessment but merely as a simple indicator of possible seismic performance of a building. The following simplified methods of analysis and corresponding indexes are considered:

In-plane indexes:
Index 1: In-plan area ratio;
Index 2: Area to weight ratio;
Index 3: Base shear ratio.

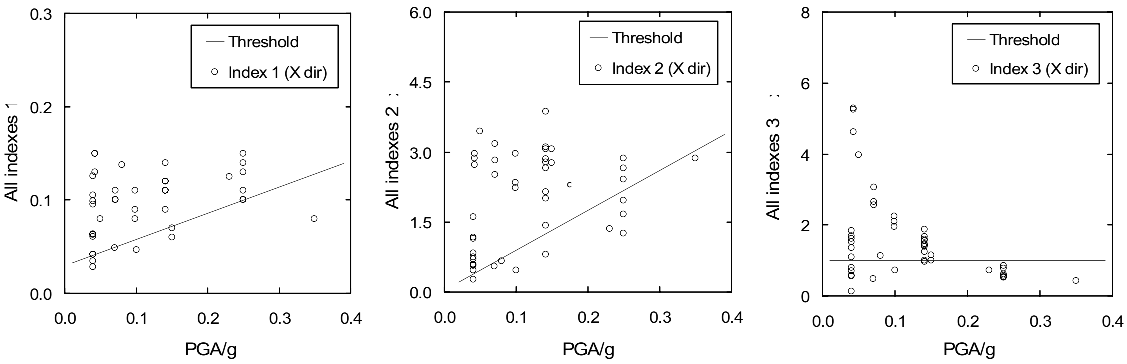
Out-of-plane indexes:
Index 4: Slenderness ratio of columns;
Index 5: Thickness to height ratio of columns;
Index 6: Thickness to height ratio of perimeter walls.

These methods can be considered as an operator that manipulates the geometric values of the structural walls and columns and produces a scalar. As the methods measure different quantities, their application to a large sample of buildings contributes to further enlightening on their application. As afore-mentioned, a more rigorous assessment of the actual safety conditions of a building is necessary to have quantitative values and to define remedial measures, if necessary.

The investigation carried out includes the application of the simplified methods to a sample of forty-four monuments (19 Portuguese, 15 Spanish and 10 Italian), selected according to the seismic level and to the availability of information. This research pursues the following objectives: (a) Validate the hypothesis of an empirical relation of the ancient builders, able to define an expedite preliminary assessment of seismic vulnerability of historical masonry buildings; (b) Validate the hypothesis of an empirical relation between architectural-structural characteristics of historical masonry buildings and seismicity; (c) Prioritize further investigations and possible remedial measures for the selected sample; (d) Extrapolate, from the results on the sample, the seismic vulnerability of ancient masonry buildings in those countries.

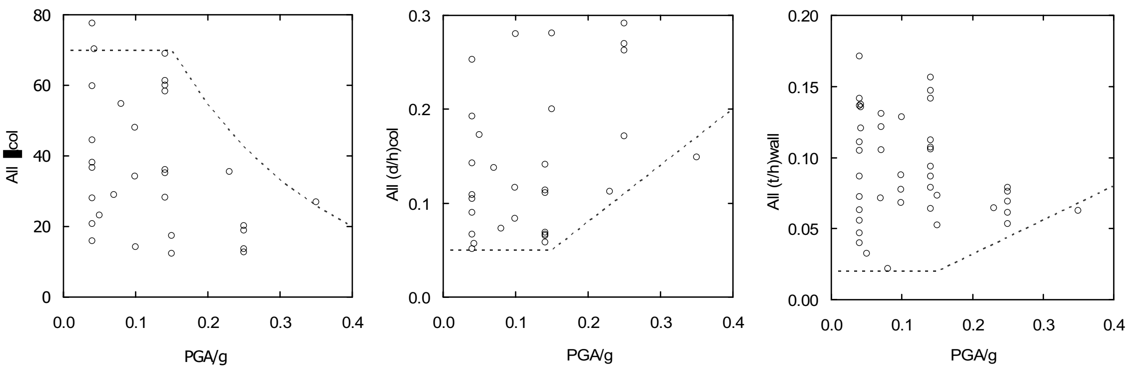
The values computed for the three in-plane indexes and the three out-of-plane indexes, which can be found elsewhere [8], are graphically represented in Figure 2, for the entire sample and for the transversal direction, and in Figure 3, for the entire sample, as a function of the local parameter PGA/g.

A proposal for the usage of simplified methods was made, taking into consideration the simultaneous violation of two or three of the in-plane indexes. The results show the need for deeper investigations ranges between 18% and 43% of the sample (8 and 19 churches, respectively), see [8] for details. The analysis of the out-of-plane indexes shows that a logical common trend can be established. For low and moderate seismicity, indexes do not exhibit a dependency on seismicity. However, for increasing seismicity, they tend to vary in a logical pattern. Furthermore, the observed trend allowed the proposal of possible threshold criteria for each of the indexes.



(a) (b) (c)

Figure 2: Relationship between in-plane indexes (transversal direction of the church) and PGA/g, for the entire sample: (a) index 1, (b) index 2, (c) index 3



(a) (b) (c)

Figure 3: Relationship between out-of-plane indexes and PGA/g, for the entire sample: (a) index 4; (b) index 5; (c) index 6

3.2 Case study – Monastery of Jerónimos, Portugal

Monastery of Jerónimos is, probably, the crown asset of Portuguese architectural heritage dating from the 16th century. The monumental compound has considerable dimensions in plan, more than 300×50 m^2, and an average height of 20 m (50 m in the towers). The monastery evolves around two courts. The construction resisted well to the earthquake of November 1, 1755. Later, in December 1756, a new earthquake collapsed one column of the church that supported the vaults of the nave and resulted in partial ruin of the nave. In this occasion also the vault of the high choir of the church partially collapsed.

The Gothic style was lately introduced in Portugal, incorporating a specific national influence. The so-called "Manueline" style (after King D. Manuel I), exhibits a large variety of architectural influences and erudite motives. An interesting aspect appears in the 16th century, when the traditional three naves churches start to be replaced by a configuration with small difference in height for the naves. Here, the vault springs from one external wall to the other, supported in slender columns that divide almost imperceptibly the naves. From the traditional art, only the proportions and roof remain, being the concepts of space and structure novel. The fusion of the naves in the present Church, see Figure 4, is more obvious than in other manifestations of spatial Gothic. For this purpose, arches are no longer visible, the slightly curved vault comprises a set of ribs and the fan columns reduce effectively the free span. Additional information about the church and the vault can be found in [9].

(a) (b) (c)

Figure 4: Church of Monastery of Jerónimos: (a) half of transversal cross-section; (b) vault and choir; and (c) aspect of the three naves

The church has considerable dimensions, namely a length of 70 m, a width of 40 m and a height of 24 m. The plan includes a single bell tower (south side), a single nave, a transept, the chancel and two lateral chapels. In order to assess the safety of the church, several in situ tests have been carried out: (a) three-dimensional survey of the church; (b) sonic and GPR tests in the columns to assess the integrity; (c) radar investigation to detect the thickness of the masonry infill in the vault and pier [10]; (d) removal of the roof, visual inspection, bore drilling, metal detection and chemical analysis of materials [11]; (e) dynamic identification, see Figure 5 for examples.

Advanced structural analysis was considered in order to quantify the seismic vulnerability. Different models have been used to study the behaviour of the compound and of the church, see Figure 6. In the complete model of the compound only the very large openings were considered and the geometry of the model was referred to the average surfaces of the elements. All the walls, columns, buttresses, vaults and towers were included in the model, with the exception of a few minor elements. The finite element mesh is predominantly rectangular and structured, but, for the towers and local refinements, triangular finite elements are also adopted. All elements possess quadratic displacement fields. The mesh includes around 8 000 elements, 23 500 nodes and 135 000 degrees of freedom. The time necessary for total mesh generation, including definition of supports, loads and thicknesses, can be estimated in three months. A push-over analysis with zero tensile strength indicated that the towers of the Museum are the critical structural elements featuring, at collapse, displacements of around 0.10 m and cracks of around 0.01 m. Smaller cracks are also visible in the church. The analyses indicate that the monastery is a safe construction, with respect to the wall behaviour. As the vaults were not properly considered, a conclusion regarding the safety of the vaults (thus, of the church) is impossible.

In order to better study the church, a more refined model was adopted for the main nave, including the structural detail representative of the vault. Symmetry, conservative, boundary conditions have been incorporated. Therefore, the model represents adequately the collapse of the central-south part of the nave. The model includes three-dimensional volume elements, for the ribs and columns, and curved shell elements, for the infill and stones slabs. The external (south) wall was represented by beam elements, properly tied to the volume elements. The supports are fully restrained, being rotations possible given the non-linear material behaviour assumed. All elements have quadratic interpolation, resulting in a mesh with 33 335 degrees of freedom.

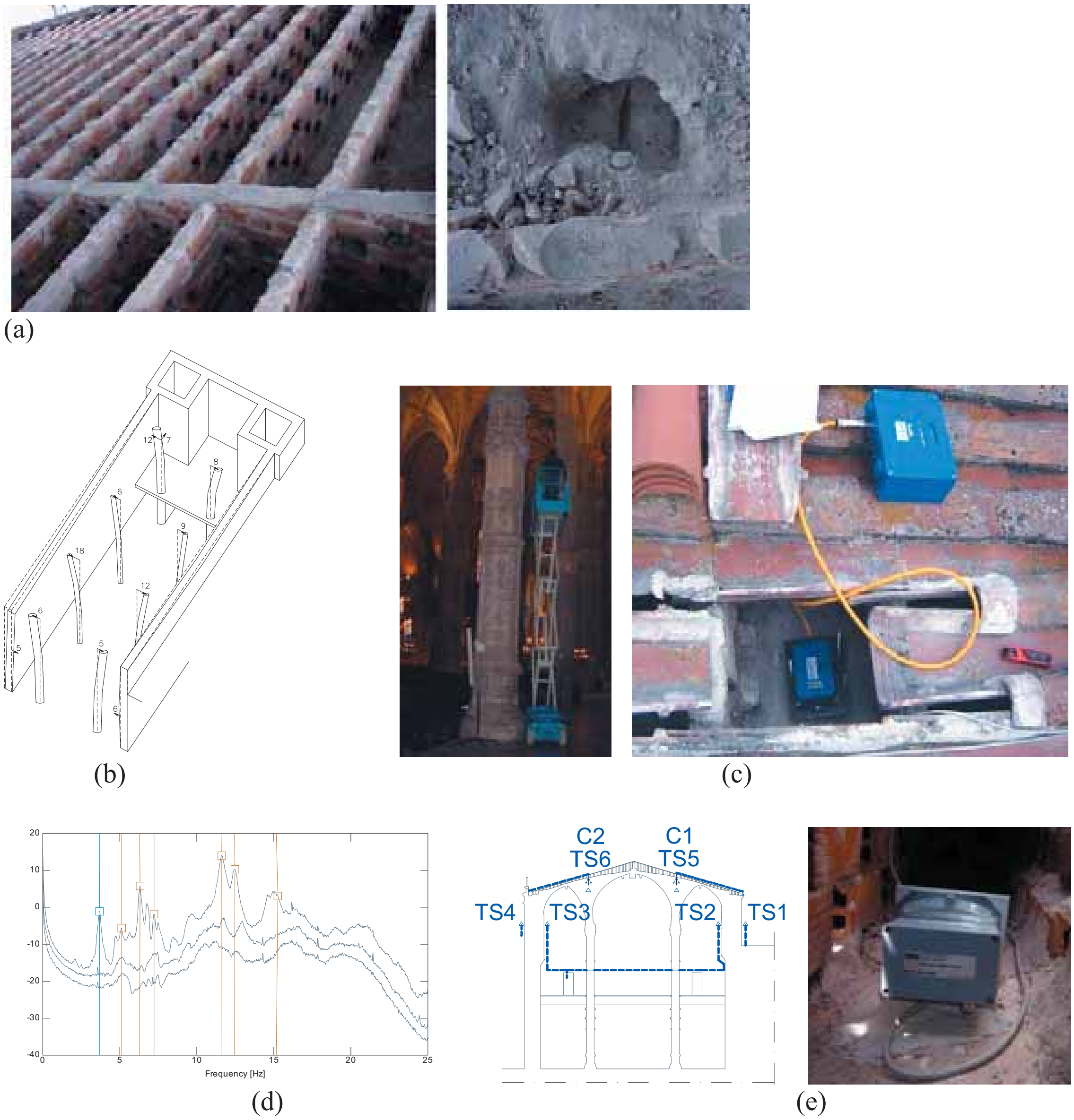
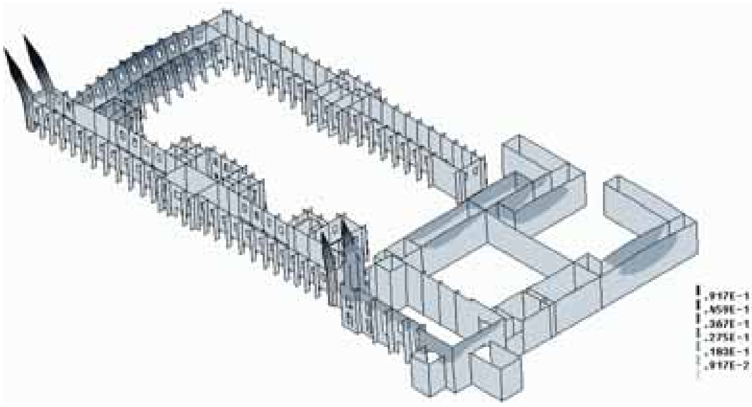
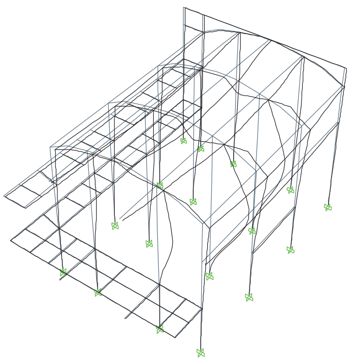


Figure 5: In situ testing and monitoring for Monastery of Jerónimos: (a) inspection of the vault nave; (b) survey of the columns; (c) radar inspection and ambient vibration acquisition; (d) dynamic identification; (e) static and dynamic monitoring

Fig. 6d illustrates the load-displacement diagrams for the vault key and top of the column. Here, the load factor represents the ratio between the self-weight of the structure and the applied load, meaning that the ultimate load factor is equivalent to the safety factor of the structure. It is possible to observe that the response of the structure is severely nonlinear from the beginning of loading, for the nave, and from a load factor of 1.5, for the column. The behaviour of the nave is justified by the rather high tensile stresses found in the ribs, using a linear elastic model. The collapse of the columns is due to the normal and flexural action. The safety factor is 2.0, which is low for this type of structures. The stresses are bounded in tension and compression, meaning that cracking and crushing occurs. The pairs of transverse ribs that connect the columns (in the central part of the structure) exhibit significant cracking, as well as the infill in the same area. Additional cracking, less exuberant and more diffused, appears in the central octagon defined by the capitals of the four columns. Such cracking occurs at the key of the octagon and in the longitudinal ribs, which confirms the larger displacements of the vault and the bidirectional behaviour of the vault.



(a)



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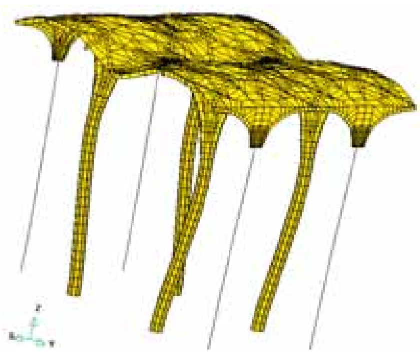

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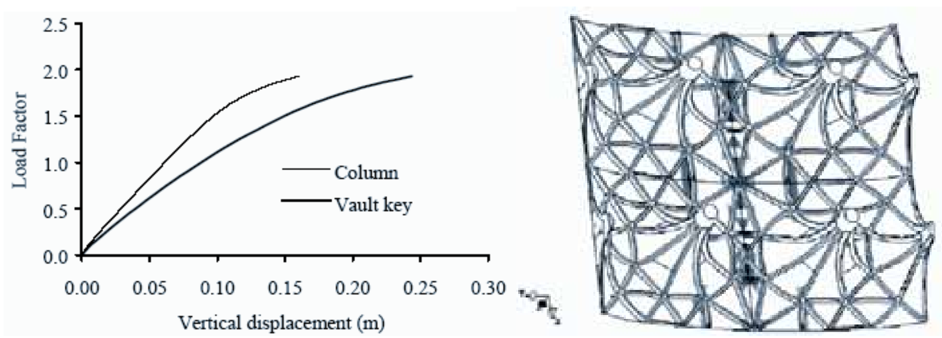

(d)

Figure 6: Structural analysis for Monastery of Jerónimos: (a) push-over analysis of compound; (b) model updating and dynamic time integration of church; (c) detailed analysis of nave; (d) results for the detailed analysis of the nave in terms of displacements and crack widths

4 Conclusions

The European Dimension of the project is clear as Europe is a leader in the generation of knowledge, methodology and technology applicable to the conservation and restoration of the architectural heritage. Equipments and research cannot be usually funded in one country and require a strong collaboration between the scientific organisms of each country, as carried out in the project. Moreover, seismic activity extends well to a wide range of countries in Europe, of particular severity in the Mediterranean basin.

The most important novelty of the programme is its integrated approach, which uses forefront developments in seismic and conservation engineering, innovative research and technology, to tackle the problem of improving the capacity of masonry cultural heritage buildings of significant value to resist to dynamic actions. This is made possible by the high level of international expertise in each of these fields that the partners have been ready to share.

The impact of the project is rather high with respect to the scientific and technical communities, with 18 papers in national and international conferences, 4 MSc and 4 PhD Theses, and 2 conference proceedings. Three workshops with senior officers of local and national heritage authorities have been held in Italy (2004), India (2005) and Portugal (2006). In addition, 3 news about the project appeared in daily newspapers in India. Dissemination will be further extended with a DVD freely distributed in the end of the project, including: (a) A database on multi-media support of structural information on the 54 monuments in Europe and India; (b) A 15 minutes DVD professional video of the project; (c) Design and validation of monitoring systems and sensors; (d) State of the art for remedial techniques in historical structures, including a comprehensive discussion on the case studies and a benchmark on dynamic identification techniques and advanced structural analysis; (e) Guidelines for seismic strengthening of historical structures; (f) Development of a 3D virtual model for Qutub Minar, including building process, flow of forces, possible structural collapse and strengthening.

5 European Project Details and Acknowledgment

Contract No. ALA-95-23-2003-077-122, Title: Improving the seismic resistance of cultural heritage buildings, Co-ordinator: Paulo B. Lourenço, Affiliation: University of Minho, Portugal. The authors gratefully acknowledge the support of the European-Indian Economic Cross Cultural Programme, under this contract.

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Earthquake protection of historical buildings by reversible mixed technologies: the PROHITECH project

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Key words: seismic protection, historical buildings, reversible systems, mixed technologies

1 Introduction

The Mediterranean and Balkan area is greatly exposed to seismic hazard. Consequently, its cultural heritage is strongly susceptible to undergo severe damage or even collapse due to earthquake. The constructions mostly exposed to seismic risk are the historical and monumental ones, since in many cases they are not endowed with basic anti-seismic features and/or no seismic retrofit has been applied to them. If the latest earthquakes occurred in this area are considered, the extremely unsatisfactory degree of seismic protection is clearly apparent. Degradation in material quality, lack of appropriate maintenance and, above all, absence of elementary anti-seismic provisions are the clear reasons of the very large number of the collapses, particularly in old masonry structures, occurred during earthquakes.

The extreme seismic vulnerability of the historical constructions is confirmed by this evidence and, consequently, urgent strategies for the seismic protection of the cultural heritage are strongly required. Considering the construction as a system, the objective is improving its global performance, rather than providing solutions to specific structural or architectural problems, requiring the set-up of new technological systems. Moreover, the new intervention methods must be not only reliable and durable, but also, if required, easy to monitor and remove, the latter aspect corresponding to the widely shared policy of safeguarding existing buildings from inappropriate restoration interventions, with particular reference to historical and monumental constructions. At the same time, modern constructional systems have provided good seismic performances, strongly limiting damage and completely avoiding collapse. Consequently, a slow but continuous increasing in the sensitivity to the use of more advanced technologies in the earthquake protection policy has begun. The excellent performances of innovative materials have been acknowledged and the potential advantages of using special techniques for seismic resistant structures has been recognized, in a step by step process. Although initially referred to new buildings, this trend represents an important study field in seismic rehabilitation of existing buildings, with particular interest for historical and monumental constructions [1, 2, 3].

The research project PROHITECH is framed within the INCO thematic areas, devoted to "Protection and conservation of cultural heritage" in the Mediterranean area. The main objective of the project consists in developing sustainable methodologies for the use of reversible mixed technologies in the seismic protection of the existing constructions.

2 The partnership

The scientific activity of PROHITECH project is subdivided into four parts, aiming at producing four main deliverables, to be developed in three years starting from 1st October 2004.

The workplan is based on twelve scientific workpackages, plus three management workpackages. A number of sixteen scientific workpackage deliverables is foreseen.

Sixteen academic institutions, coming from twelve Countries mostly belonging to the South European and Mediterranean area, are involved in the research program. The partner Countries are: Algeria (AL), Belgium (B), Egypt (EG), Macedonia (MK), Greece (GR), Israel (ISR), Italy (I), Morocco (M), Portugal (P), Romania (RO), Slovenia (SL), Turkey (TR). In the following the partner institutions and the relative responsible researchers are indicated:

- I-UNINA: University of Naples "Federico II"-Engineering Faculty, (F.M. Mazzolani, project general coordinator);
- B: University of Liège (J. Jaspart);
- MK: University of Skopje (K. Gramatikov);
- GR: Technical University of Athens (I. Vayas);
- NA-ARCH: University of Naples "Federico II"-Architecture Faculty (R. Landolfo);
- P: Technical University of Lisbon (L. Calado);
- RO-PUT: Polytechnical University of Timisoara (D. Dubina);
- RO-TUB: Technical University of Bucharest (D. Lungu);
- SL: University of Ljubljana (D. Beg);
- TR: Boğaziçi University of Istanbul (G. Altay Askar);
- ISR: Technion Israel Institute of Technology, Haifa (A.V. Rutenberg);
- M: Moroccan National Scientific and Technical Research Centre, Rabat (A. Iben Brahim);
- SUN: Second University of Naples (A. Mandara);
- AL: University of Science and Technology "H. Boumedien" of Algier, Civil Engineering Faculty (M. Chemrouk);
- EG: Engineering Centre for Archeology and Environment, Faculty of Engineering, Cairo University (M. El Zahabi);
- UNICH: University of Chieti / Pescara-Architecture Faculty (G. De Matteis, project technical coordinator).

3 The basic issues

Within the technical field of seismic rehabilitation, two aspects are receiving an increasing attention by engineers and researchers, namely:

- Preservation of Structural Integrity of existing buildings under severe or exceptional seismic actions (SI);
- Improvement of building seismic performance by means of Reversible Mixed Technologies (RMT).

Both these aspects are closely interrelated each other, in the sense that the application of Reversible Mixed Technologies is, in some cases, the only tool to achieve a satisfying level of Structural Integrity under severe earthquake actions. The concept of Structural Integrity relies on the necessity to ensure seismic protection against collapse also in case of destroying events. In this view, it can be properly framed within the advanced concept of Performance Based Design (PBD). As well known, the Performance Based Design is a new way to approach the structural design against seismic actions, having the purpose to ensure a proper degree of structural reliability under any specified working conditions, including both serviceability and ultimate limit states. Till now, the Performance Based Design has been applied to new structures, only, which can be easily designed complying with relevant behavioural thresholds set by PBD itself. No applications exist in the field of existing constructions, yet. In particular, neither criteria nor methodologies are available for achieving a satisfying design level against strong intensity earthquakes. This is indirectly confirmed by most of national seismic codifications, which, as a matter of fact, allow to avoid a rigorous seismic retrofit in case of historical constructions. This approach, of course, tends to preserve the monumental value of the construction, but at the same time is not adequate to protect against severe earthquakes. It is evident how this aspect deserves great attention not only in the perspective of saving human lives, but also at the light of preserving inestimable buildings from complete destruction. The use of innovative materials and Mixed Technologies is the most appropriate answer for ensuring an adequate performance, and hence the Structural Integrity, under strong seismic actions.

Reversible Mixed Technologies (RMT) are based on the integration of structural members of different materials and/or construction methods into a single constructional organism. The basic feature of RMT is that their application should be always completely recoverable, that is reversible, if required. This is considered as an essential design requirement in order to prevent historical and monumental buildings from unsuitable rehabilitation operations. The main aim of RMT is the best exploitation of material and technology features, in order to optimize the structural behaviour under any condition, including very severe limit states provided by strong seismic actions. This practice, initially concerned with new technologically advanced buildings, is now being looked up with increasing interest also in the field of structural rehabilitation, due to the large possibilities of structural optimization and, hence, performance maximization, both achieved thanks to mixed technologies. In few words, the use of RMT would involve the best exploitation of each material and/or technology used in the intervention, providing in such a way the best performance from both technical and economical point of view.

4 The research programme

The main objective of the research project PROHITECH is developing suitable methodologies for the use of reversible mixed technologies in the seismic protection of existing constructions, with particular emphasis to buildings of historical and artistic interest. This would primarily involve saving human lives and reducing both economic and cultural losses due to earthquakes. The main subject of the research is represented by relevant buildings erected from the ancient age to the first half of the 20th Century, all of which can be considered as belonging to the cultural heritage of the involved Countries. Such buildings cover a wide and diversified range of structural categories, including both masonry and r.c. buildings and also some steel constructions, needing to be fitted with adequate anti-seismic provisions. As the intended activity is mostly focused on the use of innovative technologies, namely those relying upon mixed systems, an urgent necessity for a more advanced understanding of both material and device behaviour, as well as for a deeper insight into the seismic response of constructions, is felt. This means specific objectives to be pursued, aimed at [1, 2, 3, 4]:

1 Drawing the attention of industry, research centres, engineers and competent authorities of European and Mediterranean Countries on the problem of safeguard of construction heritage from seismic risk, in particular when historical buildings are concerned;

2 Improving the awareness of operators listed above about the importance of using advanced materials and technologies in the seismic up-grading of constructions;

3 Improving the average knowledge of practicing engineers about innovative systems of seismic protection, so as to contribute to the institution of specialized skills in the field of seismic rehabilitation;

4 Promoting the use at a wide scale of reversible and environmentally friendly technologies, in order to fit existing constructions with easily removable and modifiable seismic protection systems;

5 Supporting the adoption of “smart” materials and special techniques for the seismic protection of constructions as a cheap and effective alternative to traditional, highly

intrusive strengthening methodologies, especially when historical constructions are faced;

6 Advancing the state-of-the-art in the field of seismic protection of constructions, by adding new information about the behaviour of structures fitted with special systems and/or using advanced materials or devices for improving the seismic performance;

7 Allowing engineers to use simple and reliable tools for analysing the behaviour of constructions provided with advanced systems for seismic protection, as well as for detailing up-grading interventions;

8 Developing advanced, PBD-complying guidelines for the practical application of innovative materials and technologies in the field of anti-seismic restoration.

5 The workplan

5.1 General

It is planned to achieve the above objectives through the creation of twelve scientific workpackages dealing with sixteen deliverables, which are aimed at the production of four main deliverables, representing the final out-put of the four parts which the research plan has been subdivided into. The interconnections among the WPs and the four parts, leading to the achievement of the project goals, is shown in Figure 1.

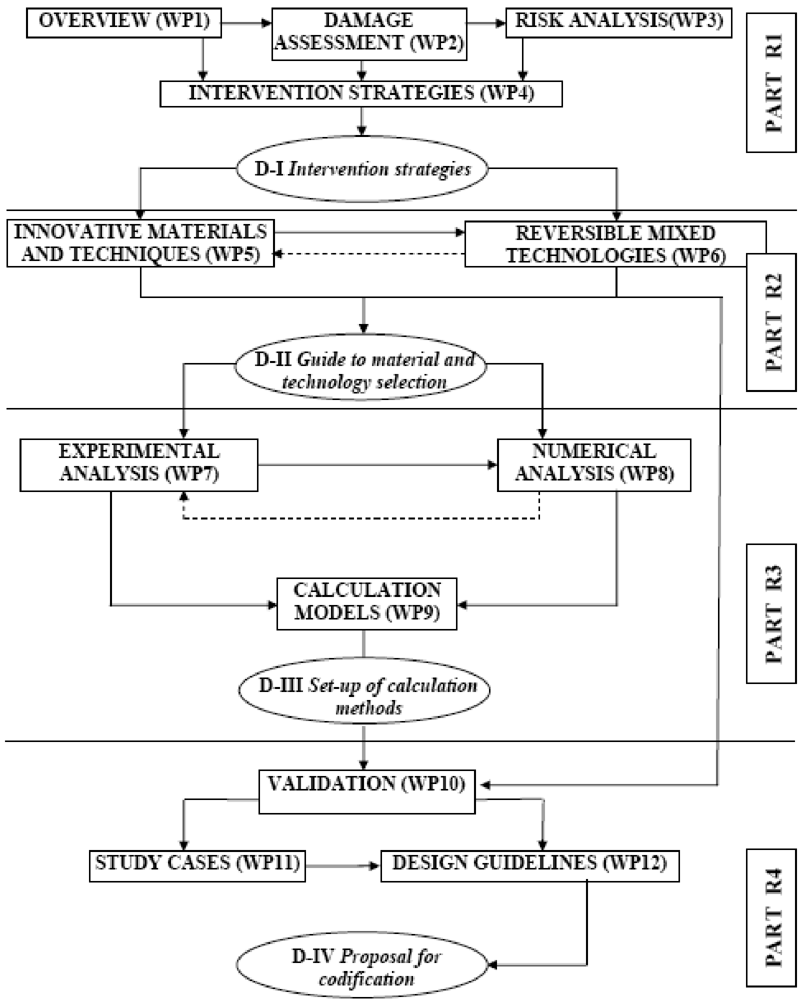


Figure 1: Interconnection among WPs, project deliverables and main deliverables

The workpackages (WPi) are listed below, grouped into the four Parts, together with the project deliverables (Di) and the main deliverables (D-I, D-II, D-III, and D-IV).

5.2 Part R1 – Intervention strategies

Part R1 is composed of four workpackages, each of them corresponding to a project deliverable. In the following the workpackages and the corresponding deliverables are listed.

WP 1 – Overview of existing techniques
D1 "Overview of traditional technological systems adopted for seismic rehabilitation of historical buildings in European and Mediterranean Countries".

WP 2 – Damage assessment
D2 "Assessment of earthquake-induced structural damage in historical buildings of the Mediterranean area".

WP 3 – Risk analysis
D3 "Assessment of seismic risk maps and evaluation of seismic vulnerability of historical building heritage in the Mediterranean area".

WP4 – Intervention strategies
D4 "Definition of methodologies for seismic up-grading of constructions based on both strengthening of structural elements and control of the seismic response".

The first main deliverable D-I deals with "Assessment of intervention strategies for the seismic protection of historical building heritage in the Mediterranean basin".

5.3 Part R2 – Selection of materials and technologies

Part R2 comprises two workpackages, the first one corresponding to one project deliverable and the second one corresponding to two project deliverables, as described in the following.

WP 5 – Innovative materials and techniques for seismic protection
D5 "Identification of innovative materials and special devices to be used for reversible mixed technologies in structural rehabilitation".

WP 6 – Set-up of advanced reversible mixed technologies for seismic protection
D6 "Development of reinforcement procedures for structural elements based on the use of reversible mixed technologies";
D7 "Set-up of seismic protection systems based on the dissipation of seismic input energy".

The second main deliverable D-II deals with "Reversible mixed technologies for seismic protection: guide to material and technology selection".

5.4 Part R3 – Experimental and numerical research

Part R3 is composed of three workpackages, the first and the second ones corresponding to a project deliverable each, the third one corresponding to two project deliverables.

WP 7 – Experimental analysis
D8 "Experimental assessment of the behaviour of true-scale structural elements strengthened with innovative reversible mixed technologies".

WP 8 – Numerical analysis
D9 "Calibration of numerical procedures for the analysis of strengthened structural elements on the basis of experimental results".

WP 9 – Development of calculation models
D10 "Set-up of analytical models for special materials and special devices for the seismic structural control".
D11 "Development of simplified models for the global seismic analysis of historical constructions".

The third main deliverable D-III deals with "Reversible mixed technologies for seismic protection: set-up of calculation methods".

5.5 Part R4 - Set-up of codification rules

Part R4 is composed of three workpackages, the first and third ones corresponding to two project deliverables each, and the second one corresponding to a single project deliverable.

WP 10 – Validation of innovative solutions and procedures
D12 "Cost-to-benefit evaluation of innovative reversible mixed technologies when used in seismic up-grading of existing constructions".
D13 "Performance assessment of new technologies compared to traditional systems".

WP 11 – Study cases
D14 "Selection of study cases belonging to the historical building heritage of the Mediterranean area: analysis of feasibility of interventions based on the use of innovative reversible mixed technologies and relevant design of seismic retrofit".

WP 12 – Development of design guidelines
D15 "Preparation of an operational manual for the practical implementation of proposed procedures".
D16 "Proposal of codification rules for the design of seismic protection interventions based on innovative reversible mixed technologies".

The fourth main deliverable D-IV deals with "*Proposal of codification on the use of reversible mixed technologies in the seismic protection of historical buildings*".

6 Main obtained results

6.1 First main deliverable

The first main deliverable is the synthesis of the results carried out during the first year activity within the project part R1. Since this part represents a sort of state-of-the-art in the field of the intervention strategies for the protection of buildings, all partner Countries have provided their own contribution, leading to the definition of a common background, which represents the starting point for the development of the innovative contribution of the project [5].

The contents of the volume, composed of five chapters, essentially derive from the material collected within the first four workpackages. In particular, the contents of Chapters 1 and 3 are mainly based on the output of WP3, the contents of Chapter 2 synthesize the output of WP2, the contents of Chapter 4 derive from WP1 activity and the contents of Chapter 5 are based on WP4.

The authors of D-I Chapter 1 "Seismic hazard in the PROHITECH Countries" are F.M. Mazzolani and G. De Matteis, who are the general coordinator and the technical coordinator of the PROHITECH project, respectively. In this chapter information on seismic hazard in the PROHITECH Euro-Mediterranean Countries are synthesized, including seismicity maps, main historical events, macroseismic intensity maps, seismic zonation maps and information on acceleration response spectra specific to different soil conditions. The study has been organized by subregions and by Countries. Thus, three main subregions have been identified on the basis of the geographical proximity and common geodynamical environment of the considered Countries: a Western PROHITECH region, which includes Algeria, Morocco and Portugal; a Central PROHITECH region, in which Belgium, Greece, Italy, Macedonia, Romania, and Slovenia are grouped, an Eastern PROHITECH region, including Egypt, Israel and Turkey.

