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DEVELOPMENT, MANAGEMENT AND ECONOMY OF SHOW CAVES

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ABSTRACT
The problems concerning the development of show caves are here considered by taking into account different aspects of the problem.
A procedure to carry out an Environmental Impact Assessment (EIA) has been established in the last decade and it is now currently applied. Such an assessment starts with a pre-operational phase to obtain sufficient information on the undisturbed status of a cave to be developed into a show cave.
Successively a programme for its development is established with the scope to optimise the intervention on the cave at the condition that its basic environmental parameters are not irreversibly modified. The last phase of the assessment is focussed to assure a feedback through a monitoring network in order to detect any unforeseen difference or anomaly between the project and the effective situation achieved after the cave development.
Some data on some of the most important show caves in the world are reported and a tentative evaluation of the economy in connection with the show caves business is eventually made.

Introduction

Nearly twenty years ago, two great experts of cave management, Russell and Jeanne Gurnee (1981), wrote: "The successful development and operation of a tourist cave depends on a combination of factors, including

1) Scientific investigation
2) Art
3) Technology
4) Management

Scientific study is recommended at the beginning of the first phase in order to determine what hydrologic and geologic factors may have an influence on the develop-

ment. Art is necessary both in determining the routing of trails and selecting particular cave scenes to feature and in lighting - which is in itself a combination of both art and the next factor, technology. The technology necessary to control water and other natural forces within the cave and to design suitable trails again combines with art to create a tasteful and agreeable cave tour. Management continues from the time the first plans are laid through the developed or operational phase.
The four factors listed above apply both to the development of private caves and public or government lands. Often, because of limited financial resources of a private owner, one or more of these factors is not considered and poor development and lack of financial success may result. Failure of a cave to succeed either through the development phase or after, when the cave is open to the public, can lead to an unprotected area which has been advertised and known to the public and thus subject to vandalism.
In order to ensure that a cave has the highest chance of success as a tourist endeavour, a comprehensive study and evaluation should be made before investment. A cave study provides a "blueprint" which investors, technical people, workmen, exhibitors and administrators can follow to bring about a successful cave operation. The study plan is coodinated by management in order to bring about a procedure which will result in the display of the cave.

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With a detailed study and price prospectus at the time the development is originally proposed, a cave can be developed less expensively, more effectively and in less time.
Technological advances in the past fifty years in lighting, communications, transportation, marketing techniques, and almost every phase of cavern development, make it important to find the most efficient ways to complete the project. Every cave must be looked at from the position of the businessman, artist, engineer, speleologist and conservationist. The modification of a natural cave to permit easy visitation of the public requires all of these viewpoints. Balance among these views, through decisions made before beginning the venture, will assure a sound development.
Speleological associations which bring together those caves being considered for tourism will be of great service not only to the group developing a cave, but also in preserving the cave as nearly as possible to its natural state."
It would be really rather difficult to have a better description of the procedure to adopt for the development of a tourist cave.

Preliminary evaluation for the development of a show cave

In addition to the Environmental Impact Assessment, the procedures devised and

implemented in the planning phase commonly include those that can quantify certain parameters (topographical, social and economic) used to predict tourist flows. Some of these methodological procedures, well known and successfully applied in the geographic-economic field, tend not to be employed in the development of show caves because of some lack of knowledge.
The topic is included in many models of tourism development, which contain useful references (Miossec, 1976, 1977; Butler, 1980; Hovinen, 1981; Brownlie, 1985; Cooper, 1989). The analyses carried out by Miossec should be particularly underlined, since they tend to determine the structural evolution of tourism zones in space and time. In this context, four basic elements are taken into account:

1) Tourism localities;
2) Transport network;
3) Behaviour of tourists;
4) Attitudes of local authorities and the general population.

Indeed, expansion of the tourism industry inevitably involves development of the tourism localities and transport network, understood both as roadways and public transport systems. This industry tends to become more and more complex and diversified in terms of what is offered. Therefore, tourists become increasingly aware of the possibilities that the site, and its surrounding area, can offer, and consequently their behaviour changes. The change in local attitudes can ensure that tourism is totally accepted, thus leading to the adoption of short- and long-term planning schemes; however, it can also lead to the rejection of tourism, and such cases have been reported in the literature. It is evident that the evolution of tourism spaces (and in this case the scale can range from a microregion to a large geographical area) follows a series of stages, outlined in Fig. 1. It is necessary to specify that the territorial size of a microregion is similar to that of a single show cave and its surrounding area; indeed this analysis deals exactly with this particular case:

Phase 1) The recently discovered cave is visited by a few connoisseurs who generally accept (and in some cases appreciate) the total lack of logistic support. The territory is crossed but not visited, and the general attitude of the local population and political-administrative authorities is rather uncertain. Often the initiative and, accordingly, the possibility or desire for investment is lacking.

Phase 2)The cave is fitted out by means of provisional interventions, with rather elementary management criteria. The local populations look on with doubtful curiosity or indifference, this attitude being explained by mistrust of the central authorities; the first tourists have only a very general perception of the surrounding territory. Often the importance of the cave is overestimated with respect to expectations, which almost always refer to enduring conditions of high interest, and this causes a loss of interest by both the tourist and the few people involved in management, with consequent abandonment of the completed infrastructure.