G. Altay Askar (WP2 Leader) and Hilmi Luş are the authors of Chapter 2 “Damage assessment”, in which the damage assessment methodologies widespread in the PROHITECH Countries are illustrated. The chapter presents an overview of building typologies and construction practices, with some emphasis on the development of seismic design provisions and it shows both quick and detailed damage assessment methods in use in various Countries. Furthermore, the damage patterns observed in previous earthquakes, the results of post-earthquake damage surveys together with earthquake history and performance of some buildings representative of the cultural heritage of the Mediterranean area are collected.

Chapter 3 “Seismic vulnerability assessment”, written by A. Iben Brahim (WP3 Leader), is devoted to the seismic vulnerability assessment of historical buildings in the PROHITECH Countries. In particular, the current approaches to damage assessment and the definition of the vulnerabilities of structural types are presented, together with the analysis of seismic risk related to the historical building heritage of the Mediterranean area, on the basis of the structural damage data reported in Chapter 2.

In Chapter 4 “Overview of existing techniques” (authors A. Mandara, WP1 Leader, and F.M. Mazzolani) the existing techniques used in the PROHITECH Countries for the protection of buildings against the seismic action, with reference to the different structural types, are described.

The last chapter of the first main deliverable (Chapter 5 “Intervention strategies”, written by D. Lungu, WP4 Leader, and C.Arion) illustrates the intervention strategies for seismic protection of buildings, with special attention towards both the technological and policy aspects of the problem.

6.2 Project deliverables D1-to-D4

Besides the main deliverable D-I, the output of PROHITECH Part R1 is completed by four project deliverables, as previously mentioned [6, 7, 8, 9].

Each project deliverable, whose contents come from the partner contributions, has been edited by the leader of the respective workpackage, and is made of two parts. The first part is the text of the deliverable, written by the WP leader on the basis of the partner contributions. The second part is an appendix, which collects all the contribution documents written by the partners. In this way it is possible to have, for the subject dealt with in each project deliverable, both an homogeneous and comprehensive document and all the single documents prepared by the partners. Each document is characterized by a specific label, reporting information related to the contribution partner, the workpackage, the document and the draft.

6.3 Second main deliverable

The main deliverable D-II is concerned with the elements required for a correct choice of both materials and technologies to be used in seismic rehabilitation (part R2). It merges the outcome of the parallel activity of WP5 (Innovative Materials and Techniques for Seismic Protection, leader L. Calado) and WP6 (Set-up of Advanced Reversible Mixed Technologies for Seismic Protection, leader D. Beg). The outcome of both WP5 and WP6 has a definitive character by itself, as it contains many elements useful to practical applications. The main objective of Part R2, in fact, has been the definition of suitable criteria for the selection of both materials and mixed technologies to be used in applications of seismic upgrading. The information provided by the partners, in form of datasheets, is collected as an Appendix of each project deliverable.

6.4 Project deliverables D5-to-D7

The project deliverables D5, D6 and D7 are related to the WP5 and WP6 activities.

Project deliverable D5 is focused on innovative materials, including new metals and metal-based intervention techniques, in order to select suitable materials for creating both strengthening systems and special devices aimed at the optimization of the structural behaviour.

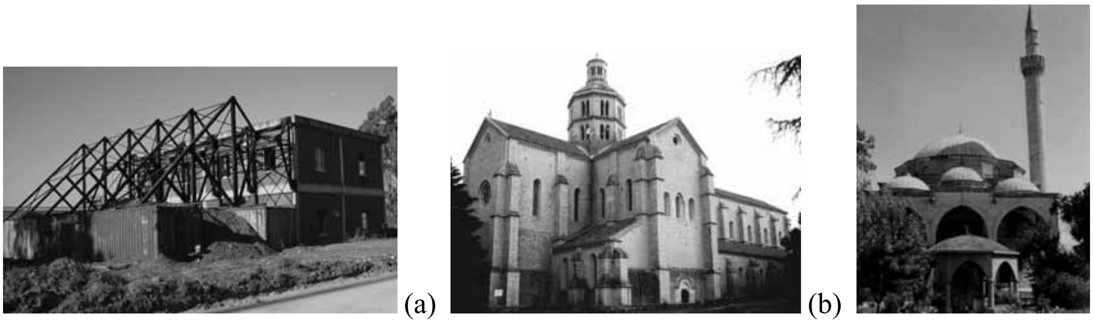
Project deliverables D6 and D7, as specific output of WP6, contemporary represent the complement and completion of the work performed in WP4 and WP5, by providing the information necessary to the proper use of innovative materials and mixed technologies in strengthening interventions, as well as the definition of special systems for seismic protection to be applied to existing buildings.

7 Activity in progress

The activities actually in progress [10] are essentially those related to the project Part R3, which is finalized to the set-up of adequate calculation methods for reversible mixed technologies used in seismic protection. It deals with the experimental and numerical analyses, which represent two fields strongly interconnected each other and undoubtedly fundamental for the project, since they are expected to yield the necessary tools for performing practical design calculations. Besides, the Part R4 activity (validation, study cases and design guidelines) is also in progress.

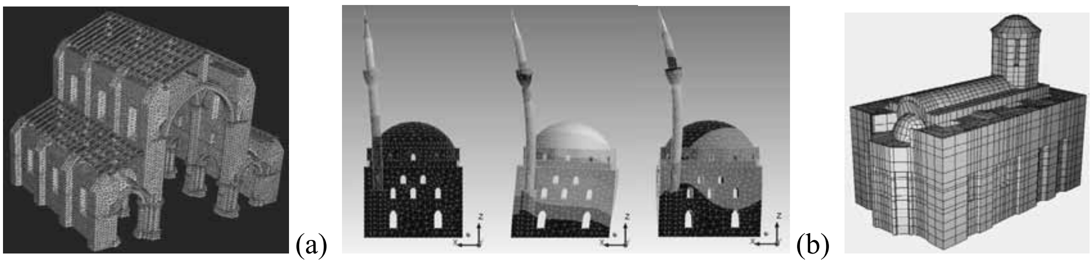
Workpackage 7 (Experimental analysis, leader: K. Gramatikov; co-leader: L. Taskov) is entirely devoted to the laboratory activity of PROHITECH, useful for giving an experimental contribution to the assessment and set-up of new mixed techniques for repairing and strengthening of historical buildings and monuments belonging to the Cultural Heritage of the Mediterranean basin. The experimental activity in progress is developed at five different levels: full scale building, large scale models, sub-systems, full devices, reduced scale devices. The full scale cyclic tests have been performed on one r.c. building in the Bagnoli area in Naples (Italy, Fig. 2a). In particular, this test represents an unique occasion of knowledge, since the studied building is not an “ad hoc” built model, but it is a “real” construction, representative of a large part of the present building stock in many Countries during 20th Century. Both full scale and large scale models are first damaged by applying a seismic in-put and, then, repaired by means of the reversible mixed technologies identified in D-II. After repairing, they will be tested again until rupture in order to check the availability of the consolidation system. The large scale tests on shaking table will be performed on four models: a Gothic Abbey (Fossanova, Italy – Fig. 2b), the Byzantine St. Nikola Church (Psacha, Kriva Palanka, Macedonia), the Mustafa Pasha Mosque (Skopje, Macedonia – Fig. 2c) and an Ancient Greek Temple. The first three models will be tested at the IZIIS Laboratory of Skopje (Macedonia), while tests on a three columns model of a Greek temple will be carried out in Athens (Greece). Tests on sub-systems will be performed both on full scale and reduced scale specimens. Full scale tests will involve innovative steel-wood-concrete composite structures and timber frames retrofitted by shear panels and/or dissipative beam-to-column connections. The mentioned experimental campaigns will take place in Lisbon (Portugal), in Naples (Italy) and in Istanbul (Turkey). Reduced scale tests on masonry walls retrofitted by steel / aluminium plates or by a steel wire mesh will be carried out in Timisoara (Romania), while the effect of openings in masonry panels will be experimentally analysed in Bucharest (Romania). Buckling and bending behaviour of iron / steel elements reinforced by FRP will be analysed by testing in Liège (Belgium). Finally, tests on DC 90 dampers and on titanium clamps will be performed in Ljubljana (Slovenia), while tests on magneto-rheological devices will be performed in Aversa (Italy).

Workpackage 8 (Numerical analysis, leader: R. Landolfo) is aimed at the set-up of numerical models for describing the behaviour of both structural materials and special devices on the basis of experimental tests. Numerical procedures are then applied to the seismic analysis of upgraded constructions in order to investigate the influence of main variables by means of parametric dynamic analysis. The first part of work within WP8 has dealt with a series of preliminary numerical studies concerning a benchmark activity, by which the partners have created a sort of collective background in the field of numerical analyses. The second part of WP8 activity has concerned the pre-analyses of some of the experimental tests planned within the project. Figure 3 shows the FEM models of the Gothic Abbey in Fossanova (a), of the Mustafa Pasha Mosque (b) and of St. Nikola Church (c), in Psacha (Kriva Palanka, Macedonia).



(a) (b) (c)

Figure 2: a) Full scale test; b) Fossanova Gothic Abbey; c) Mustafa Pasha Mosque



(a) (b) (c)

Figure 3: FEM models of: a) Fossanova Gothic Abbey; b) Mustafa Pasha Mosque; c) St. Nikola Church

On the bases of the experimental and numerical analyses, the calculation methods for reversible mixed technologies used in seismic protection will be set-up.

The results of Part R3 will compose the third main deliverable, which will be organized in three main parts: 1) Experimental activity (referring to the different types of experiments); 2) Numerical activity (dealing with the simulation of experimental tests by numerical models and comparisons of results); 3) Calculation models (referred to the identification of simplified models to be used as design tools in structural restoration).

The specific output of WP7 and WP8 will be collected in D8 and D9 project deliverables, respectively. The output of WP9 will lead to two project deliverables: D10, dealing with analytical models for special materials and special devices for the seismic structural control, and D11, dealing with simplified models for the global seismic analysis of historical constructions.

8 Future activity

The future activity, to be developed during the third year of the PROHITECH project, deals with the contents of Part R4 of the program. The results of the work performed during the first two years will be finalized to codification proposals. Contemporary, the selected innovative materials and techniques, the developed reversible mixed technologies, together with the calculation methods, will be subjected to extensive validation studies. The data obtained by WP5 and WP6 will be analysed and compared with traditional materials and technologies. Firstly, a cost-to-benefit evaluation will be performed to out-line the scope and the effectiveness of new materials and/or technologies. As a second step, the performance of the proposed solutions will be assessed in terms of strength, including low-cycle fatigue resistance, ductility and dissipation capacity compared with conventional solutions. The results from the experimental (WP7) and numerical (WP8) analysis will be extensively used. Special conclusions will be drawn on the applicability of different innovative solutions depending on the specific conditions and design requirements.

Special attention will be paid to the validation of the proposed calculation models (WP9) on the basis of experimental and numerical results, so as to prove their reliability in the perspective of their inclusion in the Design Guidelines (WP12). For the specific case of monumental constructions, a feasibility study will be performed to assess the applicability of various innovative solutions to different types of buildings. Together with the considerations based on the structural performance, additional architectural and historical–cultural aspects will be accounted for in the context of the possible interventions.

Within the WP10, the validation studies in terms of cost-to-benefit analyses will be synthesized in the project deliverable D12, while the project deliverable D13 will deal with the performance assessment of the new technologies, which will be compared to the traditional ones.

The knowledge developed within the project will be conveniently applied to some selected study cases (WP11), consisting in historical buildings belonging to the heritage of Mediterranean Countries, in order to perform analyses of feasibility of seismic protection interventions by means of reversible mixed technologies. The design of relevant application solutions based on reversible mixed technologies is also foreseen together with the critical evaluation of collected examples of real restoration cases, belonging to the current experience in each partner Country. This activity will be developed in WP11, leading to the preparation of the corresponding project deliverable (D14). The interconnection between the study cases and the development of design guidelines (WP12) is apparent, since the first step can be considered as a benchmark for the set-up of the codification rules. As a result of the WP12 activity, two project deliverables will be realized: a manual for the actual implementation of the procedures proposed and developed within the PROHITECH project (D15); a proposal of codification rules for the design of seismic protection interventions by using reversible mixed technologies (D16). The final document of the whole project will be the fourth main deliverable, downstream of the third year activity, containing a set of recommendations elaborated on the basis of all collected data and results. The proposal will comply with the most up-to-dated codification issues in the field of seismic design, say the Performance Based Design, and will share the same global layout, language and philosophy as Structural Eurocodes issued by CEN.

9 Expected results

The PROHITECH project is an important opportunity to develop knowledge and technology in the field of the seismic protection of the Euro-Mediterranean cultural heritage. The innovative character of the technical solutions proposed for seismic retrofitting is mainly based on the concept of reversible mixed technologies. The main expected results of the research activity are the following.

An up-to-dated state-of-the-art concerning advanced systems of seismic protection of existing constructions will be set-up, in harmony with the specific demand of all European and Mediterranean Countries for a more comprehensive framing of anti-seismic rehabilitation.

Both conscience and knowledge about “new” materials and technologies as a suitable alternative to “traditional” solutions will increase, since the last ones are proved to be often inadequate to provide a satisfying seismic performance, in particular when applied to historical and monumental constructions.

The adoption of materials and systems which are reversible, recyclable, environmentally friendly and economically sustainable will be supported. The present degree of knowledge on the application of these materials and systems is not particularly advanced, neither codified in any form, hence it is expected that the research activity carried out within PROHITECH will yield significant innovation in seismic protection practice.

New and up-to-dated information on the problem of seismic protection will be disseminated, thanks to the participation of acknowledged institutions, belonging to both Europe and Mediterranean basin, all of them widely experienced in the field of seismic design and with an ongoing significant research activity in such area.

Design and constructional rules for interventions based on advanced and innovative technologies could be set-up. This is expected to recall to a greater extent the interest of both construction industry and practicing engineers, so as to have a remarkable impact on the current anti-seismic rehabilitation practice.

Information on the ongoing activity is available in the web site www.prohitech.unina.it.

10 European project details

The acronym of the European project dealt with in this paper is PROHITECH, Contract No. PL 509119, the full title being: *Earthquake Protection of Historical Buildings by Reversible Mixed Technologies*. The project is co-ordinated by Prof. F.M. Mazzolani, Department of Structural Analysis and Design, University of Naples “Federico II”, Naples, Italy

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Natural multi-hazard and building vulnerability assessment in the historical centers: the examples of San Giuliano di Puglia (Italy) and Valparaiso (Chile)

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Key words: multi-hazard assessment, building vulnerability inventory, GIS, remote sensing RS

1 Introduction

Everywhere in the world, most of the highly populated cities (but also a large amount of little towns and villages) are prone to natural hazards, which can be defined as processes, occurring in the biosphere, which may constitute a damaging event. The main hazardous catastrophes (varying in magnitude, frequency, duration, extent area, onset speed, spatial dispersion and temporal spacing) are: earthquakes, volcano eruptions, landslides, tsunamis, coastal erosions, floods, hurricanes, drought, etc. With regard to urban areas, both wild and man-induced fires can be also considered. Consequently, risk DR (probability of harmful consequences, expected loss of lives, people injured, property, livelihoods, economic activity disrupted, environment damaged, etc., see Fig. 1) results from the combination between hazard H, vulnerability V (human condition or process resulting from physical, social, economic and environmental factors, which determine the probability and scale of damage from the impact of a given hazard) and physical exposure E (elements at risk, an inventory of those people or artifacts exposed to hazard), divided by RM factor (Risk Management). It is worth noting that, in absolute terms, the economic cost of disasters has been increasing over decades (Fig. 2, [1, 2]).

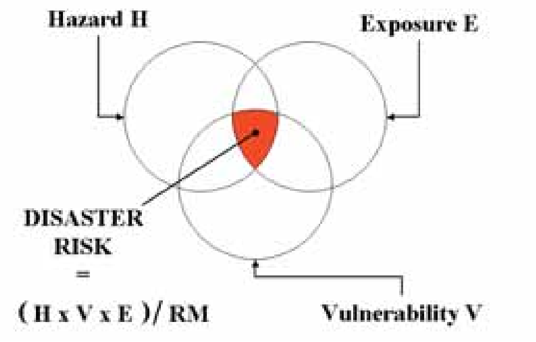


Figure 1: Risk definition

In addition, the city aggregates enshrine notable cores (like urban and social tissues, historical and architectonical constructions, precious monuments, museums and archaeological evidences) of invaluable value; in fact, such kind of patrimony, which must be handed down intact to posterity as far as possible, is often protected by international and inland cultural heritage boards. Nevertheless, a huge amount of such treasures is lost for ever, due to past natural catastrophes; just some highlighting examples can be reminded (Fig. 3): the 79 A.D. Vesuvius eruption, Italy (when Pompeii, Ercolano and Stabiae were completely covered by pyroclastic flows); the disruption of San Francisco (California, USA) and Valparaiso (Chile) during the 1906 earthquakes; the 1963 Vajont landslide, Italy (which swept away some small towns); the Firenze's flood (1966); the Lisbon great fire (1988); the Indian Ocean tsunami (2004).

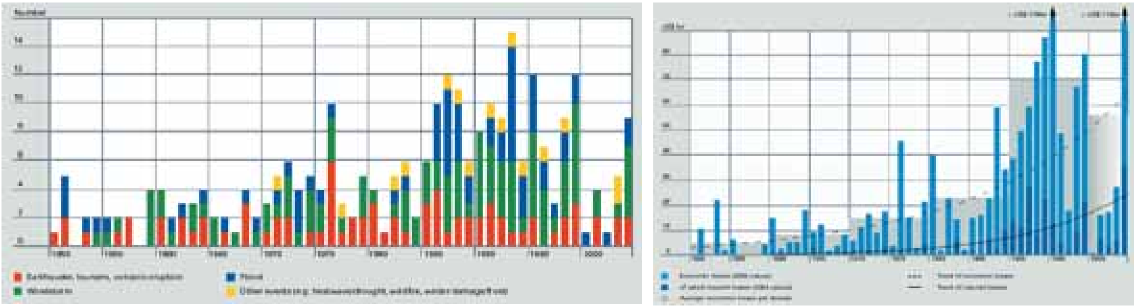


Figure 2: World natural catastrophes – left – and economic losses – right – from 1950 to 2005 (source Munich Re)

(a)

(b)

(c)

(d)

Figure 3: Valparaiso destroyed by the 1906 earthquake (a); the town of Longarone after the 1963 Vajont landslide (b); the 1966 Florence's flood (c); the 2004 Indian Ocean tsunami (d)

Thus, the accomplishment of an effective pre- and post-disaster risk management is a crucial tool, in order to minimize disaster impacts and implement potent policies and coping capacities of the society or individuals, managing the multifaceted nature of risk, realizing integrated hazard models and adopting appropriate governance for development and reconstruction planning. To these purposes, different strategy levels have to be foreseen. Obviously, during the emergency phase, it is necessary to understand, well and quickly, the dynamic development of each environmental process, provide a detailed damage assessment and address prompt civil defense interventions. Furthermore, prevention policies are also mandatory: hazard mapping, vulnerability studies, building inventory, mitigation programmes and citizenship preparedness.

In the framework of the recommendations written after a specific session regarding cultural heritage (organized, among others, by UNESCO and ICCROM) inside the World Conference on Disaster Reduction (Kobe, Japan, 2005), and enhancing what was already said by the International Committee of the Blue Shield (ICBS, Radenci Declaration on the protection of cultural heritage in emergencies and exceptional situations, 1998) it has been underlined the need to better integrate concerns for cultural and natural heritage (together with a close involvement of local communities) into the whole disaster management process, because this kind of patrimony is particularly at risk in the period following a natural catastrophe, but often emergency response activities, planning and rehabilitation are not much sensitive to this matter.
In the last decade, Geomatics (a recently emerging technology, which can play a vital role in mitigation of natural disasters) has been developing. Geomatics is a conglomerate of measuring, mapping, geodesy, satellite positioning (GPS), photogrammetry, computer systems and computer graphics, remote sensing (RS), geographic information systems (GIS) and environmental visualization. The earth observation satellites provide comprehensive, synoptic and multi-temporal coverage of large areas for a wide range of scales, from entire continents to details of a few meters in real time and at frequent intervals. Those tools have been becoming valuable for continuous monitoring of earth and its atmosphere. This approach, which started primarily with earthquake applications, broadened rapidly to tsunami, hurricanes, storms, wildfires, landslides and other matters. Thus, a multidisciplinary approach to disaster management (consisting into two main phases, prevention and preparedness) is possible:

a) disaster prevention: GIS and RS are used to manage the wide volume of data needed for the hazard and risk assessment, as, for example, early warning systems, emergency planning, hazard mapping, vulnerability evaluation, building inventory and, last but not least, estimation of socio-economic impacts on human communities.

b) post-disaster preparedness (catastrophe survey, civil defense emergency activities, fast loss estimation, rehabilitation and reconstruction): GIS and RS provide quantitative damage assessment accurately and speedily, with cost effective, unbiased, and free from subjectivity techniques. All the information can be integrated into digitized databases and transferred via satellite networks or Internet to the rescue teams deployed on the affected zone.

Focusing on cultural heritage safeguard, the situation outline is very inhomogeneous, where traditional methods (rather time consuming, labouring, expensive, and often inaccurate) coexist with advanced skills, used in particular for city planning, description of land use and historical urban development, but especially in archaeology. Regarding the latter field, GIS and RS have risen prominence as analytical tools, thanks to the widespread availability of GPS, high resolution satellite images, software improvement and sophisticated analytical models. Finally, because systematic and multifaceted in-depth studies are necessary to investigate major historical centers as a whole, due to their complexity and extension, gathering all the abounding information in tidy, user-friendly and standardized databases is indispensable.

To this purpose, a pilot project has been building up, focusing disaster mitigation and reconstruction of San Giuliano di Puglia (Campobasso, Italy), hardly hit by the 31st October 2002 earthquake. This experience, targeted on a small but significant town (in any case enough representative to check approaches and procedures), will be managed by ENEA (supported by qualified contributions of the Universities of Ferrara and Trieste), with the agreement of the local municipality, the Office of the Public Works Ministry for the Reconstruction and the Italian Civil Defense. In a second time, a more elaborate effort will be faced, regarding the evaluation of multiple risk and structural safety in the historical part of Valparaiso (Chile), in the framework of an International co-operation project, which is at an advanced stage of definition. At the present time, awaiting the official start up of both the above mentioned projects (foreseen in the next months), a preparatory work is underway, which is identifying the basic work steps.

2 Basic work steps

Trying to define the basic steps of the future work (Chapter 3), recent illustrative experiences are reported, including some carried out by the partners. With regard to mapping, and focusing mainly on seismic hazard (which is certainly a topic question), since several years ICTP and Trieste University are developing more accurate tools for the protection of cultural heritage from earthquakes. In fact, the application of probabilistic approaches is not very appropriate nor useful. Due to the many shortcomings of this methodology [3] that can be used with some degree of usefulness by insurance companies (since they tend to smooth the risk over large areas), the approach of scenario earthquake should be preferred [4], when dealing with objects that should be 100% safe. At national scale level, several studies have been performed in several countries (e.g. Italy, India, China, Cuba) and we plan to extend the method to Chile (see point 3.2), where we will also consider the definition of seismic input specific of the special objects to be protected against earthquakes. For such a purpose, we will follow the methodology developed and applied within the framework of the UNESCO-IUGS-IGCP project 414 "Realistic Modeling of Seismic Input for Megacities and Large Urban Areas" [5] for the seismic microzonation of several towns (e.g. Delhi, Beijing, Rome, Naples, Santiago de Cuba, Bucharest, Sofia). This advanced method will be used as complementary tool to the investigations so far performed in San Giuliano di Puglia (see 3.1), using routine procedures (i.e. probabilistic methods). In addition, the analytical models for multi-hazard assessment will be extended to handle not only peak values of seismic ground motion, but primarily the seismic input scenarios defined by synthetic time series, calibrated, whenever possible, against observations. A similar approach is advisable to evaluate the occurrence of tsunamis, together with the development of reliable analytical models of sea waves propagation and accurate recording systems [6].

Furthermore, a GIS-based application can join hazard and vulnerability data (splitting the whole information into different risk categories), by tracing a polygonal model of each building (Fig. 4, [7-8]) on detailed DTMs (Digital Terrain Models) and DEMs (Digital Elevation Models), merging together inputs coming from updated cadastral maps, RS satellites images (QuickBird, Fig. 5) and in-field DGPS surveys (diagnostics investigations and damage assessment included). In addition, a supplemental object-oriented reading through RS image processing can be provided through a classification procedure of the built-up texture, achieved by algorithms elaborating, for example, the building geometry, together with style and type of roofs (Fig. 6, [7]). Thus, geo-referred risk maps (in which single building structural features are linked to the surrounding environmental and social context) must identify house by house, giving a sharp classification of the danger level [9-10]. A remarkable study regarding vulnerability evaluation and building inventory is the Sana'a GIS implementation (Fig. 7), provided by the Ferrara University to the Yemeni authorities (2004), in the framework of the Conservation and Rehabilitation Plan for the Old City and other historic neighbouring settlements. A digitized database, after a detailed in-field survey, has been carried out, classifying all the buildings in different categories, depending on their architectonic relevance. Similar works, according to the ICOMOS Washington Charter [11], have been realized by the same university for the Baalbeck archaeological area (a Lebanon site included in the UNESCO List since 1995), the historic core of the Huguang Huiguan complex, Chongqing (China), the City of Madaba (Jordan); in addition, the Ferrara University has been involved as a World Bank consultant for the reconstruction and development plan regarding the city of Bam (Iran), destroyed by a devastating seismic event (26 December 2003). As told before, damage assessment cannot set aside the wide use of RS high resolution imagery (Fig. 8) after recent catastrophes, as earthquakes (1999 Marmara, Turkey; 2001 Bhui, India; Boumerdes, Algeria, 2003; Bam, Iran, 2003, Nigata-ken Chuetsu, Japan, 2004, etc.), tsunamis (2004 Indian Ocean, etc.) and hurricanes (New Orleans, USA, 2005, etc.). A very rapid comparison "before" and "after" the event can be done for large areas, by using specific software data processing techniques, capable to classify all the houses depending on the damage index.

Figure 4: 3D Digital hazard mapping [7]

Figure 5: Building extrapolation by using RS

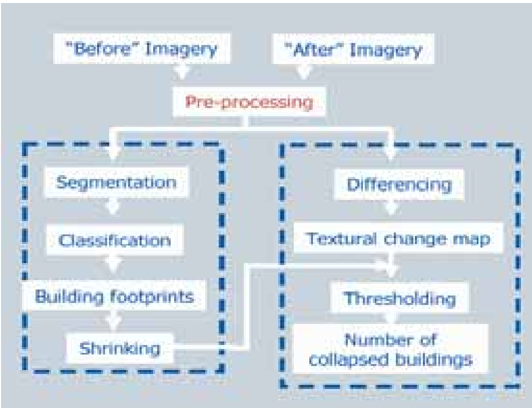


Figure 6: Satellite imagery processing procedure [7]

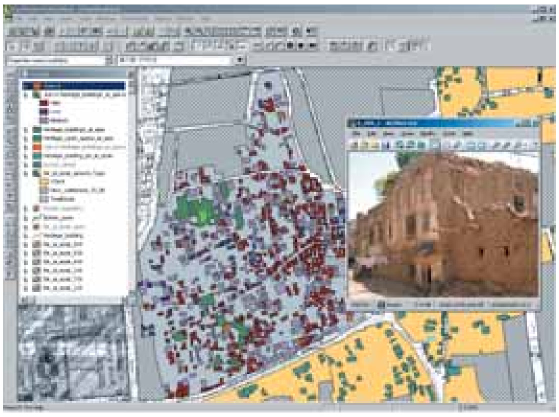


Figure 7: Sana'a GIS database

Figure 8: Satellite images of Bam (Iran) before (left) and after (right) the 2003 earthquake (source QuickBird)

It is worth noting that a powerful future development of RS techniques into GIS archives could drive to a prompt broadly preventive identification of a potential building damage level (with particular emphasis on cultural heritage), i.e. its specific vulnerability under the action of a given event, before that the disaster occurs, in order to identify the most risky building stocks, perform targeted in situ surveys, incentive retrofit policies and enforce citizenship preparedness. The identification of a global risk factor for a given area (or a building), is another crucial step to carry out, because the definition of correct combination methods and mathematical algorithms is still almost unborn. On the other hand, since in-field campaigns are money and time consuming (and funds often limited), it is indispensable to define with high accuracy what land zones and constructions need to be overriding checked with increasing depth. For example, in situ surveys may include, whenever necessary, the determination of shallow geotechnical parameters (e.g. V_{S30}) determined accordingly reliable advanced methodologies [12] so that a physically correct estimation of site effects can be performed, free from the shortcomings deriving from the blind application of convolutive methods [4]. Focusing on cultural heritage, geometric surveys, diagnostics investigations and structural vulnerability evaluations may also be provided by the aid of available in situ and laboratory sophisticated equipments (as, for example, 3D laser scanning, in addition to aerial and close range photogrammetry, but also shaking table and pseudodynamic tests, etc.).

Moreover, training an multimedia activities are also fundamental. Training on the above mentioned multidisciplinary aspects can take place at ICTP in Trieste, in the framework of the activities of the Earth System Physics section. In fact, the ICTP final aim is to transfer the technology developed in the research activities and projects to scientists of the Third World and of Eastern Europe, through joint research and development projects, with special attention to training the potential leaders, and combining the workshops with subsequent individual projects.

3 A brief description of the ongoing projects

3.1 San Giuliano di Puglia (Italy)

A moderate earthquake struck Molise (Italy) on October 31st, 2002, 11:35 local time; the first shock (M 5.9, accordingly to USGS) was followed by another (M 5.3) the day after. Spread damage was evident in San Giuliano di Puglia, a small town located 5 km far from the epicentre (Fig. 9). The maximum seismic Intensity at the site was estimate to be VIII-IX MCS, observed both during the 1456 and 2002 events. The images of the primary school collapse, where twenty-seven children and one teacher died, went around the world. The acceleration peak ground values (PGA) reported seem to underestimate the values (0.15-0.30 g) expected from a deterministic analysis, that takes into account the seismic history and seismotectonics. This problem will be further investigated especially at the University of Trieste (Fig. 10). Moreover, most buildings, nearby the school and besides the main street, were ruined, causing two further victims. Damage was not uniformly distributed inside the San Giuliano narrow area, characterized by different levels of seismic hazard and structural vulnerability. ENEA experts took part in all the activities following the seismic event: i) the emergency, under the coordination of the Civil Defense; ii) the post emergency phase, carrying out a detailed evaluation of damage, drafting the demolition plan, ensuring safe conditions to the buildings to be repaired, and operating for allowing residents to safely reenter their non-damaged houses; iii) the San Giuliano reconstruction planning, in the framework of a specific working team; iv) the technical-scientific advice to the Office of the Public Works Ministry for some important reconstruction and rehabilitation projects, including cultural heritage [13]. Before the earthquake, San Giuliano was not classified as a seismic zone. After the earthquake, it has been included in zone 2 (maximum Peak Ground Acceleration PGA equal to 0.25 g) in the seismic reclassification of Italy and the Civil Defense appointed a technical commission to provide the San Giuliano seismic microzoning. The study reflects zones with different geology, topography and seismic local amplification [13]. A specific decree of Molise Region fixed the PGA value to be used for the San Giuliano territory equal to 0.21 g. The 1456 earthquake (maximum values M 6.6, MCS XI) hit a large area of South-Central Italy for the first time on the December 5th's night. This event probably consisted in a long series of shocks, due to the simultaneous activation of several seismic sources, overlapping at least three areas encircling different epicenters. The medieval center (Fig. 11), interesting from an historical and architectural point of view, was deeply investigated. In spite of the low local amplification, it presented a medium-severe damage; only a few houses were ready for reuse. Also the more notable masonry cultural heritage (the historical castle and tower, Fig. 11) suffered heavy damage [14]. All the area was in general characterized by high vulnerability and the most usual collapse mechanisms were the wall failure with typical cross cracks, but also out-of-plane overturning [13].

Figure 9: San Giuliano aerial photo immediately after the 2002 earthquake

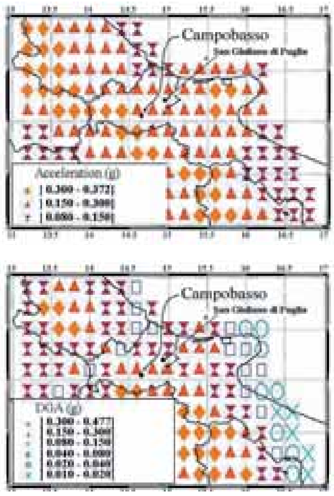


Figure 10: Probabilistic (up) and deterministic (down) PGA

Figure 11: The San Giuliano historical center (up) and earthquake damage to its castle (down)

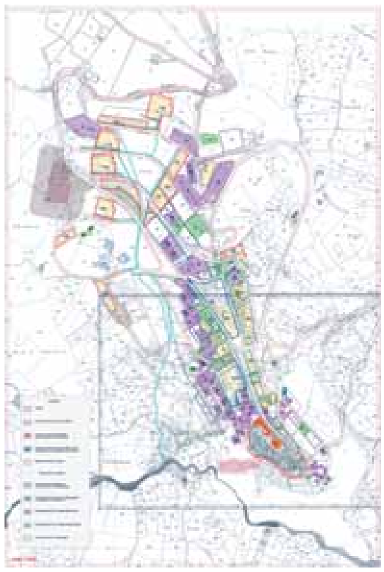


Figure 12: The reconstruction plan and yard works

In the framework of the scientific advice provided to the Office of the Public Works Ministry, some ENEA experts collaborated to the Reconstruction Plan of San Giuliano di Puglia (Fig. 12) and reviewed in detail some rehabilitation projects (in particular regarding the old castle [14] and the historical center) entrusted, as other works, to private consultants. Furthermore, ENEA presented to the San Giuliano Municipality and the Office of the Public Works Ministry, with the agreement of the Italian Civil Defense, a pilot proposal regarding the realization of a GIS digitized database. It shall consist in a user-friendly tool which organizes all the available information (cartography, imagery, hazard maps, cadastral data, damage and vulnerability assessment, reconstruction plan and projects, etc.) in a detailed and interactive building inventory, with the aim to focus the global disaster risk and manage the future town planning. The most interesting work tasks regard the reconstruction of the demolished buildings (about 130) and the rehabilitation of the whole historical center, which has been recently put under protection by the Molise Region cultural heritage board. High attention will be devoted to the design choice of traditional and innovative antiseismic techniques, in order to minimize the risk and partially reward these unlucky people by realizing a new safe town. Finally, specific training programmes (to prepare the local technicians in handling and updating regularly the final system) and multimedia activities (to involve the inhabitants, especially the children, in risk mitigation procedures) are also foreseen.