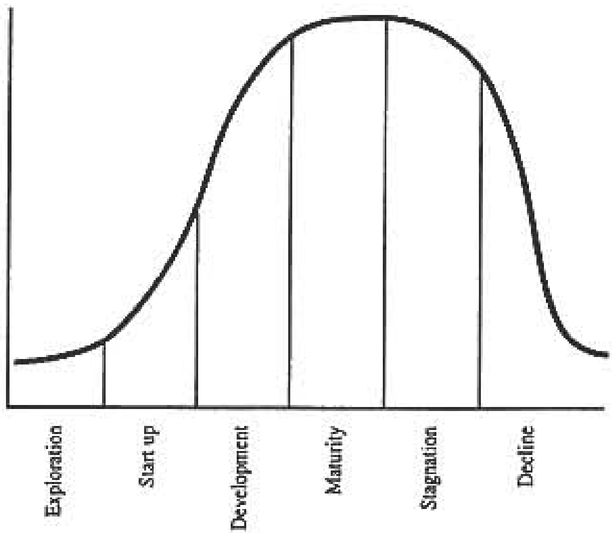

Fig. 1 - Life cycle of a tourism area (from Cavallaro & Pipino,1991; modified)

Exploration: a small group of adventurous tourists that reject institutionalised vacations. The areas are rather intact environmentally. Low impact on the local lifestyle.
Start-up: initial formation of a tourism area, with local people who organise the project. There is pressure on the public sector for funding.
Development: considerable tourist flows, outnumbering the residents in the busiest period. Local initiatives cannot control the tourism. The quality decreases on account of intense use of the structures and overcrowding.
Maturity: there is growth with decreasing marginal trends. The site is famous, but the tourist pressure separates it from the surrounding environment.
Stagnation: the maximum number of tourists is achieved, with environmental, social and economic problems.
Decline: the number of tourists decreases and the destination has an ever-smaller area of origin of tourists. New structures may be introduced to revitalise the locality.

Phase 3) The early initiatives have shown that interest in the show cave can progress and develop, with multiplication of the infrastructure. Other resources are involved (e.g. food products and local handicrafts), with greater employment of manpower, essentially the seasonal type. The number of tourists increases and their perception of the area improves. The local populations actively participate in the realisation and management of reception and support structures.

Phase 4) In response to the increasing demand, a preliminary organisation of the territory is carried out. Forms of specialisation and competition in management of the tourist space appear. The local population perceives the difference between its economic and social condition and that of the tourists and assumes imitative behaviours. Feelings of cultural expropriation and the first forms of environmental degradation inside the cave, and in the surrounding territory, begin to appear.

Phase 5) The show cave is only the primary attraction and other poles of extremely diversified interest and often (since they are artificial) with weak intercultural connections are developed. The group of attractions is structured as a hierarchical pyramid system. The structures and transport system are extremely efficient, with an increasingly massive tourist flow, to the point where the type of urban space that was once avoided is now recreated and the tourist perceives the environment as a "false" attraction founded on fictitious natural models based on advertising messages. The cave is reaching high levels of saturation and has been subjected to notable restructuring and expansion of the route, with increased tourist flow and consequent serious, even irreversible, degradation. This is the most critical phase which if it becomes chronic leads to the most serious damage, especially from the environmental point of view.

There are many possible solutions that can be proposed in this sector, mainly concerning non-traumatic revitalisation of tourist circuits with saturation of interest (Burri & Cigna, 1991).

As mentioned, the models dealt with here have been devised and tested in situations different from those of a show cave and thus their application may involve problems of adaptability. However, if this happens it is certainly not because of lack of inherent suitability of the model - indeed, these procedures are fairly well known and applied in specific sectors (e.g. the classical seaside or mountain tourism sites) where they have generated productive discussions - as much as the absolute lack of specific case studies like those of show caves. This is due to a series of not easily resolved problems, including, paradoxically, the unavailability of data concerning the true magnitude of visitor flows, especially for show caves of local interest.

In this regard, however, it is necessary to consider a fundamental concept, i.e. the visitor capacity as a limiting factor. In the next paragraph the procedures to determine this parameter, which remains propaedeutic for any other planning initiative are described. If the values of this parameter predict a rather low limit for frequentation, any intervention would be useless since the costs of installation and management can never be recuperated or amortised, nor can management produce profits. However, in the history of tourist exploitation of some Italian caves (especially in the recent past, when the use of these procedures was already known), almost all the basic structures (tour pathways, lighting systems, services) have been established independently of their prospects for economic profit and with the financial intervention of the central government.

This type of initiative, common in other European and non-European countries, is similar to the incentives provided for enterprises using private or mixed (public/private) capital. In fact, public intervention is normally limited to substantial funding (up to 100%) for the realisation of basic and infrastructural works; the management is left to local enterprises, often with the creation of "management consortiums" with mixed capital that also involves local administrations (Municipalities, Provinces, Mountain Communities, etc.). It is clear that the limiting factor, the visitor capacity, which has not been considered in calculation of the amortisation of non-repayable financing, will nevertheless have to be considered in relation to the estimated costs of management and maintenance of installations subject to natural wear and tear.

Caves, which have a very low receptive capacity, are areas with high environmental risk and thus not very suitable for mass tourism. The only possible alternative in this case is to equip the caves with routes that can be fairly easily realised and maintained - for example, excursion-type guided visits, with internal routes lacking illumination and with a low environmental and economic "burden" (Burri & Forti, 1995). Possible funding aimed at revitalising the local economy can be diverted to other sectors of environmental interest worthy of development and with less risk of degradation.

The visitors' capacity of a tourist cave

The concept of an environmental capacity has been accepted for years. It has been used for the management of low-level radioactive wastes (Amavis *et al.*, 1974) and in range management in the United States (called carrying capacity) (Huppert *et al.*, 1993).

Aley (1976), Brucker (1976), Van Cleave (1976), Forssell (1977), and Middaugh (1977) have extensively discussed the concept of 'visitors carrying capacity' as applied to caves in the literature. Van Cleave (1976) showed that there must be a commitment to cave and karst protection in both desire and money in order for the concept to work. Middaugh (1977) cautioned that carrying capacity is not the calculation of a number but rather, it is the definition of a problem, the definition of objectives to solve that problem, and the implementation of proper management to solve the problem. At this time, most of the well-known tourist caves in the world were undoubtedly operated at levels well above any reasonable or environmentally derived carrying capacity.

Cigna (1989, 1990) expanded on this concept with respect to caves as follows: "Visitors capacity can be defined as the maximum number of visitors acceptable in a time unit under defined conditions which does not imply a permanent modification of a relevant parameter." This definition is based on the following assumptions:

1. Natural fluctuations of environmental parameters are considered safe for the integrity of the environment itself. This concept implies that abnormal (and unusual) phenomena are excluded. For example, a volcanic eruption may be the cause of a natural fluctuation, which could destroy a cave. Therefore the range of natural fluctuations must be limited within the extreme values that do not result in irreversible effects on a short-term basis.

2. If the number of visitors in a cave per unit time is gradually increased, one environmental parameter will exceed the range of its natural fluctuation prior to other parameters. Such a parameter can be defined as a critical factor. The term 'critical' need not imply any idea of danger. It describes a factor, which enables managers to make decisions on levels of protection for the cave environment.

3. The visitor capacity corresponds to the maximum flow of tourists through the cave that changes the critical factor to the limit of its natural fluctuations.

4. The classification of environmental parameters into major and minor parameters is rather arbitrary. If air temperature, carbon dioxide concentration, and water quality are classified as major parameters, the appropriate classification of the other parameters may require detailed study. The significance of the other parameters may vary widely among caves.

The establishment of the maximum number of visitors is difficult and may well be impossible in some cases. Sometimes these numbers have been used to satisfy management objectives by those who, unfortunately, may put a higher priority on moving people (and therefore increasing revenue) than on protecting the karst.

Aley (1976) described another important problem in caves, which can actually become exacerbated by the use of carrying capacity numbers as a management technique. He correctly argued that most show caves have abundant non-renewable resources in their speleothems display. Once damaged, these resources cannot be replaced, at least not in human lifetimes. A cave with one or more highly decorated passages could require a low carrying capacity if the decorations are within human reach of the trail, or within the sphere of influence of human-induced changes that adversely affect the speleothems. As damage is incurred and speleothems are removed, broken, defaced, or tainted, then the passage becomes less pristine. At that point, it can be argued that the carrying capacity has risen because fewer speleothems now remain to be damaged and the quality of the experience has been denegated. This is contrary to the entire concept of carrying capacity, which dictates that use levels should decline as the resource declines. This is a phenomenon often ignored by cave managers. However, if the goal is to maintain any specific show cave in a pristine or near-pristine condition, a realistic number of visitors must be determined and applied as a management criterion. To do this with any level of confidence, a thorough study of each cave's features, ecosystem parameters, and hydrology must be made. This is undoubtedly a difficult task, given the budget constraints of some show caves, whether managed by some level of government or by the private sector. In the long run, however, this may be the most cost-effective alternative, in order to sustain the tourist-derived revenue from the cave, concomitant with sustaining its ecological and aesthetic integrity.

The concept of carrying capacity was also questioned, as it is applied to general recreational use. Hammitt and Cole (1987) felt that strict use of the concept in the recreational setting does not work well for two reasons. First, the impacts of recreational uses differ greatly from those of range animals (for which, according to the authors, the concept was originally designed to control). Second, they argued that the concept ignores the impact on the visitor's aesthetic experience; i.e., the social carrying capacity (defined as how people feel about the quality of the experience) must also be measured. However, this can vary greatly among individuals. While it may be possible to subdivide surface reserves to accommodate the tastes of the various users (e.g., from high impact use such as off-road vehicle areas to near-pristine wilderness), similar possibilities are quite limited in show caves. Unfortunately, the authors know of no study that applies this concept to the cave environment in a quantitative method.

Some years ago, Heaton (1986) reviewed the concept of energy levels as applied to caves. He classified caves into one of three categories: high-energy, moderate-energy, and low-energy levels. High-energy caves experience high-energy events on a regular basis. An example would be those caves that undergo periodic flooding. The strongest forces normally encountered by moderate-energy caves are orders of magnitude lower than those associated with high-energy caves. The most significant forces may be running water, persistent wind, or even the activities of animals. Low-energy caves are again orders of magnitude smaller. Often in these caves the highest energy event may be a falling drop of water.