3.2 Valparaiso (Chile)

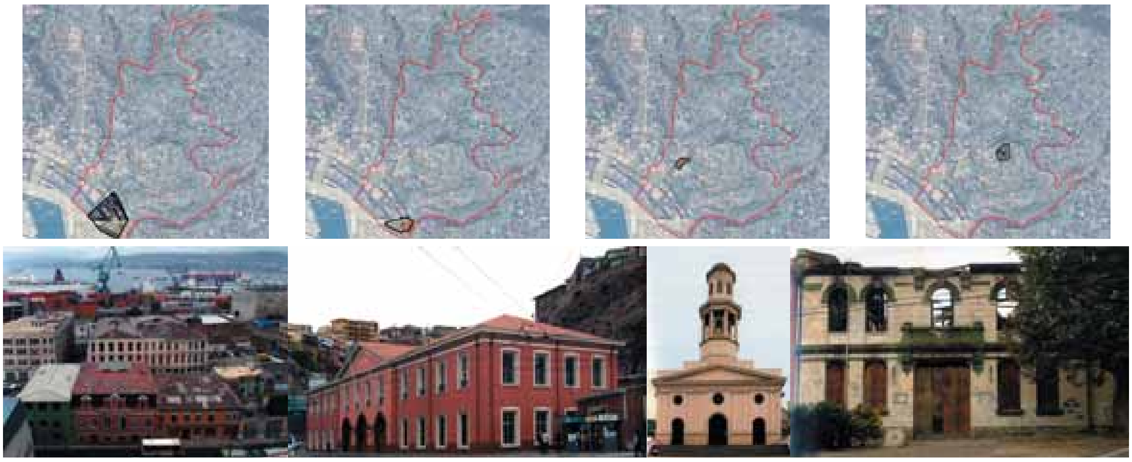
The Chilean city of Valparaiso is included in the UNESCO Word Heritage List of protected sites (since 2003). In fact, it represents a distinctive case of growth, inside a remarkable landscape, of an important Pacific Ocean seaport (over the 19^{th} and 20^{th} centuries, Fig. 13), till to reach a strategic importance in shipping trade, which declined after the Panama Canal opening (1914). Thus, Valparaiso tells the never-ending story of a tight interaction between society and environment (Fig. 14), stratifying different urban and architectonic layers, sometimes struck by seismic events and always in danger. The most disruptive earthquake happened in 1906 (Magnitude Richter 8.3), destroying and burning down a large part of the city, amplifying locally the seismic energy and focusing damage in the coastal zone, in which reclaimed soft lands are still present. Certainly, the city is subjected to various natural hazards (the above mentioned seismic events, but also tsunamis, landslides, etc.) and anthropic calamities (mainly fire, due to the large amount of wooden houses). These features make Valparaiso City a paradigmatic study case about multi-hazard mitigation, and risk factors must be very well evaluated during the restoration phases to be foreseen in the future. The Valparaiso morphology can be roughly divided into two main sectors: the flat harbour area and the hill quarters. Neoclassic great masonry buildings, some previous colonial style constructions (still standing structures spared by earthquakes and following fires) and more recent architectures take place in the commercial quarter, with large straight streets, highways and rail tracks parallel to the coast. Wide areas are occupied by the port facilities until the waterfront. Otherwise, the steep forty nine hills, cut by ravines (*quebradas*) and climbed by narrow and snaky lanes, are deeply filled by small and squat houses, typically made by wooden frames, *adobe* panels and covered by zinc tinplate (*calamina*). Several old cable cars (*ascensores*) ascend the slope. The UNESCO protected quarter is *Barrio Puerto* (Fig. 15); it lies in the Southern part of Valparaiso and embraces a sector which, starting from the flat, reaches the facing hills. In addition to the above said pervading clustered homes, notable historical buildings are present (Fig. 16, [15]).

Since 2004, ENEA convinced the Local Municipality authorities about the necessity to improve multiple risk evaluation and structural safety of Valparaiso City, with a special attention to its notable historical part. The suggested project (which is awaiting, hopefully soon, the official start up) is characterized by the collaboration of local universities and the Chilean Navy Oceanographic and Hydrographic Service. Also through RS and GIS tools, these main objectives will be obtained: to collect, analyze and elaborate all the available existing information ("state-of-the-art"), with a satisfying evaluation of the main risk factors; to perform topographic (DGPS) and 3D Laser-Scanner surveys; to provide studies on seismic, tsunami and coastal erosion hazards; to realize vulnerability analyses of the main structural typologies in Valparaiso (with particular regard to Barrio Puerto); to carry out an urban classification from high definition satellite images; to make available the results inside a GIS system, approaching a multiple natural risk assessment; to suggest guidelines for future interventions; to produce multimedia activities and accomplish training and bursary programs.

Figure 13: An historic view of Valparaiso at the end of the 19th century

Figure 14: Valparaiso satellite image

Figure 15: Valparaiso aerial photography and localization of Barrio Puerto [15]



Port area Aduana building La Matriz Santo Domingo House

Figure 16: Some Valparaiso notable buildings and their location [15]

The final goal is to realize a multi layer risk map easy to read and also attractive, making it useful and accessible for everyone and catching people's attention with multimedia outputs, internet interactive databases, virtual reality simulations. Another important way to make the map interesting is to adapt it to local scale: the citizen is not interested to territorial maps in a large scale, the information has to regard his quarter, houses block, possibly his own home. Connect territorial risks to single user's interests could be the way to approach many people. Another basic feature of the final output is a clear and well-organized building inventory, which has to: recognize the most common building typologies and simplify the features to recognize them (roofs, dimensions); extract morphologies connected to each typology; analyze materials, structures and conservation, in order to value the reaction of a single building (or typology) to damages. The work shall be carried out by operators (locals and Italians together) using standardized cataloguing sheets.

4 Conclusions

Geomatics (a recently emerging technology) is a conglomerate of measuring, mapping, geodesy, satellite positioning (GPS), photogrammetry, computer systems and graphics, remote sensing (RS), geographic information systems (GIS) and environmental visualization. It can play a vital role in natural disasters mitigation, including cultural heritage safeguard and historical centers risk reduction, coupled with advanced methodologies in engineering, seismology, diagnostics etc. Two projects (in advanced stage of definition) managed by Italian researchers could represent pilot experiences to enhance prevention and emergency policies, reconstruction and city planning.

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Retention and conservation or demolition and modernisation – that is the question? A case study from Darwen, a town to the north of Manchester UK

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1 Introduction

When we talk of cultural heritage we usually envisage large inanimate objects such as castles, bridges, cathedrals, estates, chateaux and the like; we tend not to think of smaller buildings or groups of buildings and rarely of communities. Progress is Important – but in a social context material progress for the sake of progress can be very damaging to an established community; to neglect the small often endangers the large.

Figure 1: Typical stone built worker terraced houses built 120 years ago in Darwen and due for demolition as part of a proposed 'clearance area'

Europe is a mature community of some 25 countries that have had to co-exist for most of the last 1000 years – mostly in harmony, but sometimes in conflict. We know each other well and the problems that affect the one often have similarities in other states.

This short paper refers to my personal experience concerning a small group of stone clad two-storey, terraced residential properties built over a hundred years ago in the North of England. The town concerned is Darwen, situated about 40 kilometers north of Manchester.

2 Historical background

To set the scene, from the middle of the 19^{th} century to the middle of the 20^{th} century Britain had the largest empire the world has ever known, An empire that spread all around the globe from Canada and the West Indies through Africa to India and the far east through the East Indies to Australia and New Zealand and across the Pacific Ocean. At the heart of this great empire was London – and after London – Manchester – a city that was at that time the greatest industrial city in the world.

For example, Manchester produced over 90% of the worlds finished cotton goods, along with a substantial proportion of the world's industrial machinery and other finished products for railways, ship building, the automotive industry, the emerging chemical industry, etc.

To support this vast industrial complex, numerous factories, engineering works and mills were constructed across the North of England and particularly in Manchester, these enterprises were helped by the readily available raw materials from local coal fields as well as large salt deposits and sufficient iron ore for the then demand; this was all allied to a progressive engineering and scientific community focusing on technical education in industrial processes and production methods – all driven by an obsession with 'doing business'.

Typically, in 1910, Manchester itself had 2,000 large cotton mills; all powered by massive coal fired steam engines. To man these industrial processes it required a large army of skilled and semi-skilled workers. They came in their thousands from the rural areas and other cities in the U.K and from abroad to work Manchester and its neighbouring industrial cities of Liverpool, Leeds, Bradford, Halifax, Sheffield and others.

To accommodate these workers, and bearing in mind that everyone walked to work in those days, small terraced properties were constructed in the immediate vicinity of each factory or mill.

This paper is about the recent history of one of those groups of small workers homes situated in a medium sized town in the north of England called Darwen.

2.1 But to set the scene

Two World Wars, the formation of the independent countries of the British Commonwealth and the spread of industrialization, more recently through the developing world, have seen the old heavy industries of Northern England and Manchester decline and, in substantial part, disappear.

There is now no coal worth economic exploitation; Britain no longer has an Empire to supply it with cheap raw materials and to absorb its production of finished goods, heavy industry is more broadly spread through the U.K. and even abroad to emerging countries where labour costs are now cheaper.

This has resulted in the clearance of many of the old factories and mills in the Manchester area – many of exceptional architectural quality and archaeological importance are now gone; but what has remained in significant part and in continued use is the small terraced housing. Much of this housing originally served, and continues to serve to this day, the less well off members of the community in the old industrial towns of northern England.

It would be fair to say that much of this old housing stock has been seen as out dated; it has not been maintained and so a significant proportion of it has had to be demolished.

On the other hand, despite valiant efforts from the U.K. local, regional and national authorities over the past 80-years to provide publicly owned properties for rent at reasonable levels, the supply has never been sufficient to meet the demand.

Nor has private housing for rental been a success; following tough anti exploitation laws introduced in Britain in the 1970’s and 80’s to stamp out rogue and unscrupulous landlords caused this supply of accommodation to virtually disappear.

Consequently, many of the old terraced properties that remain still meet a significant demand for the cheaper priced accommodation.

Within the U.K. domestic property ownership falls primarily into four categories:

1) Owner occupied – privately owned houses and flats;

2) Private landlord owned houses and flats let to rent;

3) Local authority owned houses and flats – generally let to the poorer groups in society, but in some cities also to key-workers who are priced out of the normal housing market (e.g. nurses, policemen, local authority employed artisans, etc).

4) Housing Associations – these are government supported private landlord agencies, but run on a non-profit basis and having charitable status.

These ‘workers’ terraced properties fall into all these categories and so still have an important part to play in the U.K. housing spectrum. But they have their advantages and disadvantages.

On the plus side, they are frequently close to the centre of towns, so access to shops and other facilities is convenient for the residents. The properties tend to be cheap to buy and so are attractive to young couples and those not so well off, particularly the elderly, many of whom have lived in them for decades.

Because of their long history, these areas frequently have well-established community structures with a full age profile of residents from the youngest to the most elderly, all of whom know each other. One might almost say that they are ghettos without the unpleasant connotations of that word. As with similar groups in any city or country, there is close and established interaction between the members of the community.

On the downside, streets in these areas tend to be narrow and there is limited room for parking the cars that were not envisaged when these terraces were built; play facilities for children are limited as are ‘green spaces’. However, in many instances, selective clearances of small groups of houses to open up ‘green areas’ provide play areas for children and also parking provision have been achieved.

Because they are old, the properties frequently require maintenance and some of this maintenance can be of a major nature (e.g. re-roofing or insertion of damp-proof courses).

Facilities provided by the Local Authority (street lighting, road repairs, etc.) are often minimal, because the properties are not seen as having significant long term potential.

Proximity to town centres means that casual car parking by non-residents is often a problem. So close proximity to the town centre – identified as a benefit for some – can be seen as a disadvantage by others, who may prefer to live away from the hustle and bustle of the town centre.

3 Future U.K. housing demand

It is estimated that, over the next ten years, at least an additional two million new homes will be required in the U.K. This demand is fuelled by people living longer, more single-person households (from choice or from divorce) and a naturally increasing population.

In addition, of the 20M remaining domestic properties, it is estimated that some 3 million properties require significant upgrading and renovation.

As in any expanding city, older residential areas close to town centres are attractive to commercial developers wishing to replace homes with new large offices, retail outlets and leisure facilities. The difficulty for these large commercial projects is in assembling the site, because of the multiplicity of individual ownerships.

To facilitate this site assembly, commercial interests often approach the Local Authority. In the U.K. the Local Authority must have an approved 'development plan' which show the allocated usage for each zone of the area under their jurisdiction: they also have a variety of statutory powers to enable the effective compulsory purchase of properties located on sites required for approved development, provided that it can be shown that the exercise of such powers is in the public interest and in accordance with the 'development plan'.

However, the compulsory purchase of residential property in the U.K. is governed by a number of criteria and most are difficult to comply with. At the present time in the U.K. one of the easiest ways of achieving compulsory purchase of a property, or group of properties, is to show that they are 'unfit for human habitation' and to prove this by surveying and categorizing the properties as such.

Obviously, older domestic properties tend to have deficiencies in their internal planning and often some need for fabric renovation (roofs, floors and walls). However, various U.K. governments have, over the last 50-years, instigated a variety of housing improvement schemes to repair and modernize older domestic properties, both within the private and publicly owned sectors.

As a consequence, most of the properties built 100-years or so ago were improved only 30 or 40 years ago to quite reasonable standards at that time. Bathrooms were modernized, w.c. cubicles were brought in-house from being 'at the bottom of the yard', roofs were stripped and relaid, insulation was provided in roof spaces, damp-proof courses were injected into the original walls, new kitchens were provided, etc. In the case of publicly owned property, this was done at the taxpayer's expense; in the case of private property – generous grants and loans were made to the owners.

Over the last five years or so, the U.K. central government has tried to assist local authorities to address this problem of serious potential housing shortage by introducing the PATHFINDER scheme which encourages the construction of 'affordable housing'; unfortunately, this has lead to many local authorities using the scheme to justify demolish existing older housing in the belief that better use can be made of these sites – sometimes by encouraging commercial rather than domestic development.

4 The Darwen experience – setting the local scene

The particular matter with which I would like to deal, and one which I believe illustrates the problems being experienced in the U.K. relating to older town centre domestic properties, is the case of the town of Darwen. This is a town with a population of some 35K situated very close to the City of Blackburn, Darwen and Blackburn are about 45 km north of the city of Manchester.

Although Darwen developed as a separate town, it was incorporated into the City of Blackburn about 30-years ago in order to create a larger and more efficient local government administrative unit – with a total population of some 138K.

However, unlike Blackburn, Darwen was almost entirely a manufacturing town with no real civic or local government centre. It did not have a cathedral, it had only a small Town Hall and was very much the poor relation to Blackburn; it had a relatively large proportion of semi skilled and unskilled people making up its workforce. These people lived close to the factories and mills in which they worked and occupied the hundreds of small properties that were built around those factories and mills. Most of the mills and factories have now gone, but the houses remain.

Figure 2: A terrace of 11 houses condemned because of relatively minor settlement at the front corner of one property – cost 30K Euros to repair, value of properties to be demolished 1100 K Euros

5 The initial local reaction

I first became involved in this matter in July 2004; I was contacted by a client who is a minor private landlord and who owns a number of small domestic properties in the north Manchester area that she has renovated over the years and let out to private tenants of modest financial means – normally young couples.

My client had received a letter from Blackburn Borough Council, informing her that an Application had been made to the Office of the Deputy Prime Minister (ODPM) for a Clearance Area covering some 160 properties; she was the owner of one of this group. The reason given for the Clearance Area and for the compulsory purchase of her property was that *"properties in the area (including her own) were unfit for human habitation"*. She was both furious and puzzled, as she had just completely refurbished her property to a very good standard both internally and externally.

I was asked to inspect the property and to give my opinion as to its condition.

At the same time, my client demanded to know from the Local Authority at Blackburn the basis upon which her house had been condemned. She was provided with a 26-page pro-forma questionnaire relating to her property, which had been completed by a (so-called) independent firm of surveyors appointed by the Local Authority. That report referred to an internal and external inspection of the fabric of the property; it also comment on the facilities provide in the property (bathroom, kitchen, etc) along with comment as to their age and condition. Comment was also made on social facilities and environmental facilities (e.g. state of the roads and pavements, the state of the public street lighting, any derelict sites in the area, deposited rubbish, etc).

No sooner had I arrived to inspect the property than I was besieged by a number of private owners, mainly elderly people and young couples, to ask if I would also inspect their properties. Subsequently, over the next week or so I inspected 17 properties; this was a 10% sample of the whole proposed Clearance Area.

In my opinion, none of the properties were unfit for human habitation; some minor repairs to their fabric was required on a number of them, but nothing major. The average sale price of the properties that I inspected was about £65,000 (110,000 Euros) I found no instance where anything more than 15,000 Euros was required to be spent on a property and the substantial majority required no more than 5,000 Euros to be spent on them.

Most of the properties were well cared for by their owners and most of these owners were elderly people who had lived in their respective properties for 20 or 30 years. One lady of 78-years of age had actually been born in her property.

6 Structural arrangement and condition of the properties

The properties themselves have slated roofs supported on conventional timber frameworks and with external stone elevations to both their fronts and rear. The properties are old, but, as can be seen from the attached photographs, the vast majority of them have been maintained in good condition with 'loving care'. Some needed bathrooms updating and new kitchen fitments, but none of these were unserviceable and the older residents were comfortable with them, most had installed them when they originally moved in 30 or more years ago.

In my view, none of the properties was unfit for habitation.

7 Public meeting and the official reaction

Having looked at the 10% sample, I attended a Public Meeting in August 2004 at which the local Member of Parliament and various Councillors for the area were present, as also were the

Local Authority officials, including the Senior Housing Manager. He informed the Meeting that the whole area was being declared a Clearance Area for compulsory purchase and demolition, because 19% of the properties were said to be unfit for human habitation. He did not identify which 25 properties were in this group!

It was worth noting that the Local Authority owned a number of properties in the area, which they had kept vacant and boarded-up over the preceding couple of years.

I asked a number of questions on behalf of my clients including:

i) I pointed out that many of the criteria against which the houses were being judged as unfit were matters for which the Local Authority were themselves responsible, such as poor street lighting, uncleared derelict sites, household rubbish not cleared, poor pavements and street surfaces.

ii) I pointed out that keeping their own properties unoccupied and boarded-up encouraged the area to look 'run down'.

iii) I asked whether it was it the policy of the Local Authority to deliberately create dereliction in the area so that they could declare the area suitable for clearance and also for them to be able to purchase the individual properties for less than they were worth.

iv) I pointed out that I had inspected a 10% sample of the properties and found that the reports prepared by the so-called 'independent surveyors' acting for the Council bore no relation whatsoever to my findings as regards the condition of the properties.

v) I stated that it was my view that the independent surveyors were either incompetent or that they were not as independent as the Local Authority was suggesting – I asked if the area was really intended for new housing or was there a hidden agenda here?

I was promised that this information would be sent to me and to my clients, but nothing materialized. Some four weeks later, 25th September 2004, I wrote a 9-page detailed letter to the Local Authority on behalf of my clients, confirming all the above five points and requesting an amount of additional information, including:

i) Financial justification for the demolition of the properties as opposed to their repair, modernisation and retention,

ii) Details of the brief given to the independent surveyors,

iii) An explanation as to why my findings were not even remotely similar to those of the independent surveyors.

iv) I asked why the independent surveyors who condemned the properties, had taken only an average of fifteen minutes to survey each of the properties; yet me to check their findings, rather than to survey the properties in detail again, took me about two hours per property.

Two months later I received a reply from the Council giving me very little information, but informing me that as the Clearance Area had been challenged by some of the residents, the matter would have to receive an official review by Central Government, at which all the information that I required would be made public.

But such a ‘review’ has no real urgency in itself; in this case it did not happen for another 18 months and then only because Compulsory Purchase Orders (CPO’s) had to be issued by the Local Authority on the few remaining owners who refused to sell. The intervening 18 months before the CPO’s were issued gave the Local Authority plenty of time to make the local situation practically irreversible, even should the residents win.

8 Reaction from the national and local media

Meanwhile, the media had taken up the cause and various articles appeared in the quality newspapers, on radio and television. Indeed, one of my clients and an effected local resident – a local tattoo artist – was discovered by the media to have such a wonderfully renovated and furnished property that it featured in the Sunday Times Magazine as a ‘desirable residence’.

There was such a hue and cry that, as I have said, the Clearance Area Order was called in by central government for examination by a Public Enquiry. Unfortunately setting up such a Public Enquiry does halt the process of property acquisition; various ‘strong arm’ tactics can still be employed by the Local Authority to acquire more properties in the area and to allow further dereliction to develop – so encouraging others to sell, before their homes became valueless or were destroyed by vandals and thieves.

Meanwhile, it transpired that Darwen was not the only local authority Clearance Area which was occurring within the U.K. in the name of the PATHFINDER scheme; there were others – mainly in the north of the country – far from the centre of Government in London, where similar activity by Local Authorities was occurring.

Action groups formed by local residents in these other areas have had mixed success in fighting Clearance Area notices. This is because the groups invariably consist of ordinary people not familiar with effective campaigning; they tend to lack focus, have no real organization and have limited funds; they frequently find agreeing an action plan difficult. As they do not understand the complexities of the relevant laws they are usually easy meat for the experts employed by the Local Authority. The people of Nelson were successful in their campaign but those of Liverpool were not.

There are in the U.K. established conservation organizations, who are registered charities, that will assist local action groups with advice and with some limited funding, such as Save Britain’s Heritage (SAVE), but they in turn have many calls on their limited resources and finances; nevertheless they can give local groups advice on how to organize their campaign – what they cannot do is organize it for them.

In the case of Darwen, SAVE did become involved at a late stage but the support that they could then offer was limited. Their National Director did attend the Public Enquiry and make representations to the Inspector.

9 Conduct of the local authority

The problem that the Local Authority faced was that they were aware that there was serious opposition to the ‘clearance area’, not just in the area itself but also in the wider Darwen community. The normal procedure to acquire property would be for the authority to issue ‘Compulsory Purchase Orders (CPOs)’ to all residents not prepared to sell voluntarily, but if the residents object and do not agree to sell, then that automatically triggers a Public Enquiry, with an independent Inspector appointed by central government to hear the arguments and to decide if the issuing of the CPOs is justified. Such a Public Enquiry must be held locally and within 6 months of the issue of the CPOs.

Strangely, the issue of a ‘clearance area notice’ does not trigger an automatic time limit for an Enquiry, so the Local Authority did not issue the CPO’s, but instead decided to pressurize the residents to ‘persuade’ as many as possible to ‘volunteer’ to sell their properties to the Authority and to then leave the clearance area. Residents say that they were bribed and coerced into leaving, as the Authority allowed the area to become progressively derelict by boarding up empty houses and generally allowing an atmosphere of neglect and insecurity to develop. Vandals came into the area to steal from the empty houses – even to strip the roofs of slates – and little was done to stop them.

By September 2005 only some 30 residents were left in the area; that was the stage at which the Local Authority issued the CPOs on those brave souls who were still in residence. This did trigger the Public Enquiry, which then had to be held by February 2006, by which time the Authority had already arranged for the properties that they then owned to be demolished – this demolition would therefore frustrate any decision that the Inspector might make in favour of the remaining residents – this was all very cleaver and, in the view of the remaining local residents, what might be the action of the worst type of private sector landlord. Perhaps to be expected in Zimbabwe, North Korea and in some of the East European countries before the Russians left, but hardly the action that on expects from a UK elected city council.

10 The public enquiry

The Public Enquiry was eventually scheduled for March of this year; eighteen months after I had first examined the properties and over twelve months since my clients had asked me to become involved on their behalf.

In the intervening period, the Local Authority progressively negotiated with private landlord owners and the Housing Associations to purchase their properties; some private owner occupiers were also coerced into selling; in my opinion the negotiations during this time with these owners were – metaphorically speaking – conducted with ‘a gun to the head’ of the owners. If they did not sell, then the area would be progressively allowed to run-down and they would only be given the ever-reducing value of their property at the time that they did sell.

My clients did not tell me of the date of the Enquiry until it was already in progress; it had been going on for 2 days in front of a government appointed Inspector. The Local Authority (who had declared the clearance area) had already given their evidence. The local residents were desperate; they telephoned me in the afternoon of the second day – could I help to put their case? I agreed to help where I could; I would come to the enquiry the next day.

I read my original notes and reports over night and went to visit the clearance area early that morning before going on to the Enquiry. I was astonished at what I saw; despite the fact that the Public Enquiry was still in session, the demolition machines were already working on the blocks of property that had been bought and cleared of owners / tenants. One or two brave souls, mainly elderly people who did not wish to see their homes demolished, were still in residence. They would of course eventually be evicted or forced out in some other manner.

It was a desperately sad sight to see 100-year old good stone built, slate roofed, low-priced homes being pulled down in the name of so-called progress.

The Council presented their case to the Enquiry with the benefit of the services of experienced lawyers and with many senior members of the Local Authority giving evidence.

The few remaining residents were un-represented legally and had to make their own individual cases. At the last minute I was asked to attend and speak on their behalf – and this I did, but their battle was already lost.

Among the questions put to me by the lawyer acting for the Local Authority was a classic – ‘Well then Mr Clancy, what do you think should be done now?’ I could only respond by saying that nothing could be done now for the residents themselves; they had been effectively forced out of their homes and the homes were being demolished as we spoke. All I expected and hoped for was that the Inspector would find it appropriate to severely criticise the Local Council, (both the elected Councillors and the salaried Officers) for the manner in which they had contrived to acquire the property and land from the rightful owners.

As I write this Paper, the decision of Mr Richard Ogier, the Government appointed Inspector, is still awaited. It is expected in late April 2006, but whatever he says about the conduct of the Local Authority, by that time all the properties making up this historic little community will have fallen to so called ‘progress’.

11 Epilogue

There is no assurance that new housing will be built in Darwen to replace that which previously existed – the Local Authority have been consistently vague about their future development plans for the area; Even if new houses were built, those local people that were displaced to allow them to be built will not be able to afford them. The new houses on a like for like basis would be at least £140K (250K Euros); that is twice as much as the properties that previously existed.

But this is not just a matter of redevelopment of an area of a town, it is not just about evicting people to knock down their homes to build something new; it is a much broader picture. It is the matter of the destruction of an established close-knit community.

Having been a Local Councillor myself for eight years in a Borough of South Manchester and having also served as a lay-Magistrate for over 25-years, I have seen the effects the breaking up of a community can have on a local population.

Vandalism, criminal activity, educational and family problems and similar, all these arise from the disruption of a community. It is my experience that it takes at least 30 years for a new community to settle down and become socially responsible and law-abiding.

Why a ‘housing improvement scheme (HIS)’ was not implemented rather than a ‘clearance area’ declared is a mystery. A HIS is a well proven procedure for improving an area of old housing, whereby houses are refurbished on a rota basis with residents being moved out to other houses in the same improvement area as the work progresses and then back their own home – if they wish to come back! This keeps the community together and the exercise can even improve community spirit.

I strongly suspect that the clearance area was declared because the Local Authority in this particular area – despite what they say – do no want housing. There is another undeclared agenda – some say that they want to apply for other government money to build a large training college. Nobody knows!

Unfortunately, the community of Blackburn with Darwen will be paying heavily for this social vandalism for decades to come and long after those local Councillors and employed officers who created the problem have retired on their comfortable pensions!

I hope that this will be a useful lesson that will be of some use to other similar small communities living in older and well managed close-knit housing communities in the wider Europe.

From it we will hopefully learn that it is always important to monitor carefully the ambitions of the local dignitaries wishing to make a name for themselves and where progress for the sake of progress is perceived to be the answer.

History may not judge them as kindly as they might hope.

Figure 3: Demolition in progress – the destruction of a community and of a part of local history

Post Script; *At the time of presentation of the above paper in June 2006 the Government ordered Public Enquiry into the correctness or otherwise of the decision by Blackburn with Darwen Local Authority to issue* ***Compulsory Purchase Orders*** *and/ or designate the area as a* ***Clearance Area Order*** *had been held – in March 2006 – in but its result was not known. The result of the Public Enquiry has now been published.*

*It may be of interest for readers to know that the independent Planning Inspector appointed by the UK Government to examine the conduct of the Blackburn with Darwin local Council in issuing the '****clearance area order****' and then the '****compulsory purchase orders****' decided in his report issued on 14th August 2006, that the Council had not acted in the best interests of the people concerned and recommended rejection of the* ***orders****.*

Unfortunately, by the time the decision of the Inspector was published, the Local Council had tempted or terrorised many of the elderly residents into selling their homes. Their properties *were then promptly demolished; so that any decision of the Inspector could not preserve the community as a whole.*

In my opinion, the best that can now be hoped for is for the area to contain a mixture of the old houses (refurbished) and some new housing. What the Local Council have actually achieved, by their narrow minded stupidity and ambition, is a complete environmental and social disaster.

Research based municipal policy saves European cultural heritage: the case study of Brandys nad Labem-Stara Boleslav in Czech Republic

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1 Project to rescue and open to the public

The town of Brandys nad Labem – Stara Boleslav is a historical site, which has touched on Czech and European history for thousand of years. It straddles both banks of the Elbe (Labe) River, 20 km north of Prague, the capital city of the Czech Republic.

Brandys nad Labem status was elevated to that of a royal city by the Emperor Rudolph II in 1581 and at its centre is a wholly exceptional monument – the renaissance imperial Brandys nad Labem castle. From 1547 onwards, this belonged to the Bohemian royal court and became a popular hunting base for the princes of the Danubian monarchy. All the Austrian rulers beginning with Ferdinand I visited the Brandys castle and for many of them it became a place where they frequently stayed for long periods. It served the emperors and kings of the Habsburg-Lotharingen dynasty for almost four hundred years. After 1918, the castle became the property of the Czechoslovak state. It was completely evacuated and used in a degrading manner as an office. It served as the premises of the state forest management authority and was also used for rented housing. Some sections ended up on the edge of devastation.

In 1995, the castle was taken over in this very problematic structural state by the town of Brandys nad Labem – Stara Boleslav, and it became the main investor and organizer behind the effort to save this important monument.

2 Aims of the project

The project's originators see its significance on several levels:

- to salvage Castle Brandys nad Labem, the unique cultural and historic monument of European significance, to make this landmark accessible to the general public and to present preserved its architectural and artistic values, to provide a reminder of the historical solidarity of the Czech lands within the community of Europe, to create a memorial bearing witness to the historical truth of leading personalities from the Central European Danubian monarchy, particularly Charles I of Austria.

3 The research

During the last five years town administration, following a general policy of internationalization, decide to involve in this research project some foreign institutions.

This brought to state a permanent relationship, thanks to the Czech National Archive, the Czech Honorary Consulate in Florence and the Romualdo Del Bianco Foundation, with some experts from Universities of Florence and Pisa.

Research has been conducted both in Prague's and Florence's archive to get a better knowledge of the architectonical evolution of the castle and to the compare and exchange documents and information. At the same time all these institutions took part to a project of international promotion of the Castle and the whole cultural heritage of Brandys nad Labem – Stara Boleslav. Result of this active collaboration is the reconstruction of the castle and exibitions and publications about the history of the castle and its owners.

4 Realization of the Project

In the period up to 2002, work focused on the structural stabilization of the building, repairs to the roofs, and the gradual restoration of the renaissance sgraffito decoration in the courtyard of the castle.

From 2003-2004 the most significant part of the project was implemented:
the reconstruction of the tower, the reconstruction and restoration of the castle's internal rooms and halls for the public and cultural life of the town and the entire region the preservation of the interiors of the castle in the spirit of its original condition from the 19th century with on historical exhibit dedicated to the most significant owners from the Habsburg-Lotharingen dynasty, particularly the Emperor Rudolph II, the scientist and traveler Archduke Ludwig Salvator of the Tuscany line and the last Austrian Emperor and Czech King Charles I and his wife Zita of Bourbon-Parma.

On 24th April 2004, in the year of the 700th anniversary of its origination, this important but until now forgotten castle was ceremonially opened to the public for the first time with representatives of the Czech government in attendance along with the town's mayor, members of the Habsburg-Lotharingen family, hundreds of foreign guests and the town's citizens and visitors. Its gates have since then remained permanently open.

5 A brief history

The basis of the construction is a Gothic castle erected around 1300 (written records date back to the year 1304) to guard a crossing on the River Elbe on an important European trade route. The Gothic castle was rebuilt many times and modified as an artistically demanding structure conceived in the shape of a late-Gothic castle. The most important period in the structural development of the castle was the Renaissance, when the building belonged to the imperial Habsburg estate. This was the reason why its reconstruction was carried out by leading artists of that time: Borgorelli, Vaccani, della Stella, Filippi, Gargiolli and others.

The castle acquired its present appearance during the reign of Maximilian 11. This comprises a four wing building on an irregular square plan with a clock tower, an inner courtyard and opulent sgraffito decoration which is among the oldest and most remarkable of its kind in the Czech lands.

The Renaissance reconstruction reached its peak during the reign of Rudolph II who had Brandys decorated with figural sgraffiti and resplendently furnished as his main seat outside of Prague where he stayed for long periods.

A castle garden was also built for Rudolph and a covered passageway ran into this from the castle over the moat. Most of the garden buildings, which were designed for the emperor by the magnificent Florentine architect Giovanni Gargiolli, felt victim to the Thirty Years War, when they were used as building material for the fortification of the army of the Swedish General Banner. The fortification has remained preserved to this day as an important and extraordinary monument to military engineering. Gargiolli's balustrade stands in its original renaissance form in the castle garden. It is the work of the Italian master craftsman Antonio Brocco's stone works and it comprises part of the emperor's private garden.

The castle's extensive and rich hunting grounds in its environs were the scene of a number of grand imperial hunts during the baroque period. The castle, however, also entertained the imperial court on the occasion of celebrated Christian pilgrimages, which took place in neighbouring Stara Boleslav. Emperor like Charles IV, Marie Therese or Ferdinand V also set out for Prague from the castle for their coronations as the kings or queens of Bohemia.

The Brandys nad Labem castle was the setting for a number of important political dealings, which had consequences for all of Europe. In 1813, the Austrian Emperor Franz I had meetings here with the Russian zar and the Prussian king Friedrich Wilhelm II in order to agree on a common approach in the war with the emperor Napoleon I. The Brandys pact was then implemented the following year at the Battle of Leipzig.

From 1860 onwards, the castle belonged to the family of Leopold II, the last governing Grand Duke from the Tuscany Habsburg line. His son, the archduke Ludwig Salvator, an internationally renowned scholar and traveler, amassed rich here collections of natural products, historical and artistic objects and archival papers, which he acquired on his exploratory journeys around the Mediterranean. He also expanded the family's local Tuscany library. In addition, he carried out the last extensive reconstruction of the castle in a romantic Neo-Renaissance style.

The last Austrian Emperor Charles I became the final Habsburg owner of the Brandys castle. He stayed here from 1908 while serving as an officer of the 7^{th} dragoons regiment. In 1911, he brought his new wife Zita of Bourbon-Parma here, and in his own words this was where he spent the loveliest time of his life, In 1918, the illustrious history of the Brandys castle was disrupted for a period of almost 90 years.

6 Reconstruction and restoration

The Brandys caste, as it appears today, is the result of a very complex building development, which was documented by a structural and historical examination.

Since 1995 on the basis of this structural and historical examination, a project has been implemented to halt the devastation of the building, to remove the degrading building operations of previous decades and To gradually get it into a good structural condition, and to generally repair the entire roof cladding with a particular focus on the restoration on the historically valuable baroque roof timbers from 1701 as well.

During the formation of the plan to rehabilitate the castle in 2003, the available historical iconography and newly discovered archive documentation was respected. On this bases, it was possible to remove the non-original and degrading building developments, and to return the individual rooms to the original historical layout corresponding to the period when they were first created, it was also possible to determine the original use of individual rooms and to take account of this in the original interior installation plan. From 2003-2004, the most significant part of the project was implemented, namely the reconstruction of the clock tower and the entire spacious grand floor area of the castle on all four wings. A permanent historical exhibit was installed in the reconstructed halls based on historical studies.

7 Methods and technologies

The methods and technologies used for the redevelopment, conservation and restoration were adapted to the fact that a whole range of structural elements and artistic details with a historical value had remained preserved in the castle covered by modern construction work – this included things such as parquet floors, doors, windows, stone jambs and paving, as well as renaissance stucco ceilings.

The building work was carried out using traditional bricklaying technologies on the basis of lime binding agents: while using the original building material obtained from building conversions that were removed, and where this had already been secondarily used. New constructions were made from traditional materials in the form of replicas or analogues only in instances where this was vitally necessary.

During conservation, traditional cleaning methods were consistently employed and restoration operations were preceded by continuous methodical research on restoration for every space, which yielded several important items of knowledge.

8 New discoveries

During alterations to the southern, residential wing of the castle, an examination revealed several layers of paintwork, from fragments of renaissance decoration to paintwork from the 19^{th} and 20^{th} centuries. One big surprise was the discovery of large areas of late baroque to classical paintwork in some rooms on this floor. The high artistic merit of this original baroque painting, as well as the fact that it was sufficiently well preserved, meant that its complete restoration was possible, thus creating an exceptionally valuable interior. This concerned a unique act in the history of the castle, because it brought about the full rehabilitation of rooms in the castle of the highest artistic quality, which for almost the entire 20^{th} century had originally been used in an utilitarian manner without any regard for the value of the building.

Rehabilitation took place in a similar manner in rooms on the first floor of the eastern wing, in which the original monochrome paints of the walls and vaults were restored. The renovation of the renaissance Venetian stucco on the walls and vault of the main hall in the Gothic part of the castle was a unique discovery and act of restoration. Using needles, the additional plaster was knocked off the damaged areas down to the level of the bottom layer. The places prepared in this way were replenished with a special prepared stucco mix, which was braced and smoothed out with iron in the old fashioned way. Another important finding was the discovery of a previously unknown Gothic window on the courtyard side of the first floor of the castle's east wing. The uniqueness of the window's discovery is the fact that, among other things, it is the only perfectly preserved window of its kind in the courtyard facade of the east wing. After being replenished with missing stone-mix materials moulded into the appropriate shape, the window was restored so that the still perceptible parts of the stone polychromy and the plaster of the Gothic facade were also preserved. The significant discovery of a section of renaissance sgraffiti was made in a room of the annexe to the staircase in the southwestern corner of the courtyard. The uncovered part of the sgraffito with a biblical Old Testament theme and hunting scenes adds to our knowledge of the opulent decoration of the castle buildings and its special value is based on understanding the original finish, because this sgraffiti was covered by plaster as far back as the baroque period. In the case of this discovery, restorative action was kept to a minimum. It only focused on the replenishment of mechanical damage so that the authenticity of the original colouring and the vestiges of the renaissance master craftsman's brush-work was not disturbed. The analytical concept also graphically presents the lamination of the sgraffito decoration of individual renaissance periods and it is therefore of great educational importance as part of the exhibit intended for the public.

9 Restoration of the tower

The comprehensive reconstruction of the tower on the castle's northwestern corner, whose structural condition was completely critical in many respects, was an extraordinary event and its restoration in a romantic neo-renaissance style has once again made it the town's highly visible dominant feature. An important discovery was made during an examination of the tower, which has made it possible to precisely clarify its gradual structural development. It is essentially a late-Gothic tower, with floors built on during the renaissance, which were furnished with extremely rich sgraffito decoration. During the baroque period, a lavishly latticed dome was built onto the tower by K.I. Dienzenhofer.

A crucial phase in the development of the tower was its radical reconstruction in the Dutch neo-renaissance style, which was carried out for the archduke Ludwig Salvator of Tuscany in 1873. It was actually this phase that was the basis for its complete reconstruction. The discovery of the original plans by the architect Bedrich Wachsmann for a chisel-shaped roof covered with coloured, glazed fired roofing material which was unique in Bohemia, also contributed to this decision. With the help of those plans, it was possible to reconstruct the coloured components of the roofing, the shade of the individual colours and the composition of the roofing material. The monochrome paint of the plaster of the tower with geometric decoration carried out in accordance with the results of an investigation made a unique unit of the entire tower section.

10 Conclusions

The Complex ensemble of building and restoration work, the study of source materials, and the conducting of research as well as the creation of an exhibit was essentially carried out in the course of one year.

The work is still in progress and there is a big job that waits to be done. Some reconstructions (such as gothic wing in the second floor) have to be finished and some others, like the corridor and the garden which would have a big impact on the turistic development of the site and the town itself, have still to begin.

Of course all these projects would need the support of the Czech State and European Union, and all of us are working to get it. By the way the quality of the results merging from the job of the implementation team confirmed that even with limited resources, the municipality is capable of bringing a demanding an extensive project for the preservation of cultural heritage to a happy end.

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From cultural heritage to sustainability: architecture and the nature-city

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1 Introduction and contents (values, objectives and results of our research)

Firstly we would like to display the problem and our hypotheses, which contain the solutions to the problem on which we work as architects acting on the city.

Everyday in the world entire towns disappear from the sight of official economies together with their well-being measures, their houses, monuments, human values, scientific traditions, and they go in stand by. Some of them are completely destroyed, others simply stop in a sort of hibernation, and wait like messages in a bottle for a future economical-ecological science to understand them, heal them and bring them back to life.

Slowly nature covers everything with soil and vegetation, destroying some things and preserving others. Sometimes, with the help of archaeology, an alliance is created between science and nature, and this process can be governed by men ... but most of the times villages and small towns in southern Italy see their population grow older and older or leave; these places are abandoned to ruin and desertification. But if we look at them with the eyes of a tourist, tired of the big cities, they are a *Great Source of Future* and a cultural heritage consisting of several models of sustainable development.

This phenomenon of *stand by* of the city from a certain point of view looks like a paradoxical aporia, but from another helps us go nearer to the heart of architecture: *when things stop and stick to a beautiful order that goes beyond an ephemeral time, then there is Architecture* [1].

But, in an age in which everybody and everything runs gaspingly, there seem to be no time left for architecture, and so no time for a concrete cultural heritage.

Thus a city, lacking an appropriate programme for the surviving and developing of future generations, slows down until it stops and it is, strangely, the perfect scenario in which to find a life-rhythm more human, in which is possible to walk around and find the time to *feel* the air, the wind, the sun light or shade, in other words the physical and psychological relationship with nature.

While in thousands of areas in the world urban relationships atrophy or disappear, in other places, like China, for example, there are programs that will attempt to create, in the next twenty years, hundreds of new cities and a number of vast and small areas of urban retraining, and projects of ecological re-conversion of villages and countryside areas.

In this various and sometimes contradictory frame, urban environments characterized by old buildings, even if abandoned and rapidly falling apart, have a higher architectural and urban value than modern constructions, which are usually realised responding to excited formalisms or to the tastes of the single architect. There are, though, examples of a new attention to the relationship with nature, such as the new Malaysian cities, where principles of sustainable development are used.

In this situation we must study the ancient centres in order to understand their cultural heritage and use it for the new architecture.

In conclusion we can say that in between the old which is fading away, and the emerging new, we find the condition necessary for the cultural and environmental heritage which creates the sustainability of the development.

The truth is that this condition isn't new, nor old; it is just an idea of regenerability of the urban features which gives the nature time to adjust, regenerate itself and accomplish it's of absorbing the impact of changing.

But then we encounter another problem: the inadequacy of economical and managerial culture which has not yet learned to be ecological, cultural and tourist economy, other than projectual.

Our research started 10 years ago in response to the problem of the depopulation and the subsequent degradation of small centres and territories in the internal regions of Europe.

We have been fortunate to be based in the Basilicata region, which, because of its size and characteristics, we were able to use as an *open laboratory*.

So in a short period of time we carried out research on the nature-city and a number of other applications (urbstourism [2] and city-inn, ecological reconversion, sustainable construction, etc...).

Starting from the main objective to stop social and natural degradation in cities, villages and landscapes, we achieved a number of results.

Our first step, in order to save these beautiful villages and towns that, standing on top of hills, are also *territorial presidium*, was to *understand* that their chances of development lay in endogenous economical, social and cultural resources, already existing but still unused, and that it was necessary to study strategies to organize these resources in order to achieve social and economical sustainability.

The methodological result of our research, offered to the population of these areas, is a *paradigm* of ten *instruments* conceived as means to pass from the discovery of the single nature-city to appropriate projects for a sustainable development.

The first *results,* achieved through pilot project, were: deep understanding, development and recovery of the historical towns in internal rural areas trough appropriate tourism (urbstourism and city-inn [3]); creation of networks of villages and small towns; ecological conversion of the countryside and suburbs; creation of parks; saving of energy through the use of ecological buildings.

Thanks to these discoveries and to these projects an important change took place in Basilicata [4], a region where, till ten years ago, the importance of internal areas was ignored and the only investments for tourism were *fake farm holidays* and a savage tourist exploitation of the coast.

Even though a long period of time is necessary for such a change to take place, we can see that our research has not only a social-economical value, but also a cultural one.

2 The *discovery of the nature-city* as an unexpected originality and the formulae for innovation

The study concerning the process of recovery of urban depressed areas led to the partly unexpected discovery of the *nature-city*.

It would not be correct to use this synthetic definition referring only to small towns or villages as ecosystems with unused or wasted resources as their own powers of sustainability; we could use it wherever the conditions of existence of the nature-city are. Even in big unsustainable metropolis (where our study becomes even more interesting).

This is the most innovative aspect of our research: it is possible to say that the nature-city is called so because its relationship with nature, together with the complexity of adaptation to human civilization, is the basis of its very existence and richness. This is evident in its physical structure: in origin there can be a dominant natural entity (like a river, a lake, the sea, a forest, a mountain or a *gravina*). Together with one or more of these strong natural entities there is an inhabited centre.

Then both the entity and the centre will evolve themselves together.

We had, then, to *match* elements of ecological quality, such as the mutual dependence, the diversification, the complexity, the cyclic nature of processes and streams of information, the contextual conditions, etc., with human experience and cultural heritage (notions of knowledge, culture, value, richness genealogy, learning ability, etc.); thus we created a *paradigm* of ten categories (domesticity, centrality, naturalness, insularity, initiality, topicity / topicality, co-existentiality, time deepness, landscapeness, representativeness) [5] of communication for the most simple eco-cultural urban phenomena.

The answers to the problems of the future are in the complexity of the nature-city, and only architecture is able to synthesize this complexity; it is only through this consciousness that is possible to realize sustainable projects.

We have proves, gathered trough the study of over two hundred cities in the world and of our pilot projects, that the nature-city is able to regenerate itself at various degrees and that inside of it are the rules with which to interact with reality creating innovative projects and strategies.

3 The strategy for the regeneration of the Nature-City and problems people have to solve

Now that we presented the results we achieved and we are preparing for new collaborations with the nations of Eastern Europe on the sustainability issue, we have to consider carefully the difficulties that we had to face and that everyone has to face if he wants to try to solve the problem of the cultural heritage and the sustainability.

In almost all the areas with social and cultural difficulties – southern Italy is such a region – a cultural resistance emerges from the political sphere every time the concept of cultural heritage is introduced in the new frame of *unstainable development*.

This problem must not be underestimated since a *sustainable* development is achieved only when, a part from answering the needs of the present without spoiling the future and preserving the conditions for the regeneration of natural resources, we can also guarantee a *democratic participation* to the development.

This democratic participation has to be able to carry out a plan of cooperation of several urban centres to the sustainable development of an area.

The single local administrators, though (sometimes without specific knowledge), couldn't fully comprehend the necessity of participation in the sustainability paradigm and so opposed to the realization of the *agenda XXI* and the creation of a real network of different municipalities.

In other words, the language of the sustainability is still to specialist to be fully understood.

In order to overcome these communication problems we had to carry on a hard work of cultural elaboration that we organized into three phases.

3.1 Phase 1: *key words*

We had to look for the *key words*, which had to be the less possible technical in order to help enlarging the accessibility to the complex phenomena linked to the sustainability.

We tried first of all to create a link between the language of cultural heritage and the one of the sustainability of development (figure 1).

3.2 Phase 2: *paradigm* of ten categories

We had, then, to *match* elements of ecological quality, such as the mutual dependence, the diversification, the complexity, the cyclic nature of processes and streams of information, the contextual conditions, etc., with human experience and cultural heritage (notions of knowledge, culture, value, richness genealogy, learning ability, etc..); thus we created a *paradigm* of ten categories (domesticity, centrality, naturalness, insularity, initiality, topicity / topicality, co-existentiality, time deepness, landscapeness, representativeness) of communication for the most simple eco-cultural urban phenomena. We selected ten words that everybody will be able to understand, even those who have no technical knowledge of the subject and so could be scared and make our progress slower. We also wanted to point out the ten features that make each city unique. These features correspond to this paradigm of ten categories.

3.2.1 Centrality

Centrality is the condition of *maximum crossing* of a multitude of beings and events through one or more centres.

It's where *multiplicative syntheses* are realized, where we pass from one to many. In Centrality's places, it seems that everything *leaves and comes back*. In Centrality we overcome *equivalence's limits* and we enter in the area where community's flow and meeting chances are at their peak.

For example a main street or a square can express this condition.

3.2.2 Domesticity

Domesticity is the repeated condition of *belonging to the house* (the cohabitation under the same roof that protects common things) of beings transferred from the fragmentary external world that tends to gather together forming *long-lasting and steady (*ständigkeit) *identities*. The culture of human domestic institutions is the explication of Domesticity. In Domesticity human beings *re-construct* themselves and find again the *limits' immanence* of those things that, being soft, ductile, flexible, defenceless, can be nearer to them without intimidating them, as in a world that remains peaceful.

3.2.3 Naturalness

Naturalness is the extended condition of *being an ingredient* of life's regeneration in relation with nature, mainly referred to climate, geography, living creature's bodies and to the extent of the resources responding to the natural substratum, which tends to regenerate within a determinable period of time.

Naturalness finds expression in the *regeneration of the living* urban culture.

In Naturalness human beings try to overcome their regenerative isolation limits, becoming part of the complex relations of *the living*.

The connection with a big natural entity (wood, sea, river, lake, ravine, mountain etc…) can strongly mark a city's Naturalness.

3.2.4 Insularity

Insularity is the recurrent condition of spatial inclusiveness in collective *self-sufficiencies* that begins in ordering *parts* in space and shapes the geography of the rules and immanent laws of belonging to the world.

Thus self-sufficiency limits and needs of going beyond them take form.

The sea, the desert, the burnt lands, the deep woods, the starry sky, every fix big expanse wraps the city fertilizing or isolating it in self-sufficiency or letting it to be wrecked in external resources' apparent unlimitation.

3.2.5 Initiality

Initiality is the renewable condition of *re-production* or *re-starting* of the city, which can regenerate or simply grow: well or badly.

It is what is *before* and *in front* of the city. The event of the time and of culture and civilization's re-generation.

It is realized, often in combination with insularity, in various project types: *topica, atopica, utopica ed eterotopica*. Thus we always have a system of areas, or re- generation places, also into the city, where the city overcomes its destiny of *being limit*.

3.2.6 Topicity / Topicality

Topicity is the diffuse condition of reciprocity, of the mutual approaching of beings in small spaces.

This mutual approaching gives a communicative sense back to the visible structure of the space, which can be defined as *the language of the space* (before, after, left, right, up, down, through). There is something that magnetizes the language of approaching, that *gathers together and invites to stop, conveying comfort*.

Topicity, that is not a global qualitative aspect, is defined in *city's quantum* that, in their diffusion, determines a recurring topic feature.

3.2.7 Coexistentiality

Coexistentiality is the concurrent condition of richness of variety, of exchange and of receiving what, as a foreigner, is expected. Trough Coexistentiality not only we recompose world's diversity, we also *create world*.

Coexistentiality is the dimension of the staying together.

In a basic *Weltlichkeit* that acts as a substratum for difference and for market, Coexistentiality is the system of limits in which we overcome ethnic impoverishment and we realize a wide concept of biodiversity, of cultures as well.

3.2.8 Deepness

Time deepness is the condition, conferred to things, to have the time to fully exist. It is also what lies *under* the city (and the earth), and connects *before* and *after*.
Sometimes it's the origin and is the destiny.

In Deepness human beings attempt to go beyond the wild and inhuman condition of present time acceleration which leads them to *do just for doing*, in order to conquer, instead, a space-time expansion going beyond present time limits, into the past and into the future, looking for permanencies.

Archaeological sites, graveyards, museums and parks are some of the places in which the city offers the collective chance for such an overtaking.

3.2.9 Landscapeness

Landscapeness is the condition in which the look opens to overall values.

In the institutional places of sight, the view points, the city gazes to throw itself ahead, and looks at itself in order to go over the immediacy.

Thus the city's opening enters the landscape, here intended as that aesthetic frame in which the value of the whole (houses, nature, centres and streets) overcomes the sum of its parts.

This is the reason why some geographer speaks about a *perception* of the landscape as a *theatre*. We never have a direct relation with the world, but we always have it with a description of it.

3.2.10 Representativeness

Representativeness is the participation to a world's representation. It is a shared representation because it involves an object, the entity or person who is representing it and their reciprocal positions.

This, in the city, is a network of points of view and values (places and place's quality), a net of connections that starts from the monuments.

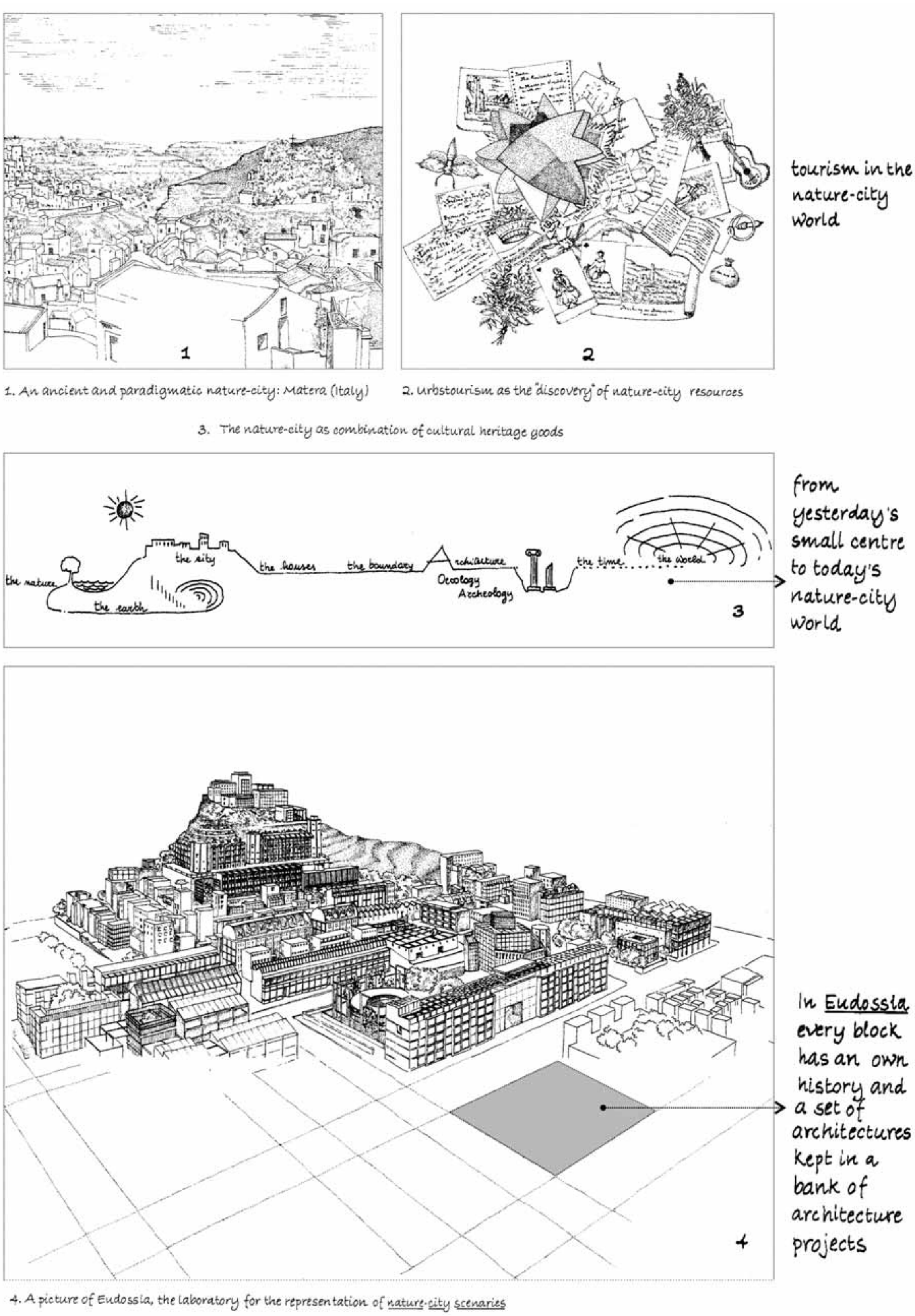

Figure 1: Products and projecting tools. Architecture is culture, environment, tourism and projects

3.3 Phase 3: the ten categories and their ecological objectives

In order to move on to the next step we started from I. Sachs's saying that a city should be considered as an ecosystem with its own potential of latent resources, poorly used or unused, or wasted.

So the application of our paradigm as a means for discovering latent resources in many cities, towns and small villages, lead us to develop a strategy that was at the same time cultural, ecological and economical that did not sever the *local* sphere from the *global* one.

The key aspects of this strategy are based on the correspondence between each of the ten categories and their *ecological objectives*, as we can explain in the next sections.

3.3.1 Centrality

Centrality is matched with the need to control the flux of substance-energy that goes through the centre, the quantity and intensity of the interactions between the parts of the whole and the elements.

3.3.2 Domesticity

Domesticity is matched with the need to ease the stability of *feeble strengths* (attention, love, for example), looking for a deeper re-balance of traveller's energies that we find in the *inhabiting*; improving the interactions and the exchange fluxes between the inside and the outside that make the *house-city* belonging self-reliant through time.

3.3.3 Naturalness

Naturalness is matched with the need to make the relation between the living creatures easier, with the need to re-generate and stimulate self-reliance (and the ability to recover from impacts and damage) of the eco-systems and of the natural *ingredients*: animals, vegetation and human beings.

3.3.4 Insularity

Insularity is matched with the need to mark the borders of the habitat, leaving the negativeness without.

3.3.5 Initiality

Initiality is matched the need to help the new re-conversions and re-starts of the different parts of the city, re-generating their natural and cultural resources.

3.3.6 Topicity

Topicity is matched to the need to multiply the *slow-spots*, and actions aimed to reduce the impacts on the ecosystems.

3.3.7 Coexistentiality

Coexistentiality is matched to the need to overcome the *difference* as an obstacle to coexistence, in order to improve the quality of life.

3.3.8 Deepness

Time-deepness is matched the need to discover the latent resources and the co-evolution of different life-times, even of slower ones.

3.3.9 Landscapeness

Landscapeness is matched the need to create a number of view-spots (but also points of view), all looking one to each other, creating a network able to convey a complete image of the view, which overcomes the sum of its parts.

3.3.10 Representativeness
Finally, *Representativeness* is matched to the need to comprehend the whole narrative frame by which each particular place described through its own cultural heritage and its own ability to show itself.

4 How transfer our discoveries to enlarged Europe

We had, in order to give the project a future, to develop the concept of *nature-city* [6] into a frame of high ecological and economical sensitivity, placing it between the heritage of the concepts of civilization and nature and the ecological conversion process.

From this point of view, all the different re-generation and safeguard techniques would become much more effective if all the single operations in which these techniques are used could find the chance to interact between each other. This can also lead to a mutual valorisation of all the cultural and natural entities of ecological system.

With the progressive enlargement of the European Community the innovative aspect of our research becomes more important; this power of innovation lies in the realization of the *nature-city cultural heritage*, which could be made easier to realize using the adequate instruments for the spread of knowledge.

The first two instruments we invented are an exploratory model of the polycentric nature-city in the geographical context and ecological network of resources, the *Polipolis,* and a new kind of cultural tourism, the *Urbstourism*.

Both consist in ways of discovery *of* nature and *in* nature. Both explore the dimension of the journey as the *discovery of a new world*: the world of the nature city.

This *new world* is made of people, places, events and products that *create world*.

Polipolis is referred to the poli-centric nature-city, it is the model (prototype) of a new multimedia way of connecting things and the technical-symbolical instruments to ecological issue. It allows us to travel in a network of nature-cities, discovering hidden phenomena, between real and virtual, through the deepest mental territories and epistemic stratifications, drowned and hidden in today's life.

We need it to draw the geography of cultural heritage, to discover areas, points of intevisibility, to study single organizing systems (joint to ten channels of ten categories paradigm), to find *discovery places*. These are knots of cities, of landscape, of ecological, archaeological, human, ecosystem places and of ecosystems of goods and activities. Urbstourism, the *nature-city* world tourism, could be seen as a particular type of rural tourism (*the countermelody of rural tourism*): as the latter is used to let people know the rural world's resources, urbstourism can be used to underline the nature-city's sources of well-being.

First of all, it could be used as a practice of direct, instinctive experience, which makes the nature-city accessible to everyone as a cultural and environmental heritage *capital*.

The original aspect of urbstourism is that it is able to connect the strong feeling of discovering a new world to the surprise of the discovery of the unknown potential of each human being that emerges when he comes in contact with this new world. Thus begins a whole process of discovery of latent potentials and abilities, the nature-city's *know-how*, which is the real resource of cultural heritage and which has the important ecological task of giving back a real *human time* to everyday's life. This is found by living for a while in the city-inn, through which the recovery of the abandoned parts of the ancient nature-cities is carried on, re-converting them to a new, sustainable lifestyles that people can experience in their holydays and in their travels.

So the urbstourism becomes an *economic engine*, able to start the nature-city recovery process where the centre development had been abandoned due to the lack of an adequate economy.

From here comes also a new vision of local systems: they are now able to evolve the old economical activities (agriculture and building trade, both in deep crisis) into an ecological conversion of a nature-city in which urbstourism, now seen as an economy of tourism and of ecological buildings [5], connects the enjoying of the cultural and environmental goods to the recovery and the new, sustainable building of the city-inn.

A lot of these re-conversions, though, have been carried out by projectors and economists not ready for real sustainability. It is useful to keep in mind that the city-inn, in order to survive, must contain the knowledge resources and the latent potential know-how that give it the ability to protect and keep its own local resources, using them in an interactive, re-generative way and reconnecting them to the renewable sources. What is necessary, then, is a sort of *ecosystem* of the nature-city, able to save energy and reduce wastes, to recover from impacts and to learn to repair the damage they cause, to self-heal and to adapt to unpredicted errors, to grow and evolve, to regenerate time.

In this frame our work, following the *Lisbon Strategy*, has been using the nature-city concept in combining economic, social and environmental aspects in order to create social cohesion and to give back a prior important role to the elderly, women and children.

The nature-city requires in fact, because of its characteristics, the conception of time that comes from the regeneration of life, which is typical of women; it recovers the wisdom of the elderly, with their slow life rhythm and it helps the sensitivity towards nature that only children and young generations can truly express.

The last instrument we want to introduce in order to pursue this *sustainability strategy* is a *projectual laboratory for new nature-cities*, which works anticipating the urban ecosystem scenario.

This scenario can be seen by introducing in abandoned old villages or in large unsustainable cities, policentrical areas or complexes in order to regenerate conditions for the existence of the nature-city and to give these conditions, in a cultural and environmental heritage, to the next generations.

The laboratory accomplish this task through a variable model of urban scenario, named *Eudossia* [7], in which the architecture of buildings and of nature synthesize the nature-city characteristics in every single spot of the area, using the ten regenerative tools presented above.

We can conclude, closing a cycle of an evolutive spiral, that the task architecture has in projecting the new conditions for the nature-city, is to discover in which way every different time a specific cultural heritage can assume a regenerative function, combining with the guarantee of the environment's future.
The origin of all this is in the experience of the *archaeological parks*, of the *Ecomuseums* and of the *open museums*, but today we are trying to bring this experience forward, as we decided to try to explain through our participation to the 2003 Barcelona Biennial [8].

This group of new *products* and projecting tools created a number of integrated applications, above all in Basilicata, where architecture is culture, environment and tourism.

It is possible to use the same concepts, the same working categories and regeneration strategies in order to help the enlargement of Europe, wherever there are the conditions, even if partial conditions, for the existence of the nature-city, and wherever there is a will of regeneration.

5 Social and economical impact of our results and possible aftermaths

The results of our research created *impacts* both inside the Basilicata region (Matera Sassi, Acerenza-Forenza in Vulture AltoBradano, Potenza University with a number of new courses and masters etc.) and in other Italian regions (Liguria: Cinque Terre, the Puglia region: Gravina in Puglia, Sicily: Treno doc etc.).

We are furthermore projecting and realizing ecological architecture prototypes with no polluting emissions, using bio-construction techniques.

These projects, on which we are still working, are examples of new constructions, recovery of old buildings and renovation of modern ones, and represent a discrete variety of possible users of the nature-city.

We want to study a range of solutions for the different lifestyles that today's society creates. These solutions can range from miniapartments (only 24 square metres) to small ecological villages.

It is only by going back to projecting houses, though, that we can create a relationship with the inhabitants of a certain area, a relationship that is a central feature in the sustainability culture and that is difficult to find in other projects.

Even the issue of energy-saving, which is now the centre of all our efforts, linked to a new vision of cultural heritage, will only gain an incisive international importance when architects will focus their studies on solving the problems concerning the new demands of great masses of humanity.

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Socio-economic impacts of cultural heritage assets

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Key words: heritage economics, economic development, cultural economic impacts

1 Introduction

In much of the world today, governments have programs, policies, and departments devoted to economic development. Those same governments have programs, policies, and departments devoted to community (social) development. What is not widely recognized is that the conservation of heritage resources is the single economic development strategy that is simultaneously a community development strategy.

In the long run the economic impact of heritage conservation is far less important than its educational, environmental, cultural, and aesthetic impact. In the long run, none of us particularly cares about the number of jobs created in building the piazzas of Florence. In the long run, those other values of heritage conservation are more important than the economic value. But as the great British economist John Maynard Keynes said, “In the long run we’re all dead.”

In the short run, however, many of those who have the most influence on what happens to our heritage resources – property owners, members of parliament, bankers, investors – do care about the economic aspects of heritage buildings. It is often through the door of economic impact that those decision makers become advocates for heritage conservation on other, more important grounds. To the extent that those decision makers can further understand that heritage conservation is economic development that is simultaneously community development, their support is likely to increase.

2 The five major measurables of economic impact

Research in the past decade has identified five major measurables of the economic impact of heritage conservation: 1) jobs and household income; 2) centre city revitalization; 3) heritage tourism; 4) property values; and 5) small business incubation. Each of those areas, in and of themselves, is also community development. While many of the studies that will be cited were conducted in North America, some are from other parts of the world, and all will have relevance in an enlarged Europe.

2.1 Jobs and household income

In the world of economic development, the top local priorities are usually creating jobs and increasing local household income. The rehabilitation of heritage buildings is particularly potent in this regard. In the United States, new construction typically will be half materials and half labour. Rehabilitation will be sixty to seventy percent labour with the balance being materials. This labour intensity affects a local economy on two levels. A plumbing system might be purchased from across the country and lumber from another nation, but the services of the plumber and the carpenter are nearly always purchased from the immediate area. Further, once the plumbing is installed, the plumbing does not spend any more money. But the plumber gets a hair cut on the way home, buys groceries, and joins the YMCA – each recirculating that pay check within the community.

The Swedish International Development Agency has funded projects in the West Bank in Palestine where they have found that every $100,000 project typically provides 3000 to 3500 workdays, with labour constituting around 70% of the total expenditures. In Australia, they have concluded that heritage conservation is more labour intensive and also stimulates the development of traditional trades and skills. Often political decision makers think of economic development only in terms of manufacturing, so that provides a useful comparison. The State of Tennessee in the U.S. is a typical example American example. For every million dollars of production, the average manufacturing plant in Tennessee creates 28.8 jobs. A million dollars spent on new construction generates 36.1 jobs. But a million dollars rehabilitating an historic building creates 40 jobs. A million dollars of manufacturing output adds $604,000 to local household incomes. A million dollars in new construction contributes $764,000. But a million dollars of rehabilitation adds over $826,000.