According to this classification, high-energy passages will be minimally affected by tourist activities because such passages will be rearranged by rockfall or flooding within a year. In moderate-energy passages, which often have the most abundant displays of speleothems, the presence of visitors may have a more lasting effect. During short periods of time the energy released by tourists can be of the same order of magnitude as that released by natural processes which normally operate in those caves. This could lead to irreversible damage.

A visit to a low-energy cave may have more serious implications because in a very short time interval more energy could be released than it had experienced in perhaps a thousand years. The damage caused by one group of visitors may be profound and the speleothems may quickly be destroyed. It is the authors' experience that most tour caves are found to be in the low to moderate energy range, due to the difficulty and great cost of developing and maintaining high energy tour caves.

The field situation is far-more complex than the simplified examples of energy levels given above. A single cave may exhibit examples of all three energy levels when different sections of a given cave are considered. Because, in principle, tourist trails may cross all three energy levels, each area should be regarded separately in a coherent overall management plan. Devising and implementing such a plan would undoubtedly be a complicated and expensive process.

The use of a visitor carrying capacity model could be modified to 'fit' certain caves that have unique resources. For example, those caves with rare and generally irreplaceable cultural, biological, and/or speleothem resources and which are easily destroyed merely by the presence of visitors should be managed in a very restrictive manner. Caves in this category would be few and considered national or international treasures. Two examples are Lechuguilla Cave in the U.S.A. and Lascaux in France.

Another category could be those caves with rare and significant ecological resources that could be sustained even with visitation, providing they have adequate management. An example would be the glow-worm resource in Waitomo Glow-worm Cave in New Zealand. The last category would be those caves with minimal cultural, ecological or speleothem resources. This type of classification is already being carried out in many of the undeveloped caves on federal government managed land in the United States.

In many cases, caves with significant resources require permits to enter and limits are put on party size; also, visitation may be restricted to a particular time of year and there may be limits as to where one can travel in the cave. These management techniques help control and direct traffic to minimise damage. They also restrict most damage to heavily travelled routes and create a distance-decay relationship of impacts as distance from the trail increases. This relationship generally applies to large show caves where the tourist route is only a small fraction of the entire cave.

Applying the concept of visitor carrying capacity to a tourist cave to set a maximum number of visitors is a difficult, however compelling, exercise. It should be undertaken after fully assessing all of the environmental data collected. In some cases, the most difficult task will be to have the political courage to resist pressure to allow excessive visitation for the sake of efficiency or tourist revenue.

The sources of disturbance to the cave environment

The different sources of disturbance, which may modify the natural equilibrium of the cave environment, are here considered and their quantitative influence evaluated (Cigna & Forti, 1989; 1990; Cigna et al., 2000).

The effects of lighting.

The lighting system in a cave will contribute a certain amount of heat. If it is not compatible with the global energy budget of the cave, the inside temperature will increase and reach stationary values higher than the natural ones. Of course it is necessary to consider separately the contribution of each possible source (lighting, visitors, other heat sources) in order to consider it in the frame of the cave capacity to accept such contribution without not-reversible consequences.

In the vicinity of the light sources the effects may be both physical (thermal) and biological. When lamps are not "hight efficiency" lamps, the thermal effect can be very important. E.g. in Castellana Caves, South Italy, the temperature of a rock wall at 50 cm from a 1 kW lamp increased in a few seconds from 15°C to more than 25°C while the relative humidity decreased from 95-100% to 55-60% and a strong upward air current was established. As a consequence of these effects (which are rather peculiar) aragonite flower grew on a calcite stalagmite (Forti, 1980).

In the biological domain a rather widespread effect is the proliferation of algae and mosses near the light sources. These organisms not only have an aesthetic negative influence on the cave environment but can also set up a corrosion of speleothems by biochemical processes. Incandescent lamps are still widely used and have an emission spectrum rather large covering many absorption bands typical of vegetal organisms (Imprescia, 1983).

The effects of tourists.

The presence of visitors in a cave may imply different types of pollution: thermal, chemical and biological. The calculation of the thermal pollution is not very easy because the heat released by a person varies within a wide range as a consequence of some environmental factors (air temperature, relative humidity) and some source-related factors (size, velocity, dress, etc.).

Some field measurements carried on by Villar *et al.* (1984) in the Hall of Paintings in the Altamira Cave (Spain) evaluated a heat release per person ranging between 82 and 116 Watts (1 W=1 J/sec). If a person is walking, the heat release can be assumed to be about 170 W and, therefore, the annual heat input, E (in J/sec) will be given by:

$$E = 170 \cdot t \cdot 3600 \cdot N$$

where:

t is the average visit time in hours
N is the total number of visitors in one year

To have an idea of the amount of heat released in an actual case, such a calculation can be made for an important show cave. Assuming 500,000 visitors per year and an average visit length of 1.5 hours, the total amount of heat released by visitors is $4.59 \cdot 10^{11}$ J/sec (= 128 MWh) each year. Therefore the effects in a moderate-energy cave can be very large.

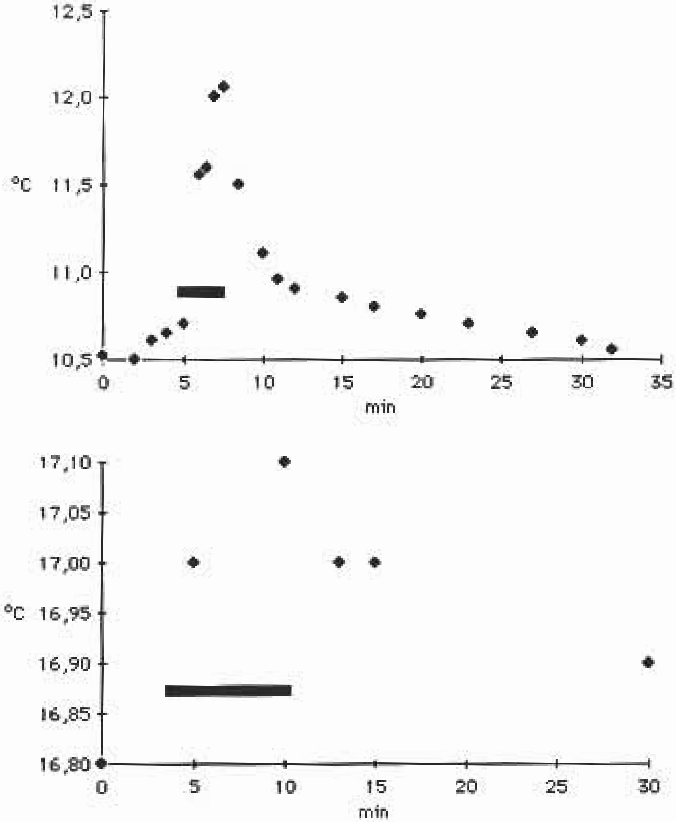

Fig. 2 - Upper diagram: air temperature measured in the cave of Remouchamps (Belgium) after the transit (near the "Boudoir des Fées") of a group of 87 tourists (black line) (from: Merenne-Schoumaker, 1975). Lower diagram: air temperature measured in the cave of Castellana (Italy) after the transit (in the "Corridoio del deserto") of a group of 105 tourists (black line) (from: Cigna, 1989).
The heat emitted by visitors raises the air temperature: in Fig. 2 two examples of this effect are reported.
The recovery time after the tourists transit is some ten minutes long.

In the case of the Castellana Cave (Bari, Italy) the global heat input from visitors and from the lighting system modified the thermal equilibrium of the cave. In an interval of 22 years an increase of about 3°C of the indoor air temperature (Fig. 3) was measured (Mongelli, 1961; Forti & Cigna, 1983; Cigna, 1989).

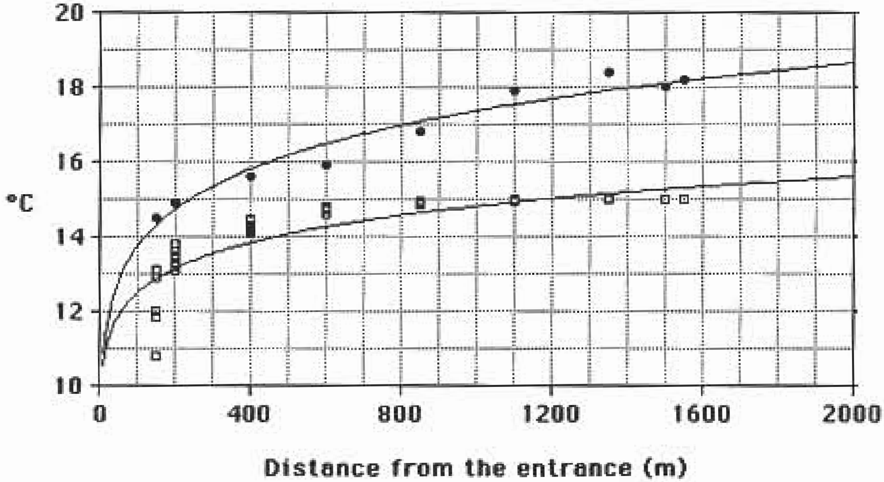

Fig. 3 - Distribution of air temperatures in the Castellana Cave (Bari, Italy). Measurements made in 1958-60 (squares: Mongelli, 1961) and in 1982 (dots; Forti & Cigna, 1983) are reported; an average increase of about 3°C is quite evident.

The chemical pollution originated by visitors is mainly due to the emission of carbon dioxide; any increase of the carbon dioxide concentration may affect, in principle, the chemical equilibria of the cave formations. Such effects are, of course, much more important in low and moderate-energy caves. Villar *et al.* (1985) reported seasonal variations of some chemical parameters (bicarbonates concentrations, dry residue and pH) of percolating waters in Altamira Cave; however no permanent changes were observed over a long period.