In Norway, historic rehabilitation creates 16.5% more jobs than new construction and every direct job in the cultural heritage sector creates 26.7 indirect jobs, compared to the auto industry where the factor is only 6.3 to 1. There is an even subtler issue regarding jobs in heritage conservation – they are generally well paying jobs, and globally there is a scarcity of the required skills. A study in Great Britain identified the need for an additional 6,500 workers in the next 12 months to meet immediate demand. The Norway Directorate of Heritage identified a huge backlog of necessary maintenance work, and too few trained people to do it. The significance and the opportunities for restoration artisans cannot be overstated. In France, 40,000 craftsmen work on repairs and maintenance of the cultural heritage. The Aga Khan Trust is funding projects in the Islamic world that are reviving traditional skills, generating new jobs, and providing on-the-job training. In Halmstad, Sweden, restoration work has put long-term unemployed back to work and provided training for immigrants, apprentices, and women. All of these efforts represent local economic development, but even more importantly, they represent community and social development. Ultimately, economic development is about jobs, and heritage conservation not only provides jobs, but good jobs and many more workers are needed.

2.2 Centre city revitalization

The second area of the impact of heritage conservation is centre city revitalization. There is a resurgence of centre cities in many places in the world, but this trend in downtown revitalization is particularly apparent all over America. But one would be hard pressed to identify a single example of sustained success in downtown renaissance where heritage conservation was not a key component. Conversely, the examples of very expensive failures in downtown revitalization have all had the destruction of historic buildings as a major element.

The most cost effective program of economic development of any kind in the United States is a program of the National Trust for Historic Preservation called *Main Street* – commercial district revitalization in the context of historic preservation. 1700 communities in all 50 states have had Main Street programs. Over the last 25 years, the amount of reinvestment in those communities has been $23 Billion. There have been 67,000 net new businesses created generating 308,000 net new jobs and 94,000 building renovations. Every dollar invested in a local Main Street program leveraged nearly $27 of other investment.

The Inter American Development Bank has had a major initiative in the city centre of Quito, Ecuador. There are multiple indicators of the success – new businesses, restaurants and cultural activities; reinvestment by existing and new residents; increased property values; and net economic benefits well above expenditures.

The ongoing efforts in the old medina in Tunis have resulted in the middle class returning, both as residents and as business and property owners. The rates of return on private investment have been high and the leverage of public funds to private funds has been 3 to 1. Centre city revitalization is economic development that, at the same time, is community development.

2.3 Heritage tourism

The next category is heritage tourism. This is a challenging area. While tourism is one of the fastest growing segments of the world's economy, not every city can or should look to tourism as a major portion of its economic base. Further, it would be a mistake only to connect historic buildings with tourism – there are many more ways that historic buildings can be used as a local resource. In the United States 95 percent of all of the historic resources in productive use have nothing whatsoever to do with tourism.

However, when tourism is identified as part of an overall development strategy, the identification, protection, and enhancement of historic resources is vital for any sustainable effort.

A study in the State of Virginia contrasted the spending patterns of heritage visitors with tourists who did no heritage activities. Here is what was found: heritage visitors stay longer, visit twice as many places, and so spend, on a per trip basis, 2 ½ times more than other visitors spend. Worldwide, wherever heritage tourism has been evaluated this basic tendency is observed: heritage visitors stay longer, spend more per day, and, therefore, have a significantly greater per trip economic impact. Many European countries have similar data.

Biltmore, a great estate in North Carolina, commissioned a study of local impact – here are the numbers – 760 employees, $215 million to the local economy, $5 million in taxes, $9.5 million in direct payroll and an additional $8.4 million in indirect payroll. However, the most impressive number is this one – for every $1 a visitor spent at Biltmore, $12 was spent elsewhere – hotels, restaurants, gas stations, retail shops, etc. Biltmore was the magnet that drew visitors, but for every dollar that Biltmore reaped, others garnered $12.

In Norway they found similar results – only 6-10% of the spending involved in visiting a cultural heritage site was spent at the site itself; the balance was spent in the community around the site.

But with all these numbers, an even more important conclusion emerges: when heritage tourism is done right, the biggest beneficiaries are not the visitors but the local residents who experience a renewed appreciation for and pride in their local city and its history – economic development that is simultaneously social development.

2.4 Heritage district impact on property values

America is a country that is obsessed with property rights. As a result, the area that has been studied most frequently is the effect of local historic districts on property values. The most common result? Properties within historic districts appreciate at rates greater than the local market overall and faster than similar non-designated neighbourhoods. The worst-case is that historic district houses appreciate at rates equivalent to the overall local market.

In England, they have found that a pre-1919 house is worth on average 20% more than an equivalent house from a more recent era and the premium becomes even greater for an earlier historic home. On the commercial side, the Royal Institute of Chartered Surveyors has tracked the rates of return for heritage office buildings for the past 21 years and has found listed buildings have consistently outperformed the comparable unlisted buildings. Analyses in Canada demonstrated that heritage buildings have performed much better than average in the market place and that the price of heritage houses was less affected by cyclical downturns in property values.

2.5 Small business incubation

An underappreciated contribution of historic buildings is their role as natural incubators of small businesses. In America, firms employing less than 20 people create 85% of all net new jobs. That ratio is similar in Europe and even greater in the developing world. One of the few costs firms of that size can control is rent. A major contribution to the local economy is the relative affordability of older buildings. It is no accident that the creative, imaginative, start up firm is not located in the office park or the shopping centre – they cannot afford the rents there. Heritage buildings become natural incubators, usually with no subsidy of any kind.

Pioneer Square in Seattle is one of the great historic commercial neighbourhoods in America. The business association asked firms why they chose that neighbourhood. The most common answer? That it was an historic district. The second most common answer? The cost of occupancy. Neither of those responses is accidental.

In Ningbo, China, a series of dilapidated, overcrowded and unsanitary buildings has been converted to the Fan Centre filled with small businesses selling antiques, books and art. The restoration of the Souq al Saghir in Damascus has stimulated new businesses and more activity from existing businesses, selling to both tourists and local residents. In Macao 60% of their retail revenue comes from the heritage conservation zones.

So there are the big five – jobs, centre city revitalization, heritage tourism, property values, and small business incubation. Other areas of impact are discovered in some analyses include: revenues from the movie industry, enhancement of crafts businesses, the connection between historic facilities and the performing arts, neighbourhood stabilization, the economic integration of neighbourhoods, tax generation, and others.

3 Heritage resources and globalization

It is also important, however, to move beyond the short-term and look at the larger economic role of heritage conservation. That means beginning with globalization.

What neither the supporters nor the critics of globalization understand is that there is not one globalization but two – economic globalization and cultural globalization. For those few who recognize the difference, there is an unchallenged assumption that the second is an inevitable outgrowth of the first. But a deeper look would suggest those are two different phenomenon, which while interrelated, are not inexorably linked. Further, while economic globalization has many positive effects, cultural globalization has few if any benefits, but has significant adverse social and political consequences in the short term, and negative economic consequences in the long term.

If cities are to succeed in economic globalization, they will have to be competitive worldwide. However, their success will be measured not just by their ability to foster economic globalization, but equally in their ability to mitigate cultural globalization. In both cases, a city's cultural heritage will play a central role.

The "modernization" of cities in terms of infrastructure, public health, convenience, and quality of life does not necessitate the "Americanization" of the built environment. An imitative strategy for the built form quickly leads a city from being "someplace" to "anyplace". And the distance from "anyplace" to "no place" is short indeed.

Globalization, be it economic or cultural, means change – change at a pace that can be disruptive politically, economically, socially, psychologically. Adaptive reuse of the heritage resources can provide a touchstone, a sense of stability, and a sense of continuity for people and societies that helps counteract the disruption which economic globalization can exacerbate.

4 Heritage conservation as public policy

Heritage conservation has been portrayed as the alternative to economic development, "either we have historic preservation, or we have economic growth." That is a false choice. In fact, heritage-based economic strategies can advance a wide range of public policy priorities.

Import substitution. Central to building a sustainable local economy is import substitution – creating locally what otherwise would be purchased elsewhere. Heritage conservation is locally based, using expertise, labour, and materials from the local market. However, import substitution also requires efforts to train local workers.

Compatibility with modernization. Many historic buildings do not meet today's standards for comfort, convenience, and safety. However, great strides have been made in methods of bringing historic buildings into compliance with modern demands, without harming their physical structure or their architectural character. Most components for modernization can be put in place almost invisibly without jeopardizing individual historic resources or their important context.

Targeted areas. Historic buildings are usually located in areas that have already been designated as appropriate targets for public intervention such as city centres, older neighbourhoods, and rural villages.

Not a zero-sum game. Many approaches to economic development are zero-sum games. That is for city A to succeed, city B has to lose. Because nearly every city has historic resources that can be economically productive, for one city to benefit from the reuse of its historic structures in no way precludes another city from doing the same.

Geographically dispersed. Public officials do not have to limit heritage conservation strategies to a single geographic area. Cities are geographically dispersed throughout a nation, so heritage-based economic development strategies can be broadly based geographically.

Range of project scales. Many factors affect the public sector's ability to implement large-scale plans. Financial constraints, political conflicts, and environmental concerns are all reasons why large projects are often delayed. Heritage conservation, however, can be done at virtually every scale, from the smallest shop building to the massive regional revitalization projects. Smaller projects can proceed while larger ones are still on the drawing board.

Counter-cyclical. One result of globalization is that cities are not immune to the vicissitudes of worldwide economic cycles. Because of their scale, cost, and labour intensity, heritage projects are often possible even in down-cycle economic periods, providing a measure of stability to a local economy.

Incremental change. Change itself does not inherently cause adverse impacts on economies and cultures. The damage comes from change that is too rapid, too massive, and beyond local control. Heritage conservation is an incremental strategy within the framework of an existing city, not an immediate and overwhelming type of change that often leads to feelings of powerlessness and a decline in the sense of community.

Good base to build NGOs. NGOs have proven themselves to be singularly effective in responding to issues worldwide, particularly in the area of heritage conservation. If policymakers want to strengthen civil society, heritage conservation activities can be an effective means of doing so.

Product differentiation. In economics, it is the differentiated product that commands a monetary premium. If, in the long run, a city wants to attract capital, to attract investment, it must differentiate itself from anywhere else. It is the built environment that expresses, perhaps better than anything else, a city's diversity, identity, and individuality – in short, its differentiation.

Heritage conservation allows a city to participate in the positive benefits of a globalized economy while resisting the adverse impacts of a globalized culture.

There is a biblical verse that reads, "So what is a man profited, if he shall gain the whole world, and lose his own soul?" Many are now realizing that if, in the name of prosperity, they lose the physical fabric of their built heritage they risk losing their national soul as well. That is economic development at the expense of community and social development.

In the 21st century, only the foolish city will make a choice between heritage and economic development. The wise city will effectively utilize its historic environment to meet the economic, social, and cultural needs of its citizens far into the future.

5 Conclusion

Advocacy for heritage conservation has traditionally been based on cultural, aesthetic, educational, historical, and environmental grounds. As governments in the enlarged Europe face pressure on public budgets as well as issues of globalization and competitiveness, an additional range of arguments for the conservation of heritage resources may be appropriate. An effective case can be made that demonstrates that heritage conservation is economic development that is simultaneously social and community development. The systematic research in Europe, as elsewhere, has been limited to date. This provides great opportunity for academics and other researchers to look more closely at the measurables identified in this paper and quantify those impacts on a country-by-country basis within Europe.

The experience in the United States in using the economic arguments for historic preservation has been directly linked to the passage of pro-heritage tax legislation and other policies that encourage conservation of the historic built environment.

This paper began with a quotation from a British economist and will end by quoting an American one. The Harvard economist John Kenneth Galbraith wrote, "The preservation movement has one great curiosity. There is never retrospective controversy or regret. Preservationists are the only people in the world who are invariably confirmed in their wisdom after the fact."

Elements to take into account in order to reconcile economic benefits and quality of life in a pro-active management of the impacts of cultural tourism

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1 Challenges and opportunities of urban cultural tourism for small and medium sized towns

Urban cultural tourism is one of the earliest forms of tourism in Europe (Origet du Clouzeau, 1998), may it be under the form of pilgrimage or the famous Grand Tour that wealthy Brits undertook on the continent to further their education. However, it was not considered a major source of income until the beginning of the 1990's, with the exception of capital cities, such as Paris and London, and some exceptional cases, like Bruges, Venice or Santiago de Compostela.

Since then, interest in tourism has spread rapidly throughout many small and medium European cities, which, previously had not considered themselves as tourist destinations. Liège, Belfast, Luxembourg, Telč, Avila, are examples of small and medium-sized cities that have recently decided to promote tourism even though it had not been part of their tradition. This renewed interest can be explained by the fact that tourism is increasingly perceived as a potential means of alleviating the crises suffered by many urban centres (Law, 2000). These crises are due to a number of broadly established factors, including the decline of industrial activities located in the vicinity of their centres, progressive loss of inhabitants and the difficulties caused by major office development. As urban cultural tourism has grown very rapidly, its further development is usually conceived as a win-win strategy. It has been viewed as a boost to urban growth while supporting a renaissance of housing, since new cultural and leisure activities may serve both tourists and local residents in search of a richer and denser life (Ashworth 2001).

Small cities, of 10.000 to 50.000 inhabitants, and medium-sized cities, of 50.000 to 250.000 inhabitants, accommodate more than 60% of the European population (Cavalier, 1998). Recent delocalisation offer them opportunities to define tourism strategies but they often lack the expertise and support to develop sustainable forms of tourism. Especially because their reduced size makes them more easily prone to suffer from negative impacts as they lack the mass of large towns to absorb the effects of tourism development (Drdácký, 2002).

2 Impacts and need for guidance

In the context of growing tourism development and the need to manage its impacts, the PICTURE project (Pro-active management of the Impact of Cultural Tourism upon Urban Resources Economies) aims to develop a strategic urban governance framework for the sustainable management of cultural tourism within small and medium-sized European cities. This framework will help to establish, evaluate and benchmark integrated tourism policies at the local level with a view to maximising the benefits of tourism upon the conservation and enhancement of built heritage diversity and urban quality of life.

In order to accomplish this goal, the project investigates the dynamic effects of urban cultural tourism at large, upon the social, environmental and economic wealth of European small and medium-sized cities, considering the *built heritage diversity* and *urban quality of life* characterising such environments. This gave way to a matrix of impacts of cultural tourism upon built heritage diversity and traffic, upon cultural practices and representations and on urban economies, available in Deliverable 3 of the project.

On the other the project, or rather its partners also research the needs and expectations of local authorities in regard to urban governance of cultural tourism. This led, for instance, to an integrated framework for effective management, available on D6 of the project. These documents served as a basis for the subsequent tasks.

In summary, the projects looks at what impacts tourism produces as well as what the local authorities say they would need in order to better manage them. This method taking different angles of approach aimed to draw a clear picture, of all the impacts of tourism, short term and long term, positive and negative, reversible and irreversible. Yet, it also intended to highlight knowledge and knowledge gaps in the different stakeholders, impacts that weigh more or are more present in their minds, as well as how these factors can influence tourism practices and development.

An analysis of the knowledge areas clearly indicates that economic benefits dominate the positive picture, while socio-economic factors are often disregarded. This tendency even translates into impact assessment procedures. Not all towns develop a structured planning of tourism development and few study potential impacts in a systematic way. Forty five percent (45%) of all towns developing tourism do not engage in any form of prediction of evaluation, and when they do, they often limit themselves to an assessment of profitability through questions such as the possibilities of return on investment, the financial impacts and the number of visitors visiting a place.

It is only when towns reach the stage of tourism maturity that they start realising the importance of assessment, as 94% of our sample declare they have recourse to it. All however, seem to focus first on economical impact, feasibility studies and assessment of ways of communication rather than impacts on quality of life, social structures, town planning or cultural representations. Even though 25% of them claim to evaluate social or environmental impacts, the tools they use bear the name of surveys, statistics, economical analyses, study of the occupancy rate, benchmarking with other destinations, ratio investment / economic consequences, exchanges with similar cities and “trying to learn from the mistakes of others” (Dumont *et al.*, 2004).

If towns study the numbers of visitors for profitability purposes, they significantly don’t think of a carrying capacity. Not a single town among our respondents had defined a limit, above which the flows of tourists would create more damage than good to the places they visit. Some are more aware than others of its need, and some mention some kind of limitation through the number of beds available. This example, evidencing the analysis of a minimum limit in the amount of people to make profit without any correlative limit above which heritage becomes destroyed, highlights the priorities of impact management. It seems that it is important to know whether one is going to make money but not whether one is going to kill the goose that lays the golden eggs.

Impact assessment procedures and voluntary schemes often reflect this bias, even though they include more and more factors and move from a restricted point of view to a broader scope, including the notion of landscape, environmental damage and public participation, they rarely include quality of life as an element to be monitored. In the light of local authorities’ focus on economic benefits, the following section of this article will present some preliminary results on economic impacts that question the notion that this end justifies all means. Given the little space usually given to quality of life preservation or even enhancement, the article will then present some preliminary results to better delineate the concept and its relationship with tourism development.

3 Economic benefits

Given the extremely positive representation of tourism cast by tourism intermediaries, and their assertion that it logically leads to economic benefits, it proves is quite striking that they cannot give specific numbers when asked how much income tourism generates within their towns. Only about 10% of all respondents gave an answer to the question regarding the percentage of income generated by tourism within the local economy and none of the tourism experts were able to give indications for the areas that they were in charge of (Dumont *et al.,* 2004).

Adding up the costs and benefits of tourism proves difficult, intricate and complex (Cazes and Pottier, 1998), because, for example, of a potential need for costly extra services in a town, the necessity to balance the calculation with additional expenses, or, on the positive side, the multiplier or soft location effect. Unfortunately, this type of reflection rarely comes forward in questionnaires or discourses. Tourism is deemed so positive that it looks as if the phenomenon does not need to be studied, neither through a preliminary impact assessment, nor through a reflection on the carrying capacity, or monitoring. In most cases, the relationship between tourism and economic development is presented as obvious, linear and, self-evident.

However, a survey (deliverable 13 available on the website) specifically investigating the economic impacts of tourism, carried out by Fondazione Eni Enrico Mattei in the context of the PICTURE project, suggests that the economic benefits do not always reach the expected high levels. Even though a specialisation in tourism can lead to prices augmenting in the short term, and a certain level of inflation, it would not automatically lead to a rise in salaries and purchase power (Bellini et al. 2005: 36).

In fact, leakages and the relationship between the tourist industry and the local economy play a significant role in the possibility to foster positive economic impacts. In a situation of partial equilibrium (when prices don't answer to the growing demand, the determining principle here being the existence of an excess capacity that can be activated before prices rise), the question of leakages proves crucial. Indeed, the multiplier effect only works when a local economy can answer the additional demand. When it cannot, import will grow, and the more import, the less positive impacts for the local economy. In some cases, it can even prove negative (Pinelli, 2005). The relationship between the local economy and the tourism sector determines the amount of benefits. If infrastructure belongs to foreign investors, only little additional revenue can be obtained at the local level (Interview, responsible of building conservation, Bruges, Belgium). Additional revenue also goes hand in hand with additional jobs (direct and indirect, in the tourism sectors and in sectors that serve or supply tourism). The quality of the jobs created also matters as positions in tourism sometimes prove quite precarious (seasonality, low-pay, no employment security, ….).

In situations of equilibrium (after an adjustment in prices, to reach equilibrium between demand and supply), the initial impact of tourism appears lower since the initial growth in local demand turns into higher quantities and prices. In theory, the benefits of tourism result from high prices in the non-trading sectors (hotels, restaurant, accommodation, price of local goods). In particular, the real estate elements (such as grounds) used by the non-trading sector (that is capable of paying high prices) benefit from tourism (Bellini *et al.,* 2005: 25).

Distributional issues also need to be taken into account, as an expansion in the tourism sector leads to a contraction of the non-trading sector (since tourist services compete with other activities for localisation and people). The real returns of all other sectors thus diminishes and therefore, the aggregated benefits of tourism risk benefiting only a small section of the economy, that of the tourist industry (Pinelli, 2005).

In a document explaining the role of consultants in urban cultural tourism strategies, Claude Origet du Clouzeau, awards the private sector the title of “main winner”. For towns, the benefits of tourism would appear later, and often occur indirectly, thanks to additional taxes from companies (2005: 21). When one compares the price of a tourism strategy for a town and the revenues from these taxes, it can take ten years to reach the point of return on investment, without any guarantee that extra investments will not become necessary (Origet du Clouzeau, 2005: 23).

Finally, there seems to exist a tension between long term and short term for towns relying on tourism for their growth. On the one hand, long term growth cannot rely on a steadily growing number of tourists, and a healthy economy can hardly rely on one single sector, especially if it is as volatile as tourism (Interview, Bruges, Belgium, representative of local residents, 2004). On the other hand, short term growth levels depend on the intensity of the exploitation of natural and cultural resources (Brau *et al.,* 2003), that are, by their very nature, not everlasting (Pinelli, 2005). PICTURE team is currently researching further to investigate facilitators of economic benefits and zones of danger. The final results will be presented at the final conference in Luxembourg.

4 Quality of life

Natural and cultural resources contribute to the quality of life of the locals who, because of overexploitation of these “public goods”, often end up deprived of them. PICTURE surveys reveal that tourism negatively impacts the quality of life of local residents in 75% of the cases for developing towns and 85% in mature towns, particularly in historic centres or and World Heritage sites. The elderly, disabled or a low income earners are particularly disadvantaged (Dumont *et. al.,* 2004).

If urban cultural tourism is to be made sustainable, quality of life needs to be taken into account by tourism stakeholders, and especially local authorities, because “*The tourist flows produce necessarily changes in the local community. The sustainability is strongly linked to the acceptability of these changes, and more precisely, to the notion of acceptable change. If the change is acceptable, the tourist development by which it is produced is considered as sustainable*” (Wall, 2003). The role of development for community has to be rethought. An integration of the concept of quality of life into tourism strategies could lead to a “*more creative approach in which cultural tourism is seen as a potential beneficial strategy to support stronger local identity and sense of belonging.”* (Sutherland & Tweed, 2005:4).

Quality of life, however, is a concept that proves quite hard to circumscribe. The PICTURE project again took a multi-sided approach in order to come to terms with the complexity of the concept and integrate different points of view. On the one hand, a literature survey was made, and on the other hand, questionnaires were passed in different towns in order to come up with bottom-up indicators, that were again tested in other questionnaires.

The literature survey available in Deliverable 12 reveals that it proves difficult to find a definition of quality of life in literature. Anderson and Czajkowski (1990) define it as “*an individual overall’s satisfaction with life*”. Sutherland and Tweed (2005: 5) note that, even though access to goods and services can easily be measured, “*less tangible feelings and* *experiences – such as freedom, aesthetics, social relationships – are more difficult to quantify".* Without indicators of quality of life, it is hard to monitor evolutions. In deliverable 12, they summarise the main subjective and objective indicators developed so far, such as Day's (1987) thirteen domains, Foo's (2000) method of scaling them or Cummins' (1996) 173 phrases and terms. Finally, it was Kim's (2002) regrouping under the categories of 1) material well-being, 2) community well-being, 3) emotional well-being and 4) health and safety well-being that led to their suggestion to choose the first three categories for the project, subdivided into different indicators.

Table 1: Preliminary Definition of Indicators for Measuring Impact on Quality of Life, taken from Deliverable 12 of the Picture Project, by M. Sutherland and C. Tweed

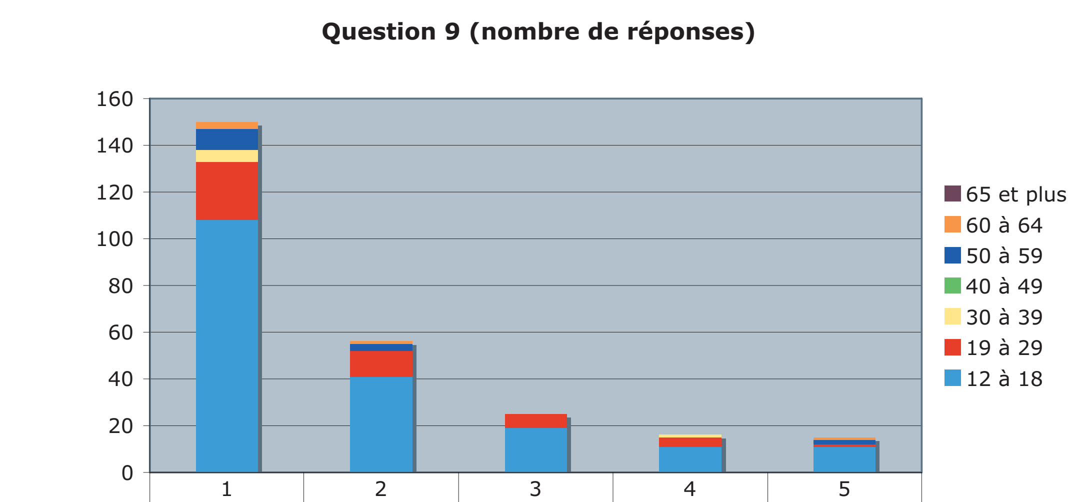
	Quality of Life Indicators
Emotional Well-being	Access to leisure and recreation facilities
	Access to religious opportunity
	Ability and opportunity to pursue hobbies
	Personal and family safety
	Improvements in social relationships
	Increasing opportunity for learning and education (including life-long)
	Overall life satisfaction
Community Well-being	Access to social and cultural facilities
	Opportunity for cultural exchanges
	Opportunity for variety of social and cultural activity
	Improved image of city
	Improvement in quality of local environment (built and natural)
	Increasing opportunity for community involvement
	Well maintained local services (roads etc)
	Increased Congestion / traffic
	Safety of local area / city
	Nuisance or inconvenience caused by visitors
	Overall satisfaction with community
Material Well-being	Opportunity for employment
	Cost of consumer goods
	Access to consumer goods
	Cost of local services
	Access to local services
	Attitudes towards allocation of public funding towards initiatives
	Overall material satisfaction

The questionnaire part of the bottom-up approach reveals similar indicators. Answers can be grouped into 5 global sections: physical environment (safety, cleanliness, green spaces, climate, noise, traffic, proximity of services), public emotional sphere (neighbours & good general contacts), private emotional sphere (oneself, friends & lovers), material well-being (nice house, good job, access to education) and psychological well-being (basic rights, possibility to make one's own choices). These categories can be made to fit the three categories suggested above. More details are available hereunder.

Table 2: Bottom-up Indicators of Quality of Life, PICTURE Project, Dumont & Lask

MATERIAL WELL BEING	**Physical environment**
	Climate
	Urban beauty, prettification
	Availability of infrastructures and businesses
	safety
	Human size
	Absence of pollution (environmental, noise and cleanliness)
	Transports (good public transportation, parking spaces, traffic management and pedestrian zones)
	Material well being
	Money, good job
	A roof above one's head
	Food
	Access to good education
	Access to technologies
	Good socio-economic environment
	Possibility to travel
	Possibility to engage in leisure activities
EMOTIONAL WELL BEING	**Private emotional sphere**
	In relation to oneself (be healthy, good life and work balance, self respect, positive attitude)
	In relation to others (couple, family and friends)
	Psychological well being
	Access to education
	Knowledge that it will be possible to find a job
	Freedom of action and choice (possibility to be oneself)
	Perspectives for the future (not too much anxiety, have dreams
	Peaceful climate (absence of violence, war, no differences between men and women)
COMMUNITY WELL BEING	**Public emotional sphere**
	Harmony and conviviality
	Social contract, mutual aid, common rules, know how to manage things, take one's responsibilities
	Respect, cultural diversity, absence of racism

Thanks to the questionnaires and the amount of answers, it is possible to see what aspects of quality of life are most valued or come to light most in the minds of the respondent. We thus receive indications, not only of what makes quality of life, but also of what aspects of it are most valued. Any urban cultural tourism development plan not only needs to take quality of life into account but specifically protect what is of most importance to residents. This can however prove rather intricate, as focus group surveys emphasise that opinions vary even within the small scale of the same neighbourhood.



	1	2	3	4	5
65 et plus	0	0	0	0	0
60 à 64	3	1	0	0	1
50 à 59	9	3	0	0	2
40 à 49	0	0	0	0	0
30 à 39	5	0	0	1	0
19 à 29	25	11	6	4	1
12 à 18	108	41	19	11	11

Figure 1: Amount of answers for elements making up quality of life, PICTURE survey, Dumont. 1 – physical environment, 2 – public emotional sphere, 3 – private emotional sphere, 4 – material well-being, 5 – psychological well-being

The example given comes from surveys in the town of Mons. Future comparison with other case studies should demonstrate whether the tendency to value physical environment and public emotional sphere can be generalised or whether they can only be applied to that specific town.

Besides, different factors such as the answer rate of the questionnaires in different towns suggest that the stage of tourism maturity plays a significant role in the possible impacts of tourism upon urban quality of life. The project will further investigate this point, as well as suggest factors that may affect positive or negative impacts. Results should be presented during the Luxembourg conference. The research so far provides indicators to help local authorities measure the quality of life of residents. Indeed, in the absence of indicators of quality of life, as well as well-defined property rights for public goods and some forms of intangible heritage, the tourism sector does not compensate local communities for the consumption of their resources in tourist developments (Bellini *et al.,* 2005). The relativity argument, claiming that locals' loss in quality of life is compensated by economic benefits does not seem to prove valid in the context of PICTURE preliminary results. Further research of the project will specifically concentrate on the relationship between quality of life and tourism development.

Old centres and the social networks of historical towns attract a lot of tourists but are usually free of charge, while food and accommodation services can rarely be considered as attractions

but enjoy the most opportunities for financial profit. Consequently, investment in infrastructure and heritage protection does not automatically lead to a direct return on investment (Orbasli, 2000). Regulating tourism development through adequate taxation, a definition of land use zoning and a redistribution of additional benefits, (Nowak *et al.*, 2003) as well as the implementation of a pricing system that would take into account environmental costs (Lask & Herold, 2004) could help to solve this problem.
Yet for this to occur would require a better awareness of the impacts, costs and benefits of tourism and to go beyond the idea that tourism generates benefits so strongly that these do not need to be evaluated. Crouch (1999) argues that *"one way of judging the impact that the tourism industry may have on communities is to assess the extent to which tourism contributes to the overall well-being or prosperity of a society"*. (Sutherland & Tweed, 2005). He calls for an holistic approach, including all four pillars of sustainability and stresses the interdependence of social, cultural and environmental well-being, as well as the economic.

The cultural tourism impact assessment (CTIA) procedure results from the same thinking that tourism is a multidisciplinary phenomenon that requires a multi-facetted approach in order to avoid quick decisions and irreversible situations. A draft of CTIA is available on the Picture website in deliverable 7 and the final version will be integrated into the strategic urban government framework, the guidance tool for local authorities that gives the basics about cultural tourism and then practical examples on what has been done elsewhere and best practices.

5 Concluding comments

Tourism, which accounts for 5% of all jobs and 5% of all consumer expenditure within the European Union (COM, 2001) is one of Europe's largest economic sectors and features among the largest key industries of the 21st century. The World Tourism Organisation estimates that the number of arrivals in Europe will double to 720 million tourists per year by 2020 (WTO, 2000).

Cultural tourism is one of the forms of tourism that is expected to witness the most important growth in the future (Aderhold, 1997). This is being fuelled by changing patterns of tourism (more vacations, shorter stays), the availability of cheap airfares, increasing discretionary time and demographic factors like the ageing of the population. All this means that, in a few years, tourism will have passed from a secondary activity to a "growth industry" for many European small and medium towns. Furthermore the tourism sector is one of the last "labour intensive" industries, with most of the goods and services provided locally by small and middle-sized business. Developing cultural tourism in small and medium-sized cities is thus in keeping with the intention expressed during the Lisbon European Council summit to place employment at the heart of the European project (Lisbon European Council, 2000).

Decentralisation offers greater opportunities for local governments across Europe to promote their own development plans and long-term tourism strategies. However, delivering pursued objectives requires effective integration of decision making and partnership building at local, national and international levels. This will involve both the public and private sectors, responsible for transport, visitor accommodation, cultural services and urban planning.

Achieving a balanced and sustainable development of the EU territory has been defined as the main objective of the European Spatial development Perspective (EC, 1999). Even though this document does not have a legally-binding character, it gives clear indications about the priorities of the EU about spatial development. Among the key priorities outlined by this document is *"the development of a polycentric and balanced urban system and strengthening of the partnership between urban and rural areas*". Current spatial trends in the EU reveal a rapid concentration of economic activities, especially high-quality and global functions, in the core area of the EU (defined in the ESDP as the pentagon defined by the metropolises of London, Paris, Milan, Munich and Hamburg (point 68) and in a few conurbations. In the view of the enlargement of the EU, a further concentration of spatial development in just one integration zone would lead to increasing disparities between the centre and a large periphery.

So far, tourism has mostly concentrated in some capitals and flagship cities, and as such, does not reflect the cultural diversity and cultural wealth of Europe (Colardelle & Monferrand, 1994). A more balanced development of tourism would help to alleviate the pressure put on small and medium-sized city centres and help the redevelopment of other regions that presently suffer from the competition with larger urban centres. This is especially of importance for the cities of central and eastern European countries that are presently suffering rapid decline of industry and agriculture. The strategic urban governance framework is thought in order to help local authorities of small and medium-sized towns (between 10.000 and 250.000 inhabitants) in their development and positioning on the European scene. It is conceived as an answer to Enriquez Savignac's (1997) comment that:

Local authorities must determine how, where and when tourism produced growth should take place. Unfortunately, with very few exceptions, they are neither experienced, nor equipped, nor financially capable, nor politically interested or motivated to set forth and implement a balanced mid and long-term program for tourism development.

Over-development of tourism leads to rapid erosion of cultural heritage: for example, the physical deterioration from pedestrian and vehicular traffic, vandalism, the construction of new facilities damaging the visual quality of the landscape, and loss of diversity of the social fabric due to an over-specialization of tourism activities. Obviously, cultural tourism should not harm the heritage that motivates it. Until now, carrying capacity has mostly been defined with environmental protection and physical conservation in mind rather than for the conservation and enhancement of built heritage diversity and quality of life, which are of paramount importance in small and medium-sized cities (Van der Borg, 1997). The PICTURE project brings these to the heart of impact assessment by giving clear conditions and points to keep in mind in order to foster economic benefits, as well as indicators that allow to measure and put a value scale on quality of life. Not surprisingly, protection of cultural diversity and quality of life is an integral part of the recommendations of UNESCO, the Council of Europe, and the ICOMOS Charter on Cultural Tourism.

Many voluntary schemes and much guidance have already been proposed to improve the management of tourism. Examples include European eco-labelling (Crem, 2000), local agenda 21 (UNEP-ICLEI, 2003), WTO guidance (1998) or integral quality management of urban tourism (EC, 2000). However, all of these schemes lack any constraining authority. This is problematic because impact upon cultural heritage is usually irreversible and local authorities tend, on the one hand, to overestimate economic benefits and on the other hand, to underestimate the negative impacts that a possible tourist development may have upon their local resources and the quality of life of their residents. The Impact Assessment procedure is one of the few regulatory instruments adopted at the European Union level. The Directives on Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) require the preparation of an impact assessment when a project, a plan or a programme is likely to have significant effects upon cultural heritage and material assets. The SEA procedure also imposes monitoring and auditing of the long-term effects of plans and programmes. There is little guidance about how to apply these tools to cultural tourism, PICTURE provides a remedy for this and makes suggestions for more holistic approaches that take the long term into account and do not focus only on expected short term economic benefits.

6 European project details

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A study on the method for extraction of tourism-impact on a historical townscape: a case of the old town of Lijiang, Yunnan Province, China

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Key words: historical townscape, traditional houses, world heritage site

1 Introduction

1.1 Background and objectives of research

The objectives of this research are to understand the use of traditional houses and the actual status of architecture, to identify the associated tourism impact from the standpoint of maintaining houses in the old town of Lijiang (Yunnan Province, China, a World Heritage Site), while investigating the social background. This is part of an investigation of the problems related to the rapid development of tourism and its pressures on Lijiang, focusing on the architectural surfaces of traditional houses, and treating them as important elements constituting the historical townscape in Lijiang.

According to records kept by World Heritage Sites, many World Heritage Site cities have experienced sharp increases in the number of tourists in recent years, and it has been pointed out that these regions may not be able to cope adequately with the social and cultural impact of such increases [1]. On the other hand, there are almost no basic databases of the use of traditional houses and the actual status of architecture on World Heritage Sites, in particular regarding the relationship between the social impact of tourism and the architectural surfaces of traditional houses, which constitute the historical townscape in most World Heritage Sites. Although research in this field has been performed by several investigators, Yamamura [1], Drdácký [2], and Utsumi [3] have made pioneering studies that have produced tangible social data through on-site studies of the relationship between the urban transition and the tourist industry. Consequently, there is a lack of specific policy measures and management of tourism with respect to most World Heritage Site cities, and a lack of ability to cope with these phenomena. Although World Heritage Site cities in China in particular have experienced rapid surges in prosperity in recent years thanks to the tourist industry, almost no data has been accumulated or research studies performed on what has taken place as a consequence of these activities. As a result, it is extremely difficult to assess the value of the heritage and legacies within the rapidly changing public spaces and communities that deserve to be preserved in good condition and passed on to future generations.

In view of the above background considerations, the author of the present study, who is member of a joint research team from Kyoto Saga University of Arts (Japan), Peking (Beijing) University (China), and Wakayama University (Japan), believes there is an urgent need to compile a database of the use of traditional houses and the actual status of architecture in World Heritage Site cities, and to identify the spatial and social impact caused by being listed as a World Heritage Site and the transition into a tourist destination. The method of this investigation is not only applicable to research on a European Heritage Site but also steering maintenance of a European historical townscape.

1.2 Related studies and characteristics of the present research

There appear to be no cases of comprehensive databases concerning the spatial and social elements that constitute a World Heritage Site city, even if one searches worldwide for examples with a narrow focus. With respect to useful materials about the old town of Lijiang, there is a 1997 study by Jiang summarizing the spatial structure of streets and waterways [4] and a series of studies by Yamamura [1, 5] concerning the transformation of residential structures. This study shares an awareness of the issues involved in such research; moreover, it is very useful in terms of materials and originality with respect to the following three points: (1) it is focused on the importance of adequately protecting the totality of a World Heritage Site city, including the surrounding local social and cultural environment as well as buildings and other elements of the physical environment; (2) it is an initial attempt to compile the social elements of Lijiang into a comprehensive database; and (3) it attempts to make a multifaceted analysis of the impact resulting from its listing as a World Heritage Site and its transformation into a tourist destination, based on primary materials from fieldwork.

1.3 Outline of Lijiang

Lijiang Municipality is located in the northwest corner of Yunnan province in southwest China (Fig. 1). The old town of Lijiang is the historical centre of the city and the great majority of the populations are *Naxi*, an indigenous ethnic minority group, who retain their own language, pictographs and religion [6] (Fig. 2). The old town of Lijiang was listed by UNESCO as a World Heritage Site in December 1997 in appreciation of the architecture of its dwellings and the historical townscape as a collective entity. The old town of Lijiang has a population of 13,780 housed in some 4,564 wooden dwellings crowded into an area of 350.2 ha [7]. The entire old town was designated as a conservation area by the government of Yunnan Province in 1997. Yamamura [1] has already reported that it would seem reasonable to regard 1995 or thereabouts as the turning point, that is, the time when the increase in the number of visitors to Lijiang and the emergence of the business category of tourism began.

Figure 1: Location of Lijiang

Figure 2: Vista of the old town of Lijiang

2 Research methods

With regard to methodology, the research was carried out on-site according to the four viewpoints established below, in order to clarify the present condition of the traditional architecture in the old town of Lijiang. In addition, the causal relationships with the social background are taken into consideration.

2.1 Urban composition and residential types of the old town of Lijiang

In general, it is impossible to obtain an accurate residential map of the old town of Lijiang. Therefore, satellite photographs taken at the beginning of 2004 were used to analyze the relationship between the city and the arrangement of architecture, as well as to understand the urban structure of the old town of Lijiang.

2.2 The characteristics and altered appearance of the composition of the exterior walls of the traditional architecture

In 1997, the main townscape of the old town of Lijiang had already been compiled into data as a series of elevations in the research of Jiang, *et al.* [4]. However, it is impossible to comprehend the materials or finishes of each building based on these elevations. To compensate for this, detailed research on the condition of the exterior wall finishes of the architecture has been done in this research and their characteristics are clarified. By a comparison between the series of elevations drawn by Jiang, *et al.*, and an original [i.e. new] series of elevations made in 2004, the changes in appearance up until now are clarified.

2.3 Changes in the way of living in traditional architecture

The traditional architecture in Lijiang was measured, and accurate plans, sections and elevations were drawn. Furthermore, the research team talked with the owners of the houses, and made each drawing a reflection of the former usage of the house and the reality of its current usage, in order to understand changes in the building usage. With regard to the seven survey subjects taken up here, by means of original discussions between the research team and the owners of the buildings in question, the subjects taken up in the measuring investigation were arbitrarily chosen.

2.4 Legal and administrative policies in the old town of Lijiang

An investigation of the administrative policies concerning building regulations currently applied to the old town of Lijiang, and while grasping these facts, verifying the influence they have on the traditional architecture in the old town of Lijiang.

3 Results

3.1 Urban composition and residential types of the old town of Lijiang

At present, the dwellings seen in the old town of Lijiang can be classified into the following five types:

1. The “*si he yuan*” – type, a courtyard house with four wings enclosing an inner courtyard
2. The “*san he yuan*” – type, with three wings and a wall enclosing an inner courtyard
3. The type with two wings in an L-shape, or parallel bars enclosing an inner courtyard
4. The type with one building and a front garden
5. A combination of the above-mentioned types.

Fig. 3 is a rooftop photograph of the area around “the central square” (note 1) in the centre of the old town of Lijiang. While on the one hand the “*san he yuan*” and the “*si he yuan*” (note 2) have a uniform direction and are systematically aligned, buildings in places along the highway and facing the central square are arranged in rows along roads, plazas and waterways. This area was once a commercial area that prioritized its facilities as a trade city, and is now a sightseeing area. In other words, patterns such as the *san he yuan* and the *si he yuan* are absent in the commercial area, and the arrangement of two-building structures in an L-shape or parallel bars shape, or the arrangement of single building structures, continues irregularly along the topographical features. Most of them face the road and contain a shop, and are houses combining residential and commercial facilities.

Figure 3: A rooftop photograph of the area around "the central square"

3.2 The characteristics and changed appearance of the composition of the outer walls of traditional architecture

In the series of elevations reproduced in (Fig. 4), the elevations above are those made by Jiang, *et al*. of a given street, while the elevations below are those made by the research team. In comparing them, the following four points can be identified.

1 The changes are concentrated in the openings
2 A section can be recognized in which the single-story houses have been changed into two-story houses
3 Buildings can be seen in the blank spaces in the elevations plans by Jiang, et al. i.e. buildings have been constructed
4 The external form of the townscape has not changed significantly

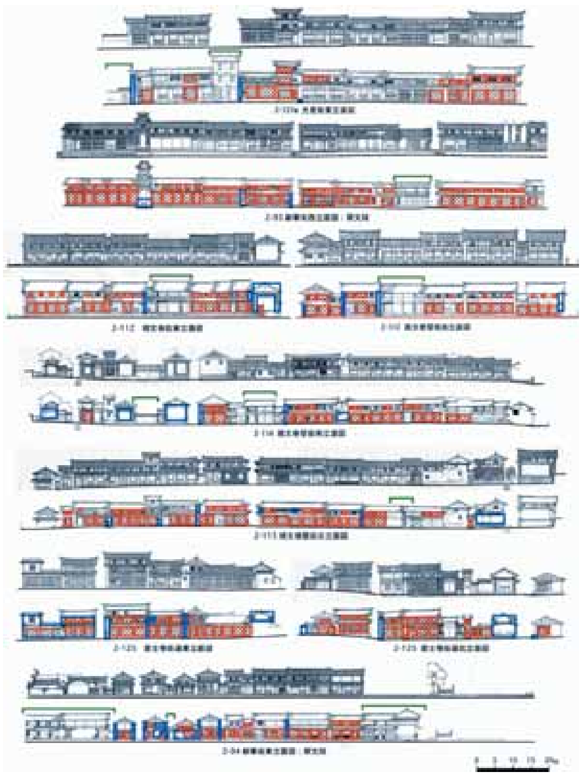

Figure 4: The series of elevations

While there are elements that become clear through the above-mentioned comparison, it is impossible to read the details of the exterior wall finishes from such serial elevation plans. Therefore, in the research carried out by this research team, attention is also paid to exterior wall finishes, and after making the outlines, they are arranged and classified. In other words, the exterior walls of traditional architecture seen in the old town of Lijiang are entirely constructed of stone on top of a platform, and this finish can largely be divided into three types as shown below:

1. Sun-dried brick (Fig. 5)
2. Plaster on top of sun-dried brick (Fig. 6)
3. Plaster on top of sun-dried brick and brick piles on the four corners (Fig. 7)

Figure 5

Figure 6

Figure 7

Among the above-mentioned exterior wall finishes, it is possible to arrange them in the following way, based on the types of bricks and the ways of stacking the bricks.

1. Blueish gray bricks that measure approximately 280 × 160 × 40 (mm) and were used prior to the establishment of the People's Republic of China in 1949 (note 3) (Fig. 8)
2. Blueish gray bricks that measure approximately 230 × 110 × 50 (mm) and were used after 1949 (Fig. 9)
3. Reddish brown bricks that measure approximately 230 x 110 x 50 (mm) and were used after 1949 (Fig. 10)
4. Hexagonal, irregular bricks, or bricks that do not fall under categories 1 through 3 (Fig. 11)

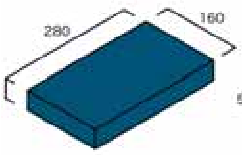

Figure 8

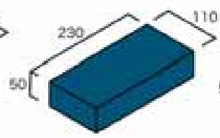

Figure 9

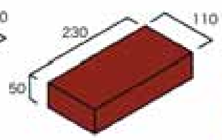

Figure 10

Figure 11

These bricks can be divided into three types of stacking. However, there are many buildings where a mixture of bricks or various types of stacking are used within one building (Fig. 12), and we can consider these as traces of repeated repairs.

1. Displaying alternating courses of bricks lying flat and bricks standing on edge, with additional bricks on edge between each of the bricks in the standing courses (Fig. 13)
2. Displaying alternating courses of bricks lying flat and bricks standing on edge (Fig. 14)
3. Flat stacking showing only the edges of the bricks (Fig. 15)

   

Figure 12 *Figure 13* *Figure 14* *Figure 15*

Furthermore, aside from these finishes of stacked bricks, there are those where the mortar or concrete wall surface is painted gray, and where the joints of the bricks are delineated with white paint (Fig. 16). Furthermore, due to the influence of tourism in recent years, imitation wall finishes such as log-house decoration or piled rocks have started to appear, and these are mostly to be seen in the shops in the vicinity of the central square (Fig. 17).

 

Figure 16 *Figure 17*

3.3 Changes in the way of living in traditional architecture

As far as the changes in the way of living are concerned, the research team randomly picked seven houses to survey, but here I will report on "60, *Zhongyi* Alley, *Guangyi* Street", where we obtained the most detail from questioning. This house is occupied by a married couple and is also used as a guesthouse.

According to traditional custom, the usage of each room was fixed, but due to changes in the composition of the inhabitants and its employment as a guesthouse, the modes of usage have changed. In addition, one remarkable change is the fact that when the house began to be used as a guesthouse, additions such as a toilet and a shower room were made (Fig. 18).

Figure 18: Plans and Section on “60, Zhongyi Alley, Guangyi Street”

3.4 Legal and administrative policies in the old town of Lijiang

The traditional architecture making up the old town of Lijiang comprises mainly residential buildings or combinations of shops and residences. These houses can broadly be divided in the following two categories, based on the composition of the exterior walls facing the street traffic.

1. Houses in which the exterior wall of the first floor facing the street is composed of wooden doors whereby the interior space can be opened to the street if necessary (Fig. 19).

2. Houses in which the exterior wall of the first floor facing the street is composed of a wall without windows, and where an entrance that links to the inner courtyard is the only opening connecting the residential part with street traffic (Fig. 20).

Figure 19

Figure 20

However, in recent years exterior wall compositions of houses that cannot be classified in categories 1 or 2 have appeared. These can broadly be classified as follows:

1. Houses which originally belonged to type 2 (discussed on the previous page), but which due to a change from private usage to usage as a shop or guesthouse have been altered to include a window or door in a wall that previously had no openings, in order to open it for street traffic (Fig. 21).

2. Houses that are used as shops, and that originally belonged to the first type with wooden doors (discussed on the previous page), but which now have a display window with glass and ornaments instead (Fig. 22).

Others, such as houses in which the structure has changed due to repairs, alterations or reconstruction (Fig. 23).

Figure 21

Figure 22

Figure 23

Among these examples, the first type originated from those that were traditionally used for private purposes but changed into guesthouses and restaurants due to the rapid development as a sightseeing location brought about by recognition as a World Heritage site in 1999. The appearance of the second type is also connected to the development of tourism and originated from a money-making point of view in anticipation of the advantages of groups of visitors, and which is especially obvious in the facades of restaurants and souvenir shops. For the third type, various social causes may be taken into consideration, but one very important cause was the effect of the earthquake in 1997.

The research team looked at the legal system and administrative policies in the old town of Lijiang on the basis of the above-mentioned facts. Presently, as far as administrative policies are concerned, there is the "Application form for Examination and Approval of Building Construction and Maintenance. Old Town of Lijiang" enforced by Office of the Lijiang Ancient Town Management Committee and Urban Construction Bureau of the Old Town District, Lijiang Municipality, as well as the "Government of Yunnan Province (1997) *Conservation Detail Plan for Lijiang Old Town*. Government of Yunnan Province, Kunming," enforced by the "Urban & Rural Planning & Design Institute of Yunnan". The "Application form for Examination and Approval of Building Construction and Maintenance. Old Town of Lijiang" comprises official documents that must be submitted in case of the new construction or reconstruction of residential buildings in the old town of Lijiang. The "Government of Yunnan Province (1997) *Conservation Detail Plan for Lijiang Old Town*. Government of Yunnan Province, Kunming" does not have the power of legal restrictions, but provides guidelines for new construction and reconstruction [8]. We must pay attention to the contents of the "Application form for Examination and Approval of Building Construction and Maintenance. Old Town of Lijiang". It appears to be premised on an ethic that exists as a tacit understanding among the *Naxi* people, and *Naxi* culture traditionally formed as a vernacular dwelling environment. In other words, the content of the application does not request specification of the composition or the surface finishes of the building, but it is rather a presentation of the opinions of the people living adjacent to the targeted site, which is deliberated upon by the authorities.

Therefore, the composition and the design of a building is entrusted to the ethics of the residents. On the other hand, through the research of this research team it has become clear that the composition of the population in the old town of Jiliang, once mainly made up of *Naxi*, has received a strong influx of Han people because of the prosperity of commerce brought about by the change into a tourist site. Therefore it is necessary to consider the relation with administrative policies based upon the ethics of the residents.

4 Conclusion and implications

The elements, clarified through research, are arranged according to the four viewpoints.

4.1 Urban composition and residential types of the old town of Lijiang

1. The old town of Lijiang has a two-layered urban structure: an area centered on living, where san he yuan and si he yuan are aligned, and a commercial area with combined living and commercial spaces.
2. The development as a tourist location is mainly visible in the commercial area.
3. In the tourist area, progressing with its development as a tourist site, are a large number of dwellings that do not belong to the san he yuan or si he yuan type, and that comprise a district of shops selling tourism-related goods.

4.2 The characteristics and changed appearance of the composition of the outer walls of traditional architecture

1. The outer wall finishes of traditional architecture in the old town of Lijiang can be broadly divided in three categories.
2. A finish imitating the stacking of bricks was discerned in the exterior wall finishes of buildings.
3. In the exterior walls visible in the vicinity of the central square, imitations aimed at the tourists can be discerned.

4.3 Changes in the way of living in traditional architecture

1. As far the usage of each building or room is concerned, there exists a hierarchy even today, in which the changes in lifestyle continue. Concretely, the first floor of the main building on the north side is the most important place in the living space, and compared to the other rooms it has the highest place in the hierarchy. On the other hand, the hierarchy has disappeared in the other rooms that have been turned into guesthouses, and in each room on the second floor.
2. In order to run a guesthouse, a toilet and a shower room are necessary, and these were remodeled together with the repairs carried out after the earthquake.

4.4 Legal and administrative policies in the old town of Lijiang

1. Under present administrative policies and legislation, decisions are made by the residents.
2. It is necessary to consider the relationship with administrative policies based on the ethics of the residents following the increase in the influx of people from outside.

From the above, we can identify two elements connected to the changes in the traditional dwellings and the historical townscape brought about by the impact of tourism on the old town of Lijiang.

1. The research team discerned changes in the traditional architecture of the old town of Lijiang influenced by the increase in tourism and other social influences.
2. The preservation of the traditional architecture in the old town of Lijiang is connected to the consciousness of the inhabitants.

Considering these conclusions, especially the second conclusion, the government policies on new construction, reconstruction, or repairs of housing in the old town of Lijiang do not regulate finishes or the composition of the buildings themselves, but are decided upon on the basis of traditional *Naxi* culture and the ethics of the residents, as stated above.

On the grounds of the traditional buildings before their recognition as World Heritage Site and the various changes that have occurred until now in the traditional townscape, we can identify that the *Naxi* culture in the town areas and the ethics of the residents have weakened due to the influx of non-*Naxi* people into the old town of Lijiang. Furthermore, because the present administrative policies are now decided on the basis of traditional *Naxi* culture and the ethics of the residents, such a policy does not function for new construction, reconstruction or repairs in the present situation of a changing population composition, and we can also say that these changes are shown as stated above, as far as the traditional buildings are concerned.

World Heritage City Lijiang differs from ruins or natural scenery, and has a high merit because it is still a dwelling space where the *Naxi* live. Therefore, the traditional architecture of Lijiang has been developed through influence on lifestyle from the surrounding people, foremost the *Han* people and the *Bai* people, and rather than the buildings themselves having their own distinctiveness, the uniqueness is found in the lifestyles within these buildings based on an etiquette particular to the *Naxi* people.

From this, we suggest as an urgent theme that administrative policies appropriate to the present conditions based on an understanding of these lifestyles are implemented.

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Notes

1. "The central square": plaza located in the centre of the old town of Lijinag. The market was formerly located here.
2. "San he yuan" and "si he yuan": traditional Chinese building style in which an inner courtyard is enclosed by three or four buildings.
3. "1949": based on information received on-site by the research team through conversations.

Tourism and multicultural heritage: tools for participation by low-income residents

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Key words: tourism, geographic information systems for participation, urban design

1 Introduction

In cities throughout Europe, leisure and tourism provides a powerful catalyst for regeneration and renewal. Adjacent to city centres, there are run-down and neglected neighbourhoods that are rich in built heritage, but poor in most other respects. Public resources are often over-stretched. Nevertheless, city governments – sometimes with external support – select particular historic districts and invest in the public realm of streets and other public spaces to create an attractive setting that will accommodate visitors, including international tourists. Thus, they seek to pump-prime an emerging visitor economy that is expected to deliver a wide range of benefits, including the re-use, restoration and conservation of redundant or under-used historic buildings. More broadly, it is anticipated that it will stimulate the urban economy, create new jobs and enhance the city's appeal as a destination for cultural tourism.

Over the past ten to twenty years, there have been some remarkable transformations of neighbourhoods that seemed unlikely destinations for urban tourism. These include inner city areas whose very street names were once associated with the marginalisation of low-income residents, especially immigrant communities. The (re-)presentation of such areas as "cultural quarters" has generated new business opportunities, inward investment and badly-needed employment. However, in some cities, the increasing number of tourists may become intrusive. Disturbance and noise continues late into the night, crime and anti-social behaviour becomes problematic [1]. "Disneyfied Latin quarters" may displace established communities, accentuating social and ethnic tensions beyond the tourist bubble [2]. The authors reflect upon this pessimistic prognosis, and whether this process of "gentrification" is inevitable.

The paper considers the rejuvenation of a historic but disadvantaged inner city area close to the city centre of London, where a two-year long consultation project led to a profound re-think. Previous assumptions as to local preferences were questioned as the ethnically diverse local communities became actively involved in proposals to re-design and upgrade public spaces to make the area more accessible, safer and attractive for local users as well as visitors. It introduces a technique that will build upon this experience, through a pilot project that will test and develop an innovative use of Geographic Information Systems for Participation (GIS-P). The authors welcome discussion on the broader application of their methodology, especially in historic cities across the Enlarged Europe. They invite comments on its potential as a tool to support urban designers and other practitioners who are working to deliver significant improvements to the public realm of historic cities.

2 Regeneration and multicultural heritage in London’s City Fringe

In countries such as the UK, there is concern that, despite the remarkable “urban renaissance” of recent years, within a short walk of rejuvenated city centres there are disturbing contrasts between rich and poor neighbourhoods [3]. Showpiece restoration of “urban quarters” may heighten rather than reduce the disparities between conspicuous consumption and poverty [4]. To what extent can low-income residents and small businesses influence and benefit from initiatives whose main priority is to accommodate visitors, especially through upgrading of streetscapes and public spaces that provide the focus for community life? In London, policy attention has focused upon an area of severe disadvantage that is located within a short walk of the “Square Mile”: one of the world's leading financial centres.

In the mid 1990’s, its potential appeal to visitors as an “emerging cultural quarter” was highlighted by the City Fringe Partnership that brought together Local Authorities, public agencies and commercial interests, and successfully bid for central government funding to rejuvenate “some of London’s last historic quarters”:

“These cultural areas, unique to the capital and on the doorstep of the City, will be developed to provide a resource for tourists as well as employees and business visitors, helping to enhance the City's reputation as the premier European business location” [5].

In medieval London, this area was known as the “Liberties”. North and East of city walls, it was beyond the jurisdiction of the mayor and burgesses, as well as the powerful craft guilds. The area thus provided a home for marginalised groups and institutions whose presence was unwelcome within the city precincts. A short distance from the Port of London, it became home to immigrants from all parts of British Isles to successive waves of foreigners. For example, in the fourteenth century, a colony of cloth-makers from the Low Countries produced sailcloth for English vessels. In the centuries that followed others arrived, many fleeing religious persecution or poverty in their homelands.

From the sixteenth century, Sephardic Jews from Spain and Portugal prospered as moneylenders and merchants [6]. Protestant Huguenots expelled from France in the sixteenth and seventeenth centuries gave the word *refugee* to the English language and the area known as Spitalfields became their largest settlement. Their particular contribution to the urban economy included silk weaving [7]. By the early 1700’s, the area was by far the greatest centre of the textile industry in the capital, but industrialisation made their skills redundant. Most moved away, but others took their place. The expression ethnic and cultural succession is well illustrated by the *Neuve Eglise,* built in the early 1700’s, a non-conforming church that stands at the corner of Brick Lane and Fournier Street [8]:

“The original congregation declined as the French-speaking minority intermarried and became absorbed, until in 1809 the church was taken over by the London Society for Promoting Christianity among the Jews. In Victorian times, it served as a Methodist chapel until the influx of north European Jews to Spitalfields at the turn of the century. In 1898 it was converted into the Great Synagogue. From the 1960’s, the Jewish congregation dwindled, and the building closed again. It was reopened in 1976 as the London Jamme Masjid, one of the largest mosques in the capital, with a capacity for 4000 worshippers in the prayer hall.”

As the Jewish population, which had been the dominant community in Spitalfields and adjacent Whitechapel moved away in the 1970’s, Bangaladeshi entrepreneurs acquired their former textile and leather workshops. The majority of the new immigrants found accommodation in low quality, often high-rise social housing, and the urban environment remained poor, with worn-out infrastructure and neglected streetscapes along roads where heavy through-traffic added to noise and atmospheric pollution. Elsewhere in the City Fringe area, other immigrants experienced similar hardship; these included Vietnamese, Somalis and Afro-Caribbeans. However, by the 1990's Brick Lane – the main thoroughfare and high street for the Bangladeshi community – was attracting visitors from the nearby City and international tourists, who were increasingly aware of its fascinating heritage, its street markets, cafes and curry restaurants. Furthermore, a growing community of artists and designers contributed to the "bohemian" ambience.

This nascent visitor economy was given a significant boost by another regeneration programme called "Cityside" – (1997-2002), whose overarching strategy was to "strengthen links with the City and encourage diversification of the local economy", especially into leisure and tourism. Cityside's vision was to "achieve a quantum leap in the area's status as a visitor / cultural destination" [9]. Particular attention was therefore paid to the main access points to Brick Lane, including its pedestrian subways to improve perceptions of personal safety, and in 1997 Eastern-style gateways were erected, together with brighter street lamps, the design of which incorporated ornamental "Asian" motifs. In the same year, Cityside set up an initiative to enable street events – notably Bengali New Year and the Brick Lane Curry Festival – to attain a higher media profile, and "Banglatown" was adopted as a brand to promote Brick Lane as a mainstream visitor destination.

3 Visitors and contested "ownership" of public spaces

The rapid rise of Banglatown as a centre for ethnic cuisine greatly exceeded expectations. A survey carried out for Cityside noted that in 1989 there were only eight cafés / restaurants in Brick Lane, with a few additions in the early 1990's. Between 1997 and 2002 this rose to 41, of which 16 had opened 2000-2, making it "the largest cluster of Bangladeshi / 'Indian' restaurants anywhere in the UK" [10]. Meanwhile, a redundant Victorian brewery was converted to provide over 250 studios for artists and designers, bars, cafés, two nightclubs, specialist shops and an exhibition centre. This transformation of a run-down and somewhat shabby historic streetscape has undoubtedly brought wealth to ethnic minority-owned businesses, and has created significant employment opportunities; the same study estimated that the restaurants employed around 400 workers, of whom 96% were of Bangladeshi origin.

By 2000, the inadequate local infrastructure was highlighted as a key constraint to further development of the booming visitor economy. In response, an outline Environmental Improvement Scheme was drawn up that would close Brick Lane to motorised traffic: an idea that was presented as something of a "win-win" concept. Exclusion of vehicles would create a setting that would attract more visitors, as well as a more pleasant environment for local residents. Initial consultation suggested that public opinion favoured the proposal; Cityside and LB Tower Hamlets thus appointed consultants Buro Happold to design a detailed scheme to pedestrianise the street. The consultant urban designers were, however, fully aware of the sensitivity of local feelings and that over the previous decade, various proposals had floundered because of disagreements between opposing local interests or because of insufficient finance.

In the months that followed, it became increasingly apparent that many local residents, community organisations and businesses were sceptical; some were deeply suspicious and strongly opposed the proposals. Pedestrianisation had been advocated most strongly by a group of restaurateurs, who anticipated new opportunities for *al fresco* dining. However, the closing of access to goods vehicles would effectively mean that other local firms – especially those in manufacturing and wholesaling – would no longer be able to function. Some residents were against any further expansion of bars, clubs and restaurants, or late-night extension of their licenses. Unfortunately, a stormy public meeting led to physical blows and the police were called to break up an unseemly brawl in the town hall. It was anticipated that the overall aim of reducing traffic intrusion would receive much wider support. However, the scheme would have to be acceptable to the diverse local communities that lived, worked, owned businesses, shopped, socialised, worshipped and enjoyed their leisure time in Brick Lane.

The consultant urban designers persuaded their client that full pedestrianisation would be undesirable and unworkable; a comprehensive programme of consultation was needed and all local stakeholders must be actively involved in the decisions affecting their neighbourhood. The two-year programme of consultation and participation (2000-2) that followed, yielded a far more accurate picture of local opinions, and prepared the way for a more satisfactory scheme that would deliver significant improvements to the public realm by means other than permanent closure. Those who took part included residents from the socially and ethnically diverse neighbourhoods around Brick Lane, restaurants as well as other established businesses such as local shops, workshops and warehouses that had different requirements for access, loading and parking, community organisations, the police and other public services, as well as visitors.

Consultation methods combined the use of workshops to elicit the in-depth views and priorities of these different stakeholders, and questionnaire-based surveys to establish whether these were shared by a statistically acceptable sample of these various “constituencies”. Maintaining the momentum to ensuring that people were kept informed was an essential feature of the approach. The initial phase of the consultation programme sought broad agreement on the strategic principles of a scheme to create a more accessible, safe and attractive pedestrian environment. The second phase engaged the various stakeholder groups in detailed design work, including the choice of paving materials, design and siting of street furniture and landscaping, and the lay-out of crossings, loading bays and parking spaces. This included a drop-in exhibition that was held in a vacant shop, where a multilingual facilitator.

As with the workshops, the aim was to create an informal and constructive atmosphere in which a wide cross-section of the local population and all local businesses were given the opportunity to express their preferences. This process seemed to encourage a new spirit of optimism and confidence that the views of “ordinary” people would be taken seriously. When funding became available in 2002, firm proposals had been drawn up. As anticipated by the consultants, there was no unanimity on how the broad objectives should be achieved. Nevertheless, the scheme that was eventually chosen had been developed through a broad consensus that informed design solutions that would minimise conflicts between pedestrians and traffic, bars / restaurants and other firms, visitors and local residents. The key features of the scheme that was implemented (2002-6) can be summarised as follows:

Traffic management and traffic calming
In accordance with the wishes of the majority, Brick Lane was not permanently closed to traffic (although the option was kept open for timed closure of one section in the evenings at weekends 6 pm – 2 am, during the summer). The pavement has, however, been widened significantly, and made flush with the carriageway. Junction designs and priorities have been changed to slow down through traffic (the right of way now is now given to traffic emerging from some side streets). At most times, traffic is now sufficiently slow and the road narrow enough to make it safe to cross at many points along Brick Lane. Drop-kerbs make pedestrian crossings more accessible, especially for people using wheelchairs, others who are mobility impaired, and parents with pushchairs.

Local identity and street furniture
Banglatown’s identity would be reflected through public art and choice of materials, not through overt branding. Yorkstone flags (a paving material that had been used in Spitalfields since the eighteenth century) were used for footpaths; black tegula blocks

for road surface, with granite setts to demarcate between footpath / road. Public art, benches, street trees / planting and additional litter bins were located where appropriate, as guided by the consultation. Existing street lighting columns were kept if possible but complemented by feature lighting.

Parking and loading, maintenance and responsibilities
Although the area is well served by public transport, there has been a shortage of parking spaces, and places for delivery / collection of goods. Priority is given to short-term parking, and new restrictions have reduced maximum stay to two hours. Loading bays and parking spaces have been redesigned to make more use of the available space and to align them with premises. The consultants recommended a 'Brick Lane charter': the Borough would maintain the street effectively and ensure that statutory services repair and make good street works, while business and residential communities would play their part in helping to look after the public spaces.

4 Geographic information systems for participation (GIS-P)

The profound re-think of the approach to public engagement and participation described above, suggests some fundamental principles:

(a) City governments and regeneration agencies must identify the full range of "stakeholders": residents, local firms and community organisations, they must not allow one interest group to drive the scheme;
(b) Each "stakeholder" group must be allowed to contribute to the design process in a calm setting, and on an equal footing: with each other, as well as with practitioners who provide specialist expertise in urban design;
(c) Differences between the priorities and preferences of the various stakeholder groups are thus made transparent, and local knowledge is used to inform the formulation of design solutions, working down from broad strategic options to the fine-tuning of proposals.

With these principles in mind, a new inter-disciplinary research project called "InSITU" (Inclusive and Sustainable Infrastructure for Tourism and Urban Regeneration) is currently being carried out as a pilot study. Funded by the Engineering and Physical Sciences Research Council (EPSRC), its aim is to develop and test new tools to deliver significant improvements to the streetscape of historic but disadvantaged urban areas, using an innovative application of Geographic Information Systems (GIS) called Geographic Information Systems for Participation (GIS-P). GIS-P differs from other participatory GIS (as often called in the American literature) in that it is designed to give participants control of creating the data, rather than just manipulating other people's data [11].

InSITU will thus address the specific needs of communities in three cities in the UK where there is significant leisure and tourism-regeneration associated with built heritage: London, Manchester and York. The GIS-P tool will enable local people to influence urban design, so that the benefits for the locality can be maximised. The aim is to allow all participants – regardless of their expertise – to frame the issues and problems in their own terms. Their preferences will be articulated through local "panels", composed of representatives of different interest groups. Through these workshops, points of conflict and consensus will be made transparent and represented on multi-layered maps and plans that can be interpreted by practitioners who are working to create safer, more accessible and attractive public spaces.

The tool will thus be developed for use by key regeneration specialists, especially transport planners and engineers, land use planners, urban designers, conservation officers and heritage attraction managers. In each of the case study areas, “roundtables” will be convened to ensure that these relevant service providers are able to set out the specific issues that they would like to be discussed by the panels. Thus, they will highlight any requirements concerning the form of the output maps and may be used, i.e. to provide a useful input to policies, plans and programmes. Roundtable participants will meet again to review the outcomes of the local panels. The technique will be used to complement other methods of consultation and participation, such as public meetings, exhibitions and questionnaires, and the intention is to compare the results with the outcomes from these more established methods.