A model predicting the carbon dioxide variation in function of visitor-flow was described by Villar *et al.* (1986). The carbon dioxide concentration is proportional to the number of visitors and the time of their stay (for intervals < 1 hour) according to the relation:

$$\Delta C(t) = \frac{17 \cdot 10^3 \cdot N \cdot t}{V}$$

where: $\Delta C(t)$ is the variation of the carbon dioxide concentration (ppm, vol) at time t
N is the number of visitors
t is the time of stay of visitors (hours)
V is the volume of the cave hall (m^3)

In Altamira Cave the carbon dioxide concentration recovered to the original level after 12 hours if groups of 6 persons were in the cave with a time of permanence from 20 minutes to 1 hour (i.e. $\Delta C(t=12) = 0$). In other cases, as for the "Grotta Bianca" in Castellana Cave, the recovery time is much longer with negative effects both on comfort of visitors and, perhaps, the cave formations.
With reference to carbon dioxide is must be emphasised, nevertheless, that, in addition to a contribution from the visitors, a source due to some natural process has already been envisaged (Castellani, 1988; Caumartin, 1993). Recent studies carried out by the team of the Laboratoire Souterrain de Moulis (France) in a famous show cave, the Aven d'Orgnac identified such a process. They found that the variation of CO_2 concentration was inversely proportional to the variation of oxygen concentration. The isotopic analysis of carbon of CO_2 pointed out a biogenetic origin and the ratio between the isotopes of helium were typical of the atmosphere and not of a deep origin gas (Bourges et al., 1998).
Therefore it was concluded that about 2000 kg of CO_2 were produced each day by natural processes in that cave at the end of the Summer, against about 170 kg released by tourists in the same time interval. It is evident that in that case the role of visitors as source of CO_2 is less than 10% with respect to natural processes.
Such a situation is not peculiar to Aven d'Orgnac because in many other caves relevant variations of CO_2 concentration were detected and their connection with the tourists was sometimes difficult to explain.
The biological pollution contributed by the visitors is due to their "cloud" of spores and bacteria. The consequence of the biological pollution seems to be not only the growth of mosses and plants around lamps. According to an hypothesis recently advanced by Cser & Gadoros (1988) some eccentrics could be originated by aerosols; the increase of condensation nuclei due to spores and droplets in the breath of visitors could reduce the concentration of aerosols responsible for the eccentrics growth with an enhanced transformation of eccentrics into coralloid formations, as it was observed in some commercial caves.
Finally, another form of pollution is introduced by tourists as lint (Michie, 1996). Such a dust is composed of hairs, dry-flaking skin, and dust from shoes and lint from clothing. In Carlsbad Cavern, USA, the average yearly rate of long-term lint accumulation in the cave was estimated at 2 kg/year (Jablonsky, 1990). In Ngilgi Cave, Western Australia, a deposition rate of $8.3 \cdot 10^{-3} \mu g\ m^{-2}\ d^{-1}$ was measured (Michie, 1997). It is evident that this kind of pollution may result in a threat to show caves. According to Michie (1997) if the use of the cave will cause dust deposition that exceeds a threshold of 0.7% in a chosen time period then it should be considered to protect the cave by constructing pathways that enable management of the dust problem.

Some protective measures against pollution effects.

As it was outlined above, in some caves, particularly in those with moderate-energy levels, the influence of visitors can play an important role in the global energy balance of the cave. Nevertheless there are some simple measures which could help to reduce undesirable effects.

The use of "hight efficiency" lamps and, in any case, the positioning of lamps at some distance from the cave walls would reduce the thermal pollution or, at least, some local consequences (Caumartin, 1993). To keep the amount of input energy as low as possible, the lighting system could be divided into many sections in order to have as few lamps as possible lit up at the same time.

Concerning the visitors, their time of stay in the cave must be limited; such a result can be achieved both by limiting their number and by a shortening of the visitors trail (e.g. by opening an artificial entrance which, in principle, could halve the time of a visit by the elimination of the return walk within the cave).

It must be emphasised that the opening of artificial entrances may result in important changes of the cave microclimate by inducing airflows, which modify the natural air circulation. Therefore it is imperative to provide an air lock in the artificial tunnel. Such air locks are normally obtained by installing sliding doors operated automatically by a photocell. This solution is expensive because it requires at least two or three doors to avoid any airflow and may cause claustrophobia to some persons.

R. Gurnee (1990) suggested an elegant solution to the problem by the use of air-curtains, which are usually mounted over entranceways of warehouses. An air-curtain uses a "wall" of air recirculated by fans in a cross section of a passage. This system has many advantages because it is completely invisible and non-obstructing to tourists, it seals itself around people passing through it and reduces the infiltration of dust and spores carried along by visitors.

A couple of air-curtains installed one after the other and operated alternatively every other day assure their operating capacity so that, in case of a failure, one air-curtain is surely available until the other one is fixed. In addition the risk of a failure is reduced with respect to a mechanical door because the only part in movement is the fan which is a rather robust and reliable apparatus.

This limitation of the time of visitation will provide not only a reduction of the input of heat to the cave but also a reduction of the chemical pollution. In some special cases, when the increase of CO_2 concentration is threatening speleothems and a limited cave environment is concerned (less than some hundreds of m^3), a simple system consisting of a fan filtering the air through an absorber (e.g. NaOH) could be very successful.

Such a system could be fully automatic, being switched on by a sensor when the concentration of carbon dioxide in the atmosphere is higher than a predetermined level. The absorber must be changed when exhausted and the wastes must be removed from the cave to avoid any further pollution.