Through the case studies, the GIS-P tool can be used to enable local stakeholders to contribute at the critical stages of the design process. If proposals are in the preliminary phase, there may be a broad range of options upon which the public can express their views. Where they are relatively well advanced, the budget will be known, as will the design constraints, e.g. statutory services, safety and accessibility requirements, planning and conservation guidelines. Nevertheless, there will be choices that affect local users. These might include paving materials, type / siting of street lighting, design / location of bus stops, signage and other street furniture, design / location of landscaping and public art. Where works have been completed, the tool can be used to enable users to evaluate the improvements, and to identify outstanding problems that have yet to be addressed, e.g. street cleaning, removal of graffiti, repair of damaged pavements and benches.

The research team anticipates that the following features of the GIS-P tool will enable it to make a valuable and distinctive contribution to street design:

1) Focus group / workshop discussion is integrated with spatial and temporal expression of participants’ views and preferences (GIS-P mapping);
2) The GIS-P maps are multi-layered to compare the opinions and priorities of different local stakeholders, e.g. residents in different age or income groups, local shops versus tourism-oriented businesses;
3) This leads to spatial and temporal analysis of points of consensus or conflict, as a preliminary to the generation solutions that are feasible within the available budget, planning and conservation guidelines, etc.;
4) The process is re-iterative and progresses from strategic design principles through to detailed, site-specific issues, e.g. choice of paving materials, street lighting, landscaping;
5) The results are presented on high-quality digitised maps that can easily be interpreted by urban designers, conservationists and others who will implement the proposals.

5 Public space and democratic participation in the enlarged Europe?

As outlined in the section above, the research consortium will work in collaboration with city governments, regeneration and development agencies in the UK to widen participation in urban design. The aim is to enable participants – regardless of their expertise – to articulate views and preferences in their own terms. The authors therefore welcome critical discussion on whether their methodologies might be transferred and applied to other European cities, where a visitor economy is being nurtured to revitalise historic but disadvantaged urban areas. A decade ago, as the European Union was expanding from twelve to fifteen Member States, Ashworth and Larkham [12] highlighted the need for a pan-European approach to heritage presentation and interpretation that would embrace the diverse cultures of recent past and immigrants, all of whom are citizens of Europe. More recently, Sandercock [13] has argued the need to celebrate the beauty of "mongrel cities": cosmopolitan places in which difference, otherness, multiplicity, heterogeneity, diversity and plurality prevail.

In practice, considerable tensions must be overcome if this explicitly inclusive "European" approach is to be accepted across the Expanded Europe of twenty-five Member States. This paper has examined critically the transformation of a 'historic quarter' at the heart of London's East End through a regeneration programme that gave recognition to the special contribution of immigrants to the creative as well as economic life to London. Its objectives emphasised the historic and continuing role of ethnic minorities in the development of London as a 'premier European business location'. However, despite these good intentions, some local residents felt threatened by an influx of visitors more affluent than their communities; visitors who were encouraged to regard Banglatown as a somewhat bohemian and hedonistic 'party zone'. It seemed to many that the requirements of the fast-expanding visitor economy – with its restaurants, bars and night-clubs – was taking precedence over established firms, including local shops and other businesses that serviced everyday needs.

The case study illustrates how serious mis-readings of the 'wishes of the local community' can occur. A very public argument over 'ownership' and use of the public realm did little to foster confidence in local democracy. There was understandable concern that leisure and tourism-led regeneration might alienate and ultimately displace the very people who were supposed to benefit. However, through the programme of engagement and participation that ensued (2000-2), the area's multicultural communities were actively engaged and participated in proposals to improve the streetscape of their neighbourhood. When funds became available, the revised scheme (2002-6) was informed by this involvement of diverse local stakeholders. Through this process of negotiation, the solutions achieved the key objectives of delivering significant improvements to the pedestrian environment for the benefit of diverse local communities as well as visitors. However, this profound re-think seems to be exceptional.

Throughout Europe, studies of urban tourism and its social impact stress the importance of an appropriate and robust planning framework to facilitate sustainable development. In the years that followed the demise of Communism, this proved to be a particular challenge for many historic towns and cities in Central Europe. Hoffman and Musil [14] highlight the influence of air transport and promotion of Prague's spectacular built heritage on the rapid growth of a short breaks market in the 1990's. They observe that despite strong local opposition, the municipality could do little to prevent over-development of hotels and other tourism facilities that displaced residents from the Old Town and heightened social polarisation. Poland's former Tourism Minister Paszucha [15] highlighted the potential of tourism to restore and revitalise whole historic complexes, but he also emphasised that a 'firm plan' would be essential, since free market forces would inevitably pose a number of threats.

In the early 1990's, leisure and tourism-led regeneration seemed to offer significant opportunities for the UNESCO-listed World Heritage site of Kazimierz: a remarkable district of Cracow that features both Christian and Jewish Heritage. Tragically, after more than five hundred years of continuous settlement, the Jewish presence was abruptly terminated by the Nazi invasion. Under Communism much of the area's housing was rented to the city's poorest citizens and historic streetscapes deteriorated. From the early 1990's, selected premises were renovated and found new uses as 'Jewish-style' cafes, bookshops, restaurants and hotels; culturally important sites were restored as memorials to the Holocaust. Thus, particular streets became objects of the international tourist gaze. A nearby square became a fashionable, late-night entertainment venue for young Cracovians.

Neither *the Detailed Local Master Plan for the Historic Quarter of Kazimierz* (1987) adopted during the Communist era, nor the EU-funded *Kazimierz Action Plan* (1994-9) achieved the intended 'balance of residential, commercial and visitor uses' [16; 17]. Indeed, as residential and commercial premises became desirable, low-rent tenants and craft industries were displaced. In 2004, 'Friends of Kazimierz' was set up as a voluntary organisation, not only to promote events to visitors, but also to enable residents to discuss local issues. With regard to the public realm of Kazimierz, a number of key concerns are apparent. Many residents complain that pavement cafés and restaurants stay open too late, encouraging young people gather outside, drinking and listening to loud music on summer nights. In the daytime, tired tourists 'occupy' public squares, and parents complain that there is a shortage of space for children to play. There is anxiety that the new 'café society' will continue to expand and drive away the popular local markets that sell food, clothing and everyday items [18].

6 Conclusion

As Wolpole and Greenhalgh [19] observed, the best of public spaces have rhythms and patterns of their own, being occupied at different times by quite different groups, occasionally by almost everybody. Historic streets and other public spaces have the potential to provide a genuinely inclusive and pluralistic public realm for the benefit of local users as well as visitors. The examples discussed in this paper highlight their significance, and the strength of local opinions concerning their 'ownership' and use. Across the Enlarged Europe, city governments are increasingly aware that tourism-led regeneration does not provide a panacea to cure the ills of historic but disadvantaged areas. If the aim is to ensure that emerging visitor economy is sustainable and acceptable to 'host' communities, programmes of engagement and participation will be critical to success. The authors will be pleased to discuss with colleagues in other historic cities, how the proposed use of GIS-P might complement existing methods and techniques for consultation where city governments are encouraging an emerging visitor economy.

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A meeting point for diversity: research and valorisation on cultural landscapes in North Western Iberian Peninsula

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1 Introduction

During the last few years the Research Group *Social Structure and Territory – Landscape Archaeology* has developed research on theoretical and methodological questions and their application to various projects in Western Iberian Peninsula. The research work done in these projects on the change from pre-Roman to Roman ages has always taken into account its social projection, addressed both to the valorisation of Cultural Heritage and knowledge formation and dissemination. The linchpins of our research at a regional and national level are in the basis of the European co-operation network articulated by the Action COST A27 *Understanding pre-industrial structures in rural and mining landscapes* (LANDMARKS), proposed and chaired by our Research Group and are based in an enlarged scope in the Cultural Heritage consideration.

In fact, our point of departure is the idea that it is crucial – within Cultural Heritage research and management – to minimise the intrinsic value of particular objects (just a small piece of art or a big building). We believe that to approach the protection and enhancement of Cultural Heritage merely by the adoption of restoration or conservation measures is no-sense if empty of a cultural historic and diachronic framework.

Historical research (including archaeological approaches) has assumed that context is not only a useful working instrument but also a key methodological linchpin in the research strategy. History must be the basis of each intervention related to the Cultural (intangible or tangible) Heritage. That is the richness and that is the necessary intellectual depth of European Cultural Heritage: an integrative discourse in which common elements and particularities have their own meaning and role.

Within this context landscapes can play a relevant role within Cultural Heritage, both for its research and management. In fact, as we will argue, the concept of *Cultural Landscape* contributes decisively to the integration of Cultural Heritage in the politics of rural, urban, environmental, agricultural and social planning.

2 Landscapes and the European cultural heritage

Landscapes are a high synthetic expression of human relationships through time. According to this, the *Cultural Landscape* concept expresses the variety of manifestations produced by the man – environment interaction along history.

This articulated view of landscape is relatively recent, being the result of the work of various disciplines. Consequently, the concept of landscape admits multiple interpretations and approaches; but still a fundamental consideration must be made: landscape is not a static object; it is the manifestation of past and present processes. This temporal dimension defines the essential archaeological-historical character of landscape and leads it to play a relevant role in the present research and management of European Cultural Heritage.

The awakening of the relevance of landscapes as an essential part of European cultural-historic identity has marked, over the past several years, both the research trends and the new ways of management of Cultural Heritage. This is currently one of the priorities of European and International organisations. In fact several European centres are currently developing powerful and convergent research lines in this field from diverse disciplines (Archaeology, Law, Historic Geography, Rural History, Ecology ...) at different levels (local, regional, national or supra-national). Some of them have already constructed common projects or networks, such as *European Pathways to Cultural Landscapes* (EPCL), *The European Academy for Landscape Culture* (PETRARCA), *Mapping the Landscape and Cultural Heritage in the Wadden Sea Region* (LANCEWAD) or *Understanding pre-industrial structures in rural and mining landscapes* (LANDMARKS). The scientific attraction of the study of cultural landscapes is reflected in the progressive formation of a community of practice, practically implemented through several forums such as the *European Association of Archaeologists* or the *Europae Archaeologiae Consilium* (Fairclough & Rippon 2002).

This important role of the landscape within Cultural Heritage has been recognised by several legal dispositions both at a national and international level. The UNESCO integrated in 1992 the *Cultural Landscape* within the categories that articulate the *World Heritage Convention*; this underlined, for the first time, the growing importance of this figure for the valorisation and protection of Cultural Heritage. Moreover, the *European Landscape Convention* (Florence, 2000) is an important step towards the definition and role of landscapes as Cultural Heritage. And it is our task – as Cultural Heritage professionals – to define this character. Within historical - archaeological research, landscape is not the scenario in which the research evolves any more: landscape is the true subject of historical analysis (Orejas 1998). Space, as time, forms part of society: this is why the landscape can be defined as synthesis of the social, "of a definite space / time and in a process of change" (Sastre 2001, 25).

The present dynamics of landscapes in Europe present a downgrading, the effects of which have to be measured in the long term, both for the Cultural Heritage policies and populations' identity: the developing of urban centres and the abandonment processes of rural areas are traumatising trends that threaten the memory of this heritage today. A general equilibrium in landscape management within Europe is necessary in order to move the gravity centre from the historical cities, singular monuments or leisure centres to an integral territorial planning. By joining efforts and addressing the notions of *cultural landscape* and *sustainable development*, landscapes can act as crucial instruments for disseminating historical knowledge and protecting and managing European Cultural Heritage.

3 From regional contexts to European dimension: research on cultural landscapes in North Western Iberian Peninsula

Archaeological academic traditions and policies all over Europe provide different approaches to cultural landscape research and management. It is noteworthy that the work on landscapes as cultural-historic resource relevant to planning policies is more highly developed in Northern and Central countries of Europe than in the Mediterranean regions. While the transformation of present-day landscape is linked with sustainable management of the cultural landscape in Northern regions, the situation in the Mediterranean basin is different and generally oriented to the protection of landscapes in specific declared regions by figures such as "cultural parks" or "archaeological protected areas" that define limited areas of cultural and environmental relevance.

Despite these differences between Northern Atlantic Europe and Mediterranean Basin planning traditions the voices against the relevance of landscape both for interdisciplinary research and European Cultural Heritage policies are less and less.

3.1 Approaches to landscape: Spanish experiences

However, practical difficulties are still evident. In the case of Spain the big extent of the territory, the autonomy and different character of regional administrations, the plurality of working parties on landscape, the reduced budgets ... are serious obstacles to the setting of a common policy on landscapes. Moreover, cultural and natural heritage are considered two different heritages, with two independent administrations, two different education and information systems and, over all, they have two completely diverse degrees of social incidence: very strong for natural heritage; not so for cultural heritage. However, within this panorama, some of the regional heritage administrations are working with success for the unification of norms, administrations and action procedures on landscapes.

Several examples within the Spanish Regions show interesting proposals in this field; these are the cases of the regions of Catalonia and Valencia where regulations have been updated for the integration of cultural and natural aspects of landscapes in territorial management initiatives. Besides this in Catalonia an Observatory of Landscape has been recently created. The case of the administration of Andalusia is also a very good example. The *Instituto Andaluz de Patrimonio Historico* (Andalusia Institute for the Historic Heritage) has implemented some initiatives of interest, as the *Ensenada de Bolonia Project*, that has stimulated a comprehensive landscape project and produced a Guide of the Cultural Landscape that will serve as a model for future projects (Salmerón 2004).

The weight of synthetic historical – archaeological landscape research strategies in establishing a holistic understanding and management of the Cultural Heritage has also a good example in the Galician region. There, the creation of the *Galician Archaeological Heritage Network* can be mentioned; this is an organisational body created by the regional administration for the protection, conservation and dissemination of the Galician Archaeological Heritage. This Archaeological network is based on four parks (one per province) representative of the main cultural periods of Galician archaeology. Landscape, considered as a whole, is the fundamental basis of the network structure (Tallón *et al.* 2005).

The example of Las Médulas, in the province of Leon, stresses the important role research strategies need to have when determining the planning policies on landscapes. During the last few years, our Research Group *Social Structure and Territory – Landscape Archaeology*, has developed research on theoretical and methodological questions and their application to various projects in Western Iberian Peninsula (Orejas & Sánchez-Palencia 2002; Sánchez-Palencia, Orejas & Ruiz del Árbol 2005). The research work done within these projects has always taken into consideration its social projection, addressed both to the protection and valorisation of Cultural Heritage and knowledge dissemination and formation. Its results allowed the valorisation of Las Médulas as Area of Cultural Interest, which lead to its inclusion in 1997 in the World Heritage List.

3.2 Social structure and territory – landscape archaeology: research as a mean for cultural heritage protection and valorisation

The research line Social Structure and Territory is being developed in the Institute of History of the CSIC since the end of 1980. Nowadays seven researchers are integrated in our team through different projects and another ten collaborate in a co-ordinated way with us. From the very beginning, our work has been carried out with two main aims:

- The development of new methodological approaches and new research techniques from a Landscape Archaeology perspective (Orejas, Ruiz del Árbol & López 2002; Sastre 2004; Ruiz del Árbol 2004).
- The practical application of research results through mechanisms of heritage valorisation, planning and dissemination in the studied areas (Sánchez-Palencia et al. 1996; Sánchez-Palencia et al. 2002).

Our research line operates under the conception of landscape as a cultural synthesis of the social relations and the application of specific methods and techniques of analysis to enable its understanding. The aim is the study of provincial Hispanic societies, their processes of change, mainly in the transition from pre-Roman to Roman times, and their historic development during the Early Empire. Areas covered by our research are located in North Western Iberian Peninsula, in particular the ancient Astur territory; it has been amplified recently to the Western part of Hispania, Lusitanian and Cantabrian territories.

Studies of pre-Roman times in North-western Iberian Peninsula, addressed from this landscape conception, have allowed a new view of the archaeological record, both regarding the settlements and territories. From here, a review of social organisation forms has been carried out, and a model of domestic economy in segmentary societies has been proposed, based on the non-hierarchized communities and the spatial independence of settlements (Sastre 2002).

The study of the Roman period has been focused on territorial and social organisation forms in rural world including, as an essential element, mining areas. A broad range of aspects like the research on mining techniques, the study of the juridical status of provincial soil, the work in the mines, the analysis of agrarian structures and settlement models have been studied. The review of the traditional image of Roman influence over these territories has been possible, which turns out to be deeper than traditionally admitted. A social model has been proposed, being its main characteristic the rurality, which responds to Roman juridical, fiscal and administrative organisation forms, existent in other non urban areas (Orejas & Sastre 1999).

All this has been carried out from a non hierarchized research strategy, that incorporates interdisciplinary methods and uses both the archaeological record in a broad sense (including geoarchaeological and paleoenvironmental data, Ruiz del Árbol *et al.* 2003) and the ancient written sources, literary and epigraphic (Plácido 2002).

In our scientific projects we have always considered that History and Cultural Heritage research, valorisation and diffusion cannot be considered separately; because of that we have attempted to reach an adequate social projection of the results, especially through its dissemination to all the public: scientists, scholars, local population, children and visitors.

One of our most important actions, as we have already pointed out, is *Las Médulas Archaeological Zone Project* (Sánchez-Palencia 2000). Thanks to various projects (regional and national), our research team has carried out for a decade a systematic research of the area. Three stages have articulated our intervention there from 1992 to 2000:

- The study of viability of the area as a Cultural Park.
- The project for the construction of an Archaeological Information Centre and marked itineraries.
- The preparation of a Management Plan.

Besides all these, diffusion initiatives through publications, courses and exhibitions have been developed. One good example is the Madrid exhibition which took place in 2002-2003 in the Royal Botanical Garden that reached sixty five thousand visitors. Nowadays an agreement between the regional government of Castilla y León and the CSIC has been signed for the collaboration in all the scientific initiatives and Heritage actions in Las Médulas and other cultural landscapes in Castilla y León region. It is the present framework for a series of operations as the design of new Archaeological Information Centres, co-ordination of cultural and environmental initiatives, formation and dissemination activities, etc.

From 1997 till now, our team has been also responsible of various scientific projects on the Archaeological Zone of Las Cavenes (Salamanca) another rural area of the North-western Lusitania, where Roman mining activities had a strong impact. The study of this area, articulated on different projects, offers new data for a region very little studied up to now. There, the geo-archaeological approach has been decisive, both for the study of Roman mining and the agrarian structures. It is worth to say here that we have worked hard in the construction of a marked itinerary in the area (Sánchez-Palencia *et al.* 2003). The results of our research have lead to the creation of an Archaeological Information Centre and the development of future actions for the protection of the cultural landscapes in the area.

3.3 The integration of regional initiatives into the European context

The research and Heritage proposals managed by our research group are supported both by regional and national research projects. The main lines that guide these investigations are the linchpins for the international co-operation that our team directs through the Action COST A27 LANDMARKS and other international projects.

An historical – landscape perspective has three main requirements directly connected with the major aims of this integration of regional research and international collaboration. First of all there is the need of articulating different scales (from local studies to the international collaboration). Our work is nowadays supported by the national project (financed by the Spanish Education and Science Office) *Rural patterns in the Northwest of the Iberian Peninsula – Change and transitional processes in Antiquity* (TERRITORIA). The historical study of agrarian and mining structures as an expression of social relations in a wide sense is in the core of the aims of this project. Actually we broach historical problems shared by many European research teams and institutions both at a national and international level. The links with other departments involved in these research topics are important from 1980s, and particularly strong with the University of Besançon (France), the University of Leicester (UK) and the University of Perugia (Italy). The COST Action G2 (*Ancient landscapes and rural structures*), under the presidency of Monique Clavel-Lévêque, has been – between 1995 and 2001 – the meeting point for an important number of researchers. Thus, our research is inscribed in a European scope in methodological aspects, the role of regional projects and the interest in the protection of Cultural Heritage.

The second point we want to stress is the importance of a diachronic view in landscape studies. Landscape is diachronic and we cannot ignore it, even if our research focuses on ancient times. Historical research requires the analysis of large series of pre-industrial elements particularly sensitive and breakable, fragile due to land use quick and violent changes in the regions traditionally devoted to the agriculture or mining exploitation. Industrialisation, large-scale production, etc. have introduced dramatic modifications in landscape. Currently the abandonment of traditional practices promotes a quantitatively and qualitatively important change.

Thirdly there is the necessary connection of research, Cultural Heritage protection and dissemination. It is also an axis in our programmed research as we have developed in the precedent paragraphs. Besides this, the stable connection with other Spanish scientific institutions (Universities of Jaén, Santiago, Teruel, Autónoma of Madrid, Complutense of Madrid, Autónoma of Barcelona, Seville, Murcia) makes it possible the efficient articulation of research work and the development of common initiatives. In fact at the Spanish level we are really working as a network and it should be inscribed in a major-scale network through the COST Action LANDMARKS. It's for us a significant point: our capacity of enlarging research through contacts both at the national and the international level.

4 Conclusions

In the current state of the art, further historical – archaeological work is needed to underline the crucial place that the cultural landscape occupies in establishing Europe's common Cultural Heritage. Research and action on the landscape have to be integrated in an inter- and trans-disciplinarian approach as it crosses the borders of various disciplines (archaeology, history, historical geography, environmental approaches) and sectors (planning policies, agriculture, housing, infrastructure) within an European context. This is why the proposals of our COST Action A27 had a double departure point: our own research and the knowledge of parallel trajectories in other research groups in Europe.

Within current trends towards horizontal and interdisciplinary work increasingly imposing in humanistic studies, one of the main contributions behind our research projects is its potential for crossing borders within Cultural Heritage research and other disciplines within Europe. Moreover, our proposals have the novelty of putting forward the study of cultural historic identity as a determining factor in the future spatial design of Europe.

Our work aims to get over one of the problems currently presented in the knowledge and conservation of cultural landscapes: the homogenisation of Europe that hides its regional diversity, giving rise to excessively rigid interpretations and unbalanced policies within Europe (or the lack of these for some territories). Moreover, one of the strengths of our initiatives is the convergence that exists between it, the scientific interests of several European research teams and certain priority lines in the European common policy on landscapes.

In this context (as part of plural and working parties) Cultural Heritage professionals have the opportunity of putting forward the study of cultural historic identity as a determining factor in the future spatial design of Europe. Moreover, we can contribute to the spread and development of new visions of landscape understanding and management linked to technology transfer and knowledge application, and involving sectors such as cultural heritage, transformation of agrarian economies, cultural industries and others.

The FP6 has provided a response to the strong demand for access to scientific knowledge and adequate cultural training. The Thematic priority 7 has proposed the necessary link between research and the emergence of new forms of cultural identity. Our projects want to be a direct response to these expectations by proposing the study of European territories that share common historical processes but nevertheless reveal regional particularities. They also meet the requirement for developing new methods to improve the production, transmission and utilisation of knowledge, both through its multidisciplinary approach and by making cultural landscapes the subject of research and heritage management.

Moreover, both the rich European Cultural Heritage, based on the diversity and quality of its cultural landscapes, and the aspirations for creating an authentic "knowledge-based society", form an integral part of the development of the ideas and concepts relating to the creation of identities in the general context of European integration. It is our responsibility to avoid as far as possible the use of these reference points to distort historical reality. That is why it is essential for it to be founded on rigorous research that allows scientific knowledge to be obtained and disseminated. In this context, European Cultural Heritage can play a fundamental role as a means of providing society with access to the results of research. The current development of the landscape as a scientific and heritage concept responds directly to these expectations.

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Application of an air pollution modelling tool to cultural heritage buildings

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Key words: air pollution, modelling, building

1 Introduction

Air pollution from the outdoor environment whether it is from industrial, transport or domestic sources has long been recognised as a significant agent of deterioration of cultural heritage collections housed in museum, gallery, archive and library buildings. [1]. Past responses to the need to understand the behaviour of reactive air pollution in museum buildings (reference to museum buildings throughout this paper includes all cultural heritage building types) have largely been based on measurement techniques. In the last couple of decades, with the widespread availability of personal computers, mathematical modelling has also begun to be used to understand air pollution behaviour and effects on collections [2]. Many of the models have been adapted from the public health field where they have been used to predict exposures to pollutants of humans inside buildings. This paper describes the application of a Java applet based on the mass balance equation of Weschler et al. [3] for non-specialist use by conservators, architects and engineers, to predict damaging pollutant exposure of collections in the indoor environment. The Weschler equation relates the indoor/outdoor pollutant ratio (C_i/C_o) directly to building parameters: the air exchange rate (λ), indoor volume (V) and indoor surface area of materials (A), and their affinity for reaction with air pollutants which is expressed in the term deposition velocity (v_d):

$$\frac{C_i}{C_o} = \frac{\lambda}{\lambda + \bar{v}_d A / V}$$

This equation assumes that the principal mechanism for reactive pollutant removal in the indoor environment (assuming no filtration) is heterogeneous reaction, i.e. reaction between a pollutant gas and internal building surfaces. Homogeneous reactions (gas-gas interactions) are considered to be insignificant. Another underlying assumption is that the only source of pollutant gas is the external environment and that there are no indoor sources. The validity of these assumptions is discussed below. Gases that cause damage to the material heritage will, by definition, be those that have significant deposition onto indoor surfaces, be they objects or parts of the building fabric. The most important gases that are sourced outdoors have long been considered to be sulphur dioxide, nitrogen dioxide and ozone. Their main sources are, respectively fossil fuel combustion (sulphur dioxide and nitrogen dioxide), motor vehicle emissions (nitrogen dioxide) and photochemical reactions of those emissions (ozone). In domestic and workplace environments there may well be significant indoor sources of these pollutants, for example, nitrogen dioxide from gas heating and cooking appliances, and ozone from electrical appliances such laser printers and photocopiers. Such appliances are normally specifically excluded from collections spaces, so our assumption of no indoor sources is valid for these spaces.

Homogeneous reactions can also be discounted for sulphur dioxide but are known to play a part in the formation and decomposition of nitrogen dioxide and ozone [4]. The validity of this assumption will be discussed later in the paper.

The simple Weschler mass balance equation is useful for understanding the relationship between air pollution and collections. Objects and materials do not have the ability to metabolise pollution, but instead slowly react over time, accumulating damage with the overall pollutant dose (i.e. concentration over time) that they receive. The Weschler equation predicts the long-term average pollutant concentration, rather than the short-term dynamic concentration, minute by minute. A measure or prediction of long-term average pollutant exposure will be more relevant to the collection environment than a dynamic model for predicting object deterioration due to air pollution. Dynamic predictions of effects such as peak traffic hours, diurnal variations are more relevant for human health, where increases in concentration above a threshold can overwhelm people's ability to metabolise or adapt to pollution exposure.

2 Interpreting the Weschler Equation Parameters for the IMPACT Model

Interior volume and surface area. The building interior volume and areas of different materials are relatively easy to obtain, being calculable from building plans and an inventory of the main surface types and the area exposed to pollutants. Not every surface needs to be considered; it is sufficient to estimate up to the six most significant surface types.

Air exchange rate. The building air exchange rate can be measured using standard tracer gas decay or pressurisation testing techniques. These methods are rather specialised and expensive, and therefore likely to have been carried out on only the most prestigious heritage buildings. Therefore an estimate method is provided for users who do no have measured ventilation rates.

Pollutant surface deposition velocity. Though somewhat confusingly expressed as a velocity with units of cm per second or m per second, deposition velocity can be better understood as the flux of pollutant gas to a surface per unit time, expressed as m^3 gas per m^2 surface per second. Normalisation of these units gives velocity units, hence the confusing term deposition velocity. However deposition velocity usefully expresses how well a particular pollutant gas will react and deposit on a particular surface material, be that a historic object or building interior finish. Deposition velocity is usually measured in controlled laboratory experiments. In the IMPACT model these data were organised for the users so that the selection of a surface material would automatically select the appropriate value of deposition velocity for the pollutant gas in which they are interested. To achieve this, a large number of deposition velocity measurements were carried out on the types of material found in museum buildings, and existing literature data was critically evaluated. This work is described by Grøntoft and Raychaudhuri [5].

Gas-surface reactions can be reversible and re-emission can occur. The deposition velocity measurement method used expresses the equilibrium between deposition and re-emission, thus a gas which is not very reactive at surfaces will have a low deposition velocity since when it comes into contact with a surface there is a lower probability of reaction and decomposition, and it may simply be reemitted after a short time. This process of reaction and reemission is temperature and relative humidity dependent – the presence of adsorbed water on a surface increases its reactivity to pollutant gases, particularly for acidic reactions involving sulphur dioxide and nitrogen dioxide, and less so for oxidative reactions, such as those involving ozone. Therefore temperature and relative humidity are needed in the calculation. Fortunately relative humidity and temperature are parameters that museums and other cultural heritage organisations expend considerable effort on controlling and measuring, and these data will usually be available. Surface reactions involving sulphur dioxide are thought to result in non-reversible assimilation of sulphur dioxide as involatile sulphate, e.g. the accumulation of high concentrations of sulphate in materials such as leather [6]. Ozone is also thought to decompose fully at surfaces, but the reaction is less water-dependent than for sulphur dioxide, being oxidative rather than acidic in its chemistry. For nitrogen dioxide the situation is more complicated. It tends to have lower deposition velocities than the other two gases, indicating a lesser affinity for surface reaction. Where it does react on indoor surfaces it is believed to decompose to nitric (HNO_3) and nitrous (HONO) acids. Nitric acid is a strong acid and will cause damage to surfaces, whereas the weaker nitrous acid is volatile and over a period of several hours after deposition it is re-emitted to the air [7,8]. HONO is less reactive and therefore not a significant threat to materials, and is eventually removed by ventilation within the space. It is important to recognise the significance of surface chemistry as deposition is simply not the end of the story.

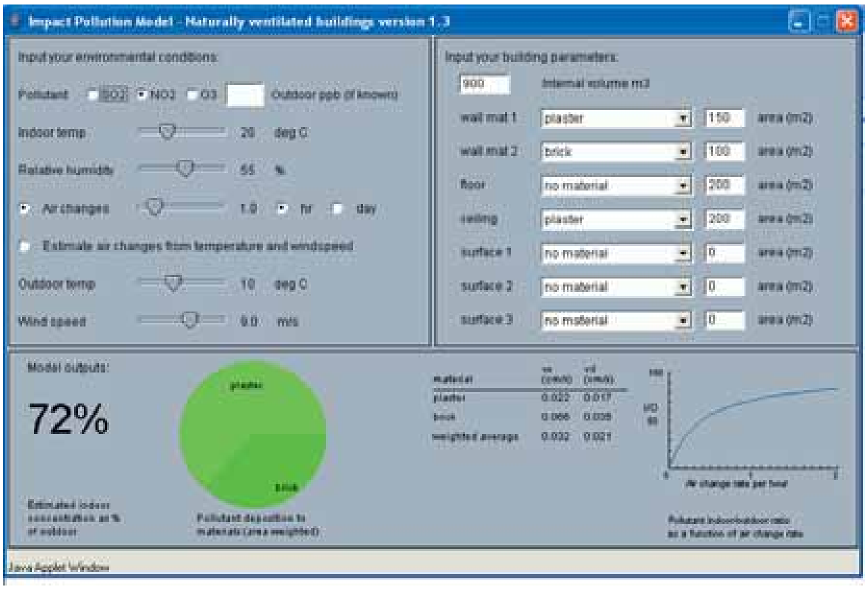


Figure 1: The IMPACT model computer interface. The model is written as a Java applet that can be accessed freely using any internet browser programme at: http://www.ucl.ac.uk/sustainableheritage/impact/

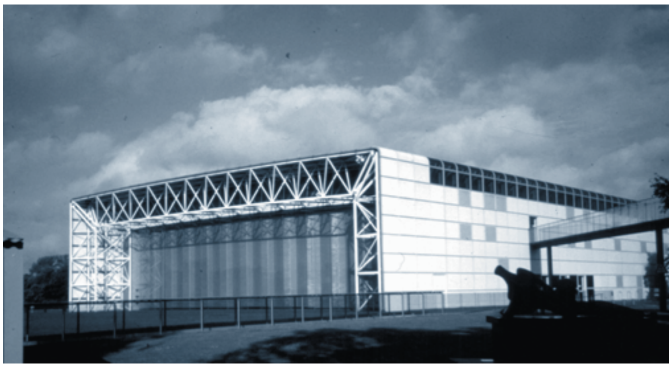
Figure 1 shows the interface of the IMPACT model implementation of the Weschler equation. The applet interface is divided into three sections: environmental inputs, top left; building inputs, top right; and outputs, below. It is not the purpose of this paper to describe the input process – a set of help pages are provided to do this. However, the model outputs will be described. These consist of: (i) the building I/O pollutant ratio for the gas selected; if the outdoor pollutant concentration is known, then this can be inputted and the model calculates the corresponding indoor concentration; (ii) A pie chart showing the relative amounts of deposition occurring to different indoor surfaces. It assumes all inputted surfaces are equally likely to come into contact with the polluted air. It does not take into account strategic location of materials, such as window and door materials that are closest to paths of infiltration. The pie chart gives a useful visual indication of the most important surfaces for pollutant removal. In some cases the most active surface may have one of the smallest areas, but it may play a greater role than might be anticipated due to its high deposition velocity. This output is also useful for appraising what happens to collections materials indoors – what will be the pollutant deposition to materials we wish to protect? Deposition to objects is particularly important when they form a large part of the surface area of a room, for instance paintings hung in a gallery, or tapestries on walls and historic carpets on floors; (iii) The model also outputs the deposition velocity values for the selected surface materials and (iv) a graph of I/O ratio vs. air exchange rate to show how building pollution levels will vary with differing air change rate.

3 Case Study Applications of the Model

The modelling of two case-study buildings will be described, demonstrating the application of the IMPACT natural ventilation model to the understanding of the interaction of buildings with outdoor air pollutants and the implications for the collections housed within them.

3.1 Sainsbury Centre for Visual Arts, University of East Anglia, Norwich, UK

The Sainsbury Centre for Visual Arts (SCVA) is an early building of the international architect Sir Norman Foster. When first opened it was unique among museum buildings in that collections, teaching spaces, offices, café and restaurant were all housed in the same open plan space. Note that the description, images and data presented relate to the SCVA prior to its major refurbishment in 2004-06. The SCVA has a rectangular design and is of lightweight construction with double skinned metal long sidewalls and huge glass end walls and a metal and glass ceiling. The inner surfaces of the sidewalls consist of a slatted metal skin, behind which is a layer of a chipboard-type insulation material. The floor of the gallery and restaurant area is carpeted whilst the lobby and café areas have synthetic hard flooring similar to linoleum.