The growth of algae and mosses in proximity to light sources can be greatly reduced or entirely avoided by the use of special vapour discharge lamps which have a light emission limited to some narrow bands not useful for the physiological processes of plants (Imprescia, 1983).

The Environmental Impact Assessment (EIA) for caves.

In early 1970s the process of impact statements on the surface was proposed by J. Gurnee (2001) to be extended also to the underground. Land Use Planning for show caves was therefore proposed when cave owners had not yet considered the creation of a master plan for their land. As a result of their not preparing a master plan, a number of caves had made large parking facilities for visitors that prevented the percolation of waters into the cave, preventing the process of speleothem formation and growth below.

Now it is commonly known that the surface and underground are inexorably linked and cave development must be planned with this in mind.

To ensure the best application of the criteria reported in the previous section and to control the feedback to the cave environment from a tourist development, a procedure to establish an Environment Impact Assessment (EIA) has been developed. In fig. 4 the steps for such an assessment of a tourist cave are summarised.

If possible data collection of the main parameters of the cave climate should be collected during one year (at least) before the start of any intervention on the cave. Such a collection can be obtained either by spot measurements or by data loggers which are presently rather inexpensive and assure a continuous monitoring without attendance of personnel. In fact data can be discharged every few months, according to the frequency of measurement.

Once an energy balance of the cave is obtained, the perturbation due to the cave development (lighting, pathways, etc.) and visitors can be evaluated and compared to the natural variation of the parameters taken into consideration. An optimisation of the project is then set up on the basis of the constraints given by the protection of the cave environment and the requirements of the commercial exploitation.

It is convenient to establish an *ad hoc* scientific committee in the early phase of the cave development in order to insure the best implementation of the results of the monitoring of the project. In addition such a scientific committee will play an important role after the cave is open to tourists. In particular monitoring would compare the visitors' capacity as evaluated by the previous monitoring with the real effects of the visitors to avoid that the uncertainty of the determination of some environmental parameters would not lead to unacceptable consequences.

In some instances this scientific committee has played an additional role, in co-ordinating scientific researches in the cave. This was the case of the Caves of Frasassi (Ancona, Italy) where the committee promoted a large number of studies, that were successively published (Bertolani & Cigna, 1994).

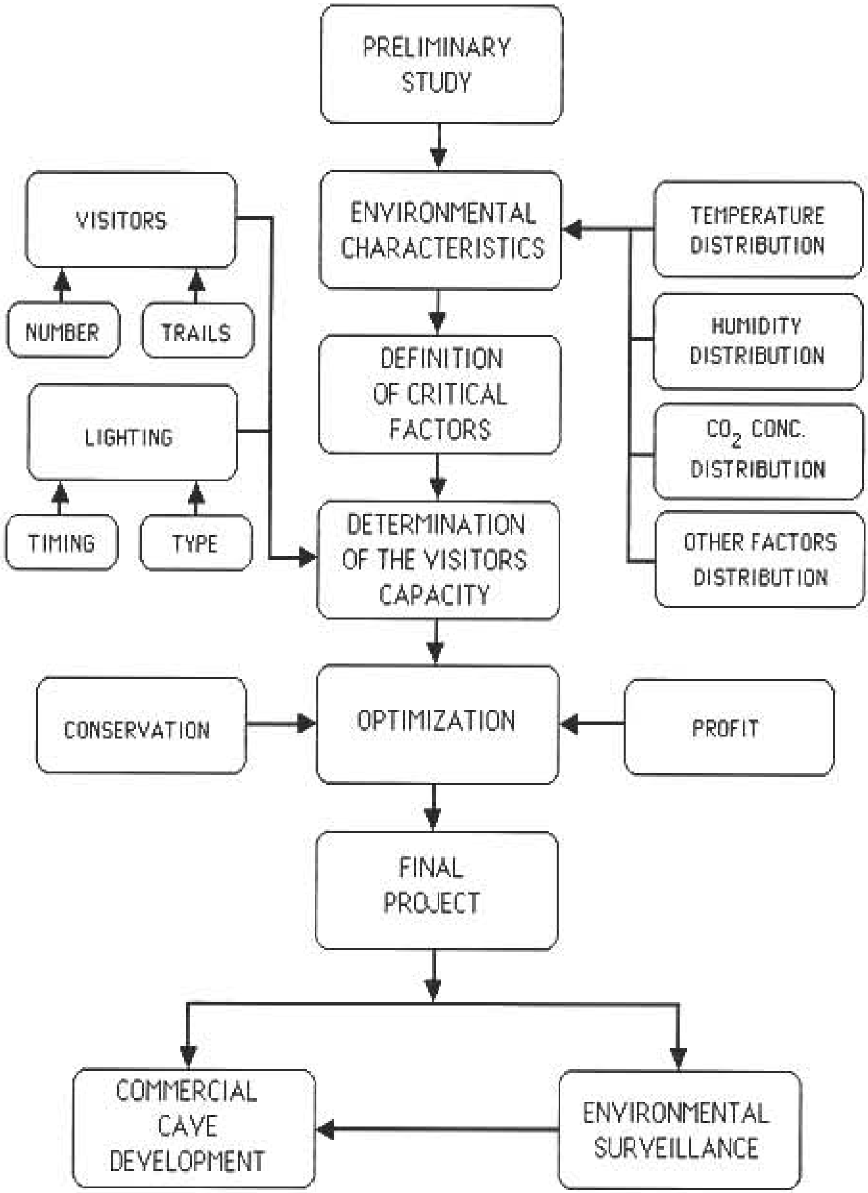

Fig. 4 - The Environmental Impact Assessment for the development of a tourist cave.