Figures 2 and 3: The Sainsbury Centre for Visual Art, Norwich, UK. Figure 2, left: the metal and glass exterior; figure 3, right: the open plan gallery interior

Table 1: Data on the SCVA used in the modelling. Dimensions are taken from the architect's drawing and the ventilation rate was measured as described above. The model default values of temperature and relative humidity were used

Internal surfaces	Area [m^2]	Other parameters	
Metallic wall finish	2620	Room volume	42570 m^3
Metallic ceiling finish	4585	Air change rate	1.5 ach
Glass	528	Temperature	20 °C
Carpeted floor	4257	Relative Humidity	55%
Inner wall insulation	2064		

The SCVA has a simple mechanical ventilation and heating system with air intake using fans installed in the side walls. There is no facility for humidification or cooling. The ventilation rate of the SCVA was measured using the sulphur hexafluoride tracer gas decay technique. It was found to be 1.5 air changes per hour (ach), a comparatively high rate for a museum building, for instance a museum gallery of traditional 19th century design was found to have a ventilation rate of 0.7 ach. As a single zone building the SCVA was relatively straightforward to model using the IMPACT tool. The data in table 1 were used as the model inputs.

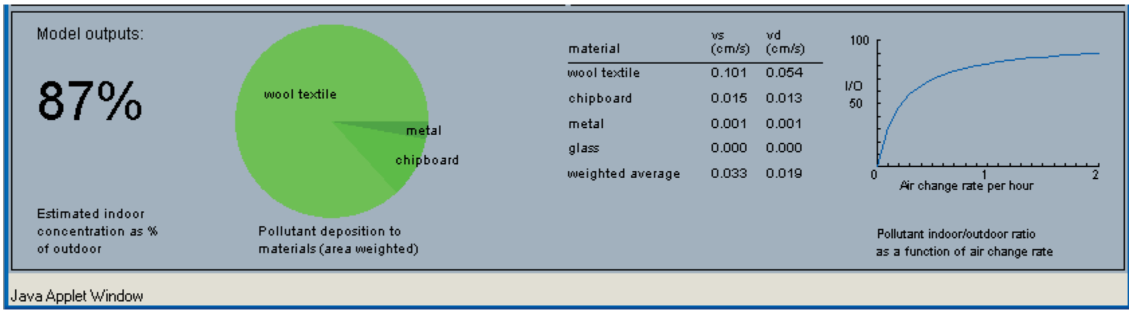


Figure 4: IMPACT model outputs for nitrogen dioxide at the SCVA using the inputs in table 1

The IMPACT model estimated the indoor/outdoor ratios (I/O) for the different gases to be: sulphur dioxide, 0.89; nitrogen dioxide, 0.87 (expressed as 87% in figure 4) and ozone 0.88. These ratios indicate a close relation between external air pollution and the building internal environment. The model outputs of deposition velocity and the area weighted deposition pie chart (see figure 4) show that of all the interior materials, only the wool carpet plays a significant role in absorbing or reacting with the outdoor pollutants, accounting for approximately 80% of the total deposition in the case of nitrogen dioxide and ozone and around 66%. The other surfaces are relatively insignificant as pollution sinks, glass not registering at all. The high air change rate of 1.5 ach also contributes to the high pollution level by drawing in fresh pollution into the building with the intake of fresh air.

The combination of these factors explains the high I/O ratios for the SCVA, exposing the objects on display outside display cases, to the virtually the same amounts of pollution as are present outdoors. Fortunately the SCVA is located in a semi-rural site on the outskirts of Norwich, in a relatively unpolluted location. Furthermore, most of the collection is exhibited in display cases, principally to act to stabilise relative humidity and temperature conditions, but also providing protection against outdoor pollutants. For objects on open display at the SCVA, the building design and construction do little to mitigate outdoor pollution; it is chiefly because the building is in an unpolluted location that there is little pollution threat to the collection. Were this type of building to be constructed in a polluted urban location much greater problems for the collection could be expected. The IMPACT model can also be used to explore changes to the building that could improve control of external pollutants, such as: (i) reduce the building ventilation rate; (ii) change the surface materials to increase their pollution absorbing properties; (iii) increase the surface area; or (iv) introduce mechanical ventilation with filtration. These measures are graded in the order of increasing intrusion, with (iv) involving major modifications to the building and unlikely to be acceptable from a design aesthetic.

The SCVA has a comparatively high ventilation rate, given the level of occupancy of the building, so it may be feasible to undertake measure (i) reduce the ventilation rate. For instance, a UK authority [9] recommends a fresh air ventilation rate of 10 litres per second per person. The SCVA with a volume of 42570 m^3 and an air change rate of 1.5 ach has a sufficient fresh air ventilation rate for occupancy of over 1700 people, much higher than the likely peak occupancy of the building, which receives in the order of 100,000 visitors per year. So there is scope to reduce the ventilation rate. From the graph of I/O ratio vs. air change rate in figure 4 it is apparent that substantial reduction in ventilation rate would be needed to make a significant difference to the I/O ratio. For instance, reducing the ventilation rate from 1.5 to 0.3 ach would reduce the nitrogen dioxide I/O ratio from about 0.9 to around 0.5. Practically this would entail improving the sealing of the building, especially the entrance doors, with the introduction of more tightly sealed lobbies or revolving doors. Such measures may still be insufficient in a building where people are coming and going all the time. This measure will also require consideration of the amount of cooling needed during summer. The SCVA is known to overheat on hot summer days [10], and reducing the amount of ventilation could make the problem worse. Pollution control issues cannot be considered in isolation from other building factors. The IMPACT model should be used as one of several tools or approaches needed to achieve a sustainable solution to museum environments.

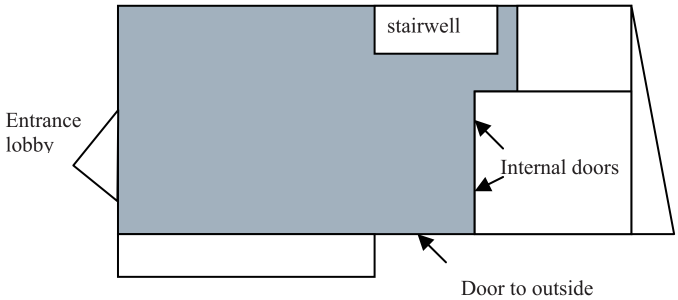
An alternative approach to pollution control that might be carried out with less impact on other aspects of building management, would be option (ii) change the surface materials to increase their pollution absorbing properties. Paints and other surface coatings with enhanced pollution absorbing properties are currently under development [11] for both indoor and outdoor applications. If we assume that such a paint finish may have a similar affinity for absorbing nitrogen dioxide as carbon cloth, currently the only enhanced absorber in the IMPACT materials database, then its effect can be modelled using IMPACT. The simulation assumes that the paint is applied to all the metal surfaces in the SCVA by modelling them as carbon cloth and that other parameters are unchanged. The modelled I/O outdoor ratios for various control strategies are summarised in table 2. The results show that introducing highly absorbing surfaces causes a greater reduction in pollution concentration than reducing the ventilation rate, but even with both these measures combined, the pollutant I/O ratios are still of the order of 0.6, a value that is often achieved in more traditionally designed and constructed museum buildings without the need for special measures. This reflects the open plan design of the SCVA, which makes it inherently difficult to control pollution by passive means. To achieve reductions of below I/O = 0.6 may well entail the installation of a full air conditioning and filtration system. As stated above the SCVA is in a low pollution environment and hence the indoor levels of pollutants are not as serious a concern, as they would be if it was constructed in a more polluted urban area.

Table 2: Comparison of pollution control methods on pollutant I/O ratios calculated by the IMPACT model

Model scenario	Sulphur dioxide	Nitrogen dioxide	Ozone
(a) SCVA without interventions	0.89	0.87	0.88
(b) Reduce ventilation rate to 0.3ach	0.76	0.78	0.78
(c) Introduce enhanced pollution absorbing paint	0.72	0.70	0.72
(b) and (c) combined	0.62	0.62	0.62

3.2 Archive store in a converted factory building, London, UK

The second building studied is an archive store, housed in a former factory building in an urban location that has been adapted for use primarily as a repository. It is a 1930's concrete structure with substantial floor slabs, and originally it had a large glazed area to provide natural daylight to the main factory hall. The glazing has been largely covered over in order to improve the security and to help achieve the thermal performance required from an archive building. The original open plan factory hall has been divided up into several rooms by partitioning, so that it is now one large rectangular repository with several smaller storerooms.



Figures 5 and 6: Interior view of the archive store and plan of the building (figure 5, left) Plan of the archive store ground floor (figure 6, right) with the modelled room shaded

The IMPACT model was applied to the main archive storeroom, treating it as though it were a single zone building. This was a reasonable assumption because doors to adjacent store rooms and entrances to the building are kept tightly closed most of the time. The storeroom will be largely exchanging air with the external environment, but there will also be some exchange with the adjacent internal rooms and through the stairwell, though this is also closed off by doors. The archive has made considerable efforts to seal up the building against the entry of dust and pollutants, but chiefly to stabilise the indoor climate. The surface materials inside the repository are quite different from those at the SCVA, being more reactive to air pollution. This includes the collections materials of paper, board and leather, which form a substantial proportion of the indoor surface area of the storeroom.

Table 3: Data on the archive store used in the modelling. Dimensions are taken from the architect's drawing and the ventilation rate was measured as described above. The exposed area of paper was estimated on the basis of the archive records of the run of used shelves in the repository. It was assumed that only book spines and the tops and ends of pages were exposed to the air. The model default values of temperature and relative humidity were used.

Surface	**Area [m^2]**	**Other parameters**	
Concrete wall	582	Room volume	7972 m^3
Chipboard window covers	214	Air change rate	0.3 ach
Synthetic flooring	1355	Temperature	20 °C
Concrete ceiling	1355	Relative humidity	55%
Exposed paper and book boards	6934		

The archive building relies on natural air infiltration to provide sufficient ventilation for the collection and the small number of people who use the repository from time to time. The ventilation rate was measured on a working day and a weekend with the result in both cases of 0.3 ach, indicating that the occupancy level on a working day did not lead to detectable changes in ventilation due to the opening of doors. In absolute terms, this measurement is also a low value reflecting the fact that the building has been well sealed. Using the data in table 3, the IMPACT model calculated the following of I/O ratios for the storeroom: sulphur dioxide 0.33, nitrogen dioxide 0.46 and ozone 0.34. These are much lower values than those calculated for the SCVA, and are a function of the low air change rate of this building and also the large amount of available surfaces with good pollutant adsorbing properties. Whilst at first sight these low I/O values may seem quite beneficial for the collection of archive material, a closer inspection revealed that much of the pollutant removal has been occurring by deposition onto the collection itself, as is evident from the IMPACT model output shown in figure 7.

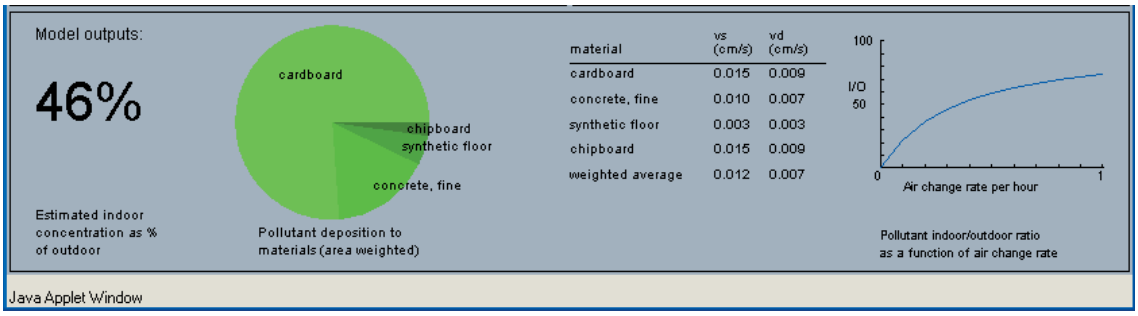


Figure 7: IMPACT model outputs for nitrogen dioxide at the archive store using the inputs in table 3. The absorbing properties of collections materials in the store (paper, end boards and boxes were simulated as 'cardboard' in the model)

The collection is the largest area component in the room, as was shown by the model output, but it also has the highest deposition velocity of all the materials present, greater even than the pollutant-reactive material, concrete that forms the building structure. Hence approximately 75% of the deposition of nitrogen dioxide and ozone and slightly less for sulphur dioxide is taking place on the paper collection itself. At first glance in might appear beneficial that the archive store has low I/O pollutant ratios, but as the IMPACT output in Figure 7 shows this is at the expense of pollution deposition and hence degradation to exposed collections materials.

3.3 Discussion

These two case studies demonstrate a number of important points when considering the effects of air pollution in buildings. At the SCVA the high I/O ratio indicated that, there is little pollution deposition taking place inside the building, but that introducing vulnerable objects or materials on open display would expose them to pollution concentrations comparable with outdoors. Conversely, at the archive store, the pollutant concentration is quite low indoors because the collection is acting as the main sink for the external pollutants that get into the building, quickly removing them from the air. Thus, a low internal air pollution concentration in this situation, where most of the deposition surfaces are objects that we wish to protect and not 'sacrificial' surfaces such as structural elements, building surfaces or decorative finishes, can be an indication of the damaging uptake of air pollutants, not the opposite. The location of the archive store in a busy urban area which is more polluted than the environs of the SCVA, could lead to significant collections damage over time.

4 Comparison of modelled and measured data

Pollution measurements have been made at both case study buildings using both passive and active sampling methods. In particular long-term passive measurements are on the most appropriate basis for comparison with the steady-state predictions of the IMPACT model. Table 4 compares measured and modelled data for the two case study buildings. The measured ratios are generally lower than the modelled ones, with reasonable agreement for nitrogen dioxide and sulphur dioxide less so for ozone. This discrepancy could occur for a number of reasons:

(i) the amount of active surface area in the building had been underestimated. The model included only the geometric surfaces and shelved archive paper surfaces. Other fixtures and fittings, for example display cases or shelves have not been estimated.

(ii) In the case of the archive store some of the air infiltration comes from other parts of the building, such as the adjacent storerooms. These have a lower pollutant concentration than outdoors, causing the model to overestimate the concentration in the modelled zone. In this type of situation, the single-zone nature of the model increases the level of approximation.

(iii) Related to this, it is possible that enhanced pollutant deposition occurs onto surfaces neared to the points at which air infiltrates the building, rather than deposition being equally distributed on all surfaces which is an assumption that the model makes. This process could enhance pollutant removal, leading to lower measured than predicted I/O ratios. This explanation has also been suggested by Glytsos et al. [12].

(iv) Homogeneous chemistry could play a role in reducing ozone concentration. Evidence of this has been found recently in monitoring of European museums [13].

Table 4: Comparison of measured and modelled I/O ratios for the SCVA. Sulphur dioxide was not detected inside the SCVA and only at very low levels outside, so I/O ratios could not be calculated

Pollutant	**Measured**	**Method**	**Modelled**
SCVA:			
Nitrogen dioxide	0.74-0.91	Diffusion tube	0.87
Ozone	0.3	Diffusion tube	0.88
	0.7	Instrumental measurement [14]	
Archive Store:			
Nitrogen dioxide	0.24	Diffusion tube	0.46
Ozone	0.1	Diffusion tube	0.24
Sulphur dioxide	0.4	Diffusion tube	0.33

5 Conclusions

The comparison of measured and modelled results shows reasonable agreement between the IMPACT model predictions and measured data for nitrogen dioxide and sulphur dioxide, with a considerable underestimation of ozone concentrations. It would be possible to improve the prediction of ozone concentration by more complex modelling techniques, and many such models already exist. However, the philosophy of the IMPACT tool was that it should be a simple and straightforward method of estimating pollutant concentration inside buildings that could be used to show how different building designs and characteristics can influence pollution levels indoors. Provided its limitations are recognised then it can usefully achieve this aim.

The case studies presented here have demonstrated how materials, layout, ventilation and other services affect the pollutant concentration found indoors. The model predicts indoor concentrations, but also allows the conservator or conservation scientist to gain insights into deposition of air pollutants onto surfaces, which include the surfaces of objects. For building designers and engineers, the IMPACT model has shown how building structures can provide a means of passive pollutant control through low ventilation rate and the use of sacrificial surface pollutant-absorbing materials. The advent of new products such as pollution-absorbing paint can make this feasible for controlling pollutants inside collections spaces. This has been demonstrated to work best in building and rooms with low air change rates, and so may be more suitable for closed stores rather than open galleries.

Air pollution is a trans-national problem and there is a need across Europe for these issues to be better understood in relation to the care of cultural heritage. The IMPACT model is contributing to this process and has found a role as an educational tool for conservators and conservation scientists in particular. It is being used as part of a case study exercise for students on conservation courses in the UK and Malta and has also been used as part of a COST G8 Training School [15]. The model has also been taken up by organisations such as English Heritage to assist in their work on collections care.

6 European project details

IMPACT, Contract No. EVK4-CT-2000-00031, Innovative Modelling of Museum Pollution and Conservation Thresholds, Nigel Blades, UCL Centre for Sustainable Heritage.

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The APPEAR method for guiding the valorisation of urban archaeological sites

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Key words: archaeological remains, valorisation projects, urban environment

1 Introduction

European towns and cities are the theatre of human activities which constantly build, destroy and rebuild new urban landscapes. The archaeological remains revealed during this process represent a tangible yet fragile witness of the progressive shaping of our cities.

The exploitation of urban substrata is increasingly constrained by legal instruments (laws, international conventions and so on). These usually set the conditions for the investigation of archaeological remains and impose a number of constraints on all parties concerned. Still the valorisation of discovered sites usually falls outside the scope of these instruments. By valorisation, one should understand opening the sites to the public, on a regular basis, within a museum or any other structure (underground, parking, etc.). Although valorisation is increasingly acknowledged in Europe as a desirable outcome of many excavations for its social and cultural benefits, it is not yet framed by any guidance nor code of practice.

It can be argued that every valorisation project is a one-of-a-kind and that few lessons are transferable from one site to another. The European APPEAR project (2003-2005) highlighted on the contrary that most these valorisation initiatives share common challenges, namely nurturing a coherent project in the face of sometimes conflicting interests and reconciling four legitimate issues: social and economic development, archaeological research, conservation of the remains and public access to the site [1]. A method has been developed to address these issues and enhance the decision-making from the initial decision to valorise archaeological remains to the continuous operation and maintenance of a site [2].

2 Identification of the issues at stake

The valorisation of urban archaeological remains does not sit in isolation, divorced from reality. It falls firmly within a framework of policies managed on a daily basis by those involved, particularly public authorities. These policies present common characteristics specific to the urban context. The issues addressed are interdependent and must be treated together. The valorisation of archaeological sites cannot escape this demand. Its management must be closely linked with that of its surroundings and the resulting collective values must be appreciated in relation to the urban environment [3].

Most of our towns and regions are progressively adopting a planning strategy to help manage urban space harmoniously and coherently. The guiding principles of this strategy must integrate the valorisation of urban archaeological sites. The valorisation of archaeological heritage does not make senses if it is not seamlessly integrated into the town's general development policy, including the principal elements of community life: infrastructure, environment, culture, tourism, housing, mobility, security, etc. operating in a system of mutual reinforcement.

The management of archaeological heritage must also be seen as a driving force for an economic policy conscious of the legitimate concerns of the citizens and the protection of non-renewable resources. The integration of the remains into an economic development programme has often shown its relevance in terms of direct and indirect returns, even though it should be admitted that most valorisation projects cannot be financially viable on the long term without some form of public support.

Finally one sees the emergence of structural policies at local, national and European levels, which aim to associate the citizen with management of the public estate (new governance, participative management). These policies do not replace the delegated powers of public authorities but represent an effective management tool favouring the prevention of conflict and the involvement of the citizen in the conservation of common values.

All these issues are bound in a sustainable development perspective, which requires to formulate dynamic and economically viable local policies which are mindful of passing down a heritage of quality to future generations. The APPEAR method suggests effective solutions to the requirements faced by those involved in the sustainable management of valorisation projects.

It should be stressed that the APPEAR method does not advocate a systematic valorisation of discovered remains. In many cases, alternative methods such as total excavation or the establishment of protected archaeological areas may be a better solution. Moreover, it is acknowledged that, once a local authority decides to valorise archaeological remains, the subsequent project can take many different forms. Practically its scope will be determined by the urban and economic context and the means that are realistically available.

Whatever the reality on the ground and the path taken by the principal players, the APPEAR method hence intends to help those involved address the right decisions in due time, taking into account the resources available. Accordingly the proposed process tries to be as detailed as possible to cover all requirements of larger projects, but it can easily be adapted to smaller projects.

3 The APPEAR method

The method suggests ways of controlling the process by acting on the following areas:

- Reducing uncertainty by developing the ability to anticipate,
- Enhancing the effectiveness of the methods in relation with stated objectives,
- Encouraging convergence of contradictory viewpoints,
- Involving the players in the operations they have planned.

The method does not favour one participant over another. Its role is to facilitate exchanges between individuals and organisations defending legitimate interests. The players belong to the following five categories which are not necessarily mutually exclusive: political and administrative actors, funding bodies, specialists and consultants and the larger community. The roles of each of these categories can sometimes be taken on by the same players, sometimes simultaneously. This movement between categories is a reality in most projects. At each stage of the process, several persons participate as key players because of their special status or their specific input at a particular point in time. The identity, function and motivations of these key players has been given particular attention [4].

The method is further based on the principles of strategic management adapted for the specific needs of the valorisation of urban archaeological sites. Its aim is to control the process through the combined efforts of partners and planning. It offers a structured mechanism that enables the user to consider the issue to be addressed, the objectives that need to be reached and the methods to be used to achieve them. It is a conscious and continuous management activity – anticipating, complementing and supporting the decision making process.

The efficiency of the process relies on a proactive attitude of the players, their willingness to work together and the precision with which they define their methods of working. The process is neither fixed nor purely descriptive: it is constantly evolving. It uses a planned sequential process consisting of six phases:

- Assessment: initial assessment of the site and its context,
- Feasibility studies: evaluation of the feasibility and viability of valorisation,
- Definition of the options: fundamental choices for valorisation,
- Project design: establishing methods for formulating the final project plan,
- Execution: implementation of the project,
- Operation: management, assessment and adaptation of the site once opened to the public.

Each phase is divided into three stages which allow every aspect to be dealt with and the application of the most relevant measures in relation to the set objectives.

- Planning: identification of the players and their interactions; setting up the working structure so that the decision making process is seen to be performing and appropriate. This means developing a method to ensure maximum co-operation throughout the phase,
- Action: implementation of the tasks required to make informed decisions. This is the work programme for achievement of the objectives,
- Review: analysis and synthesis of the results and amendment of the decisions made. The results achieved during the planning and execution stages are assessed to produce the most relevant decisions during each phase of the project. Assessment of the results examines their reliability, validity and usefulness.

During each of the three stages, questions are raised about the decision making process, the tasks to be undertaken to take the project forward and the evaluation of the results. These are dealt with through a series of inter-related tasks. The most important of these, called key actions, are described and defined in a practical way.

4 An integration of different fields of expertise

The players are called upon to deal with a series of issues which relate to seven fields of expertise involving a number of disciplines. Financial management: analysis of the economic factors of a valorisation project including its effect on urban life, on a local and regional level, with a view to setting up the financial programme and optimising the quality and quantity of investments.

Archaeology: exploration and study of excavated archaeological remains and objects to gain a better understanding of the past and to assess their potential for re-use. Preventive conservation: study of the conditions and scientific and technical methods needed to ensure long-term conservation of the archaeological remains and objects.

Urban and architectural integration: study of the methods for the creation or adaptation of an architectural envelope to optimise conservation of the archaeological remains, public access, continuing archaeological research and the integration of the formal and functional characteristics of the envelope into its surroundings.

Display of the site to the public: study, design and implementation of systems to make the archaeological site more intelligible, to increase its power to attract and to promote its adoption by the community. Visitor management: study of the methods available for management of the cultural facility for education and information and communication programmes so as to ensure its acceptance by the community and its full integration into the existing cultural and tourist offer.

The actions undertaken in each of these fields are analysed side by side in order to address the overall issues adequately. The matters raised and proposed solutions are compared and confronted regularly to ensure the quality and consistency of the results.

5 Conclusion

The long-term viability of valorisation projects require that their social, economic and scientific sustainability on the long-term is guaranteed. The project must hence be anchored in its urban environment and firmly linked to the various policies driving the town. Valorisation of archaeological remains is not a finality in itself: it only makes sense when it becomes part of the everyday life of urban citizens. The management team, supported by the project owner, must harmonise with the community.

This openness is not only motivated by the wish to ensure the long-term future of the facility. It is also the only legitimate answer to the current and future needs of the urban community. A system of exchange and mutual support is the only way to forge lasting links between the site and the visitors.

The manager and partners will pay particular attention to expressed or sensed changes in cultural, tourist and socio-economic needs. They will regularly evaluate the relevance of their operation against the planning, employment, mobility, participation, etc., policies of the local or regional authorities.

The effectiveness of this evaluation depends on the capacity of those involved to use the tools produced in each of the fields of expertise. It also depends on their ability to anticipate changes by using the interdisciplinary tools developed throughout the valorisation process.

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Session IV

Research infrastructure – sustainable scientific impact of EC research project on movable and immovable heritage

Recent developments of the heritage and archaeology liaison office at the SOLEIL synchrotron

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Key words: cultural heritage, archaeology, conservation science, synchrotron, X-ray

1 Background

Ancient materials, most often handmade from natural ingredients and sometimes heavily altered due to long-term ageing, are highly heterogeneous. Additionally, art materials are usually subject to treatments and modifications to play with their optical appearance that is strongly influenced by the material texture at the micrometer length scale. In addition, the chemistry of the systems under consideration is usually very complex. Organic, inorganic compounds, their mixtures, alteration and interaction products need to be understood. Complementary to topographic imaging and mere elemental identification, chemical selectivity is required to reach a satisfactory understanding of these materials.

Coordinating the four levels of information (elemental, chemical, structural and topographic) is crucial to better cope with the heterogeneity of such materials. In particular, the ability to resolve local information on mineral grains, inclusions, surfaces and interfaces, cracks, micro-structural defects, etc. is of paramount importance. Most often, the relevant heterogeneity length scale falls into the 100-nm to 10-µm range. This "mesoscopic" scale is usually specifically difficult to reach through non-photonic methods. However, synchrotron radiation techniques are particularly efficient to obtain chemically-selective information at these length scales and to obtain 2-d or 3-d maps of elemental, chemical and structural information. These capabilities triggered a strong interest from the archaeology and heritage research communities (museum research laboratories, conservation units, university archaeology and natural science departments) for the advanced spectroscopy and diffraction techniques provided at synchrotron facilities.

In 2004, the SOLEIL synchrotron set up a dedicated liaison office with the support of the users community to develop additional support at the facility towards the heritage and archaeology research communities.

2 Summary of the needs expressed by the heritage community

Following a users' initiated symposium (Royaumont, March 2003), the SOLEIL synchrotron started to develop a liaison office dedicated to heritage research in January 2004. Simultaneously, the French Science Research Centre (CNRS) launched a 4-year concerted action at the national level ("groupement de recherche", or GdR) entitled *Matériaux du Patrimoine et synchrotron SOLEIL* (Heritage materials and SOLEIL synchrotron).

Before the start of operations of the facility (due early 2007), the target of the liaison office has been to contact potential users from the cultural heritage community in order to clarify their needs and define an organisation mode that could solve the major limitations identified.

2.1 Initial assessment

Data on the use and requirements concerning synchrotron techniques from heritage users were obtained from a variety of sources, primarily through individual meetings, congresses, round tables, reports from the LabsTech networking activity and a review of existing synchrotron / heritage publications (time span: 1986 – May 2006; number: 226). The latter is made publicly available through the Internet and regularly updated [1]. More than 50 groups were met at an international level in this process.

This review clearly shows that four major heritage fields have already benefited from synchrotron techniques with contrasting needs:

1. History of art and technologies, *e.g.* identification of copper pigment materials using X-ray micro-diffraction [2];
2. Archaeometry, *e.g.* provenance and technology of ancient glass [3];
3. Studies in conservation and restoration, *e.g.* fine understanding of the corrosion mechanisms of iron artefacts of the Iron Age in order to optimise subsequent stabilisation procedures [4];
4. Palaeontology, *e.g.* X-ray micro-computed tomography of ancient primate jaws to determine key geometric parameters and to locate them in the primate clade [5].

As a consequence, the variety of the fields under the general term 'cultural heritage' should not be under-estimated and the main focus of synchrotrons on a restricted set of topics (mainly theme 1.) is by no mean satisfactory to the heritage users community.

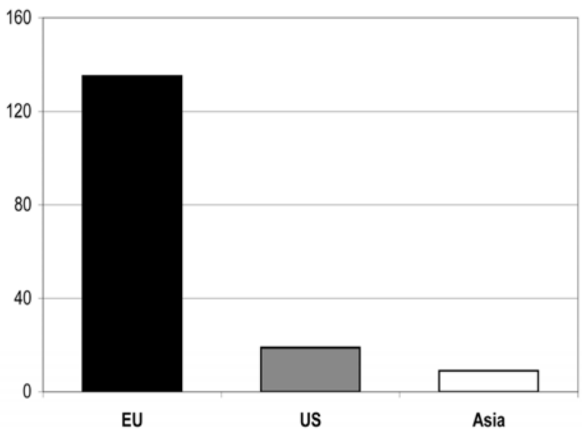

Figure 1: Comparison between the number of heritage publications arising from research carried out at European Union (EU), American (US) and Asian synchrotron facilities. Facilities from three European countries have been playing a prominent role since 1986: France (LURE / SOLEIL and the multinational facility ESRF), the UK (SRS) and Germany (HASYLAB and BESSY primarily)

As indicated by the LabsTech data, European cultural heritage research laboratories are heavy users of photon-based laboratory methods such as infrared microscopy, X-ray diffraction, X-ray fluorescence and radiography, all four among the top ten methods employed to study ancient materials. These methods find direct counterparts at synchrotron sources with µm-scale imaging capabilities, extremely short acquisition times and a strongly increased analytical sensitivity. Indeed, the use of imaging acquisitions is specifically high for this community [6].

The work done so far at synchrotron facilities on heritage has primarily been carried out by a fraction of expert users. These users usually belong to regular laboratories in direct contact with museum conservators, curators or archaeologists, that constitute so-called *interface laboratories*. It is noticeable that European synchrotron sources have strongly been involved in the field compared to Americas and Asia (see fig. 1).

2.2 Major limitations

Although one can notice a very steep increase in the number of heritage / synchrotron works over the recent years [6], heritage experts tend to remain sceptical as they regard many of these studies as mere feasibility works ('case studies'), hardly usable for in-depth heritage research purposes.

The major limitations that were signalled to us are:

- the insufficient experimental *support* from synchrotron facilities;
- the lack of *statistics* as the analysis of heritage materials most often requires a statistical approach absolutely not available in the current operation mode of synchrotron facilities;
- the inappropriate *peer-review selection process* at synchrotrons that does not take into account heritage specificity in the evaluation of experimental proposal, is focussed on a very restricted set of heritage topics and is confusing for heritage actors.

Both non-expert and expert users could be supported in their access to synchrotrons. On the one hand, the whole process that researchers have to follow to access the facilities is a major difficulty for non-experts. New users should be backed appropriately through information on analytical capabilities, proposal preparation, sample preparation and partial data processing.

On the other hand, expert users should be given the opportunity to develop new methods and specific sample environments to study heritage artefacts. When applicable, standardised protocols could be developed to address the most common characterisation needs (*i.e.* 'service' activities).

3 The SOLEIL heritage and archaeology liaison office

Although strongly influenced by the setting-up of the *Archaeometry unit* developed by Dr M. Pantos at the SRS synchrotron, this interface is the first ever at this scale at an international level [7-8]. The initiative at SOLEIL is focused on the major issues raised and seeks to address them on a pragmatic basis.

Five actions are currently being carried out in parallel: (1) facilitating the access, (2) building a technical platform, (3) training and informing the community, (4) fostering networking activities and (5) disseminating to the public. Access to all beamlines of SOLEIL will be provided, among which 6 to 8 should particularly contribute to heritage research. An expected uppermost involvement of imaging beamlines is expected: infrared microscopy, X-ray fluorescence, absorption and diffraction and X-ray micro-computed tomography.

For the period 2004-2006, the key actions of the SOLEIL liaison office were:

1. the hiring of a dedicated officer on a permanent basis fully devoted to the setting-up of heritage activities;

2. the organisation of the first international training school on the synchrotron analysis of museum objects *New lights on ancient materials 2004* co-organised by SOLEIL and the European COST G8 action at the synchrotron (Dec. 2004) [9] and the preparation of its follow-up *New lights on ancient materials 2007 – Ageing, alteration and conservation* due March 2007;

3. the setting-up of an *Earth sciences, environment, archaeology and cultural heritage* peer-review committee to select the proposals submitted by the community, in order to take into account the specific evaluation criteria of the discipline and to provide for direct input by heritage professionals;

4. the co-supervision of a PhD thesis to start in October 2006 (funding: CNRS Humanities department / SOLEIL) that will launch an internal research activity on heritage from the very start of the facility;

5. the co-organisation of several workshops and dedicated sessions at national and international congresses: SR2A (Grenoble, Feb. 2005), Archéométrie 2005 (Saclay, Apr. 2005), etc.

6. the launching of a dedicated web portal [10].

These key actions are intended to complement the access itself that will be supported through the IA-SFS transnational access for non-national European users.

4 Conclusions: efficiently supporting the heritage community to access large scale facilities

Although the development of this project at the national level can be funded through national sources, the present survey shows that the moderate size of the community and the adequacy between a variety of needs and the offer provided by advanced synchrotron sources seems ideal for the development of joint activities in the years to come at a pan-European level. In the following conclusions, the SOLEIL team would like to underline major points regarding the development of such a supra-national project, with a contribution from synchrotron sources and more generally from large-scale facilities (LSF).

Such an initiative would ideally contribute to providing support, training, networking and dissemination in order to ease the access of the community to the facility. Its setting-up should benefit from the best achievements of former and on-going European projects such as LabsTech, EU-Artech and COST action G8. *The European institutions should ensure further projects be based on a truly multinational representation of European heritage institutions, as is currently the case for COST action G8.*

Such a project must be driven jointly by the heritage community, interface laboratories and the LSFs. The stronger visibility of LSFs at a European level should not distort this mandatory equilibrium. *A way to make sure that end-users get the most benefit from the research carried out at LSFs is to make sure that the evaluation of the efficiency of such a European project is primarily carried out by heritage actors (restorers, conservators, curators, archaeologists).*

Except for specific standardised activities, heritage actors are expected to contact LSFs through these interface laboratories and via liaison office for heritage (see fig. 2). A very efficient network of interface laboratories is in the best position to co-develop this area of research. *The latter constitutes a difficulty, as interface laboratories may not have a sufficient size to be regarded as pan-European actors. As far as the review process is concerned, the European*