Such results must be emphasised because too often the development of a cave into a show cave is considered a pure loss for science. To the contrary if the development is carried out according the principles of cave conservation, the final balance will be largely positive because a small fraction of the commercial profit of the show cave may provide an invaluable source for a research budget.
In addition to this advantage, there is also a direct positive effect on the protection of the cave environment, because when part of a large system is developed for tourism, a control is automatically assured also for the other parts of the cave which would have been open to everyone if the cave would have remained wild (Gurnee, 1967; Forti, 1996). These considerations introduce to another argument, the economy in connection with show caves.

Show caves and economy.
Dell'Oca has published one of the first papers dealing with this subject (1962) and it was concerned with many different aspects of the use of caves with an economical involvement. In particular it was pointed out the effect of a show cave development on the local economy and the example of Castellana Caves (Puglia, Italy) was described.
It is evident that the economy of a region around a show-cave-to-be can be radically modified by the cave development. Therefore strenuous opposition to any tourist visitation appears to be rather unfair towards the local people particularly when a suitable compromise between strict conservation and a sound development can be found. But in any case, as it was previously reported, a cave development cannot be accepted if it is not supported by appropriate preliminary research.
In Table 1 nearly 200 show caves of 28 countries from all over the world are reported with the indicative number of visitors per year. It must be stressed that such figures are not homogeneous because they have been determined according to different criteria. In particular the number of visitors per year is not constant and varies as a consequence of many factors. The number reported in the table refers to a recent year in some case or refers to an average among some years in some others.

Table 1 - Some important show caves from all over the world.

COUNTRY	Show Cave	Region	N° of visitors per year
ARGENTINA	Caverna de las Brujas	Mendoza	12,000
AUSTRIA	Eisriesenwelt	Salzburg	150,000
	Rieseneishöhle	Oberösterreich	120,000
AUSTRALIA	Abercrombie Caves	New South Wales	10,000
	Jenolan Caves	New South Wales	240,000

	Wee Jasper Caves (Careyís)	New South Wales	3,000
	Wellington Caves	New South Wales	42,000
	Wombeyan Caves	New South Wales	30,000
	Yarrangobilly Caves	New South Wales	23,000
	Buchan Caves	Victoria	60,000
	Princess Margaret Rose Caves	Victoria	10,000
	Murrindal Caves	Victoria	2,000
	Cammoo Caves	Queensland	10,000
	Olsens Capricorn Caverns	Queensland	35,000
	Chillagoe Caves	Queensland	18,000
	Undarra Lava Tubes	Queensland	40,000
	Cutta Cutta Caves	Northern Territory.	34,000
	Englebrecht Cave	South Australia..	10,000
	Naracoorte Caves	South Australia.	60,000
	Tantanoola Caves	South Australia.	20,000
	Gunns Plains Cave	Tasmania.	10,000
	Hastings Caves	Tasmania.	38,000
	Augusta/Maragaret River Caves	Western Australia.	60,000
	Ngilgi Cave, Yallingup	Western Australia.	65,000
BELGIUM	Grotte de Han	Namur	500,000
BERMUDA	Crystal Caves	Bermuda	80,000
BRASIL	Gruta de Maquiné	Minas Gerais	47,000
	Gruta da Lapinha	Minas Gerais	36,000
	Gruta Rei do Mato	Minas Gerais	30,000
	Nucleo Santana (3 caves)	São Paulo	24,000
	Caverna do Diabo	São Paulo	27,000
	Grutas de Intervales	São Paulo	12,000
	Poço Encantado	Bahia	> 5,000
	Gruta Botuverá	Paraná-Santa Catarina	7,000
	Gruta Angélica	Goiás	3,000
	Gruta dos Ecos	Goiás	20,000
	Gruta Terra Ronca	Goiás	7,000
	Gruta Lago Azul	Mato Grosso	44,000
	Gruta São Miguel	Mato Grosso	5,000
	Grutas da Serra da Capivara	Nordeste-Norte	5,000
	Gruta de Maroaga	Nordeste-Norte	4,000
	Gruta de Ubajara	Nordeste-Norte	47,000
	Gruta do Castelo	Nordeste-Norte	20,000
	Gruta dos Martins	Nordeste-Norte	9,000
CHINA	Alugu Cave	Yunnan	350,000

	Benxi Water Cave	Liaoning	280,000
	Biyundong Cave	Guzhou	150,000
	Boyundong Cave	Hunan	300,000
	Furongdong Cave	Qongqing	300,000
	Guilin Reed Flute Cave	Guangxi	920,000
	Huang Long Cave	Hunan	300,000
	Jiutiendong Cave	Hunan	200,000
	Kongshan Baiyun Cave	Hebei	170,000
	Longgong Cave	Guizhou	400,000
	Longgong Cave	Jiangxi	300,000
	Shanjuan Cave	Jiangsu	400,000
	Shihua Cave	Beijing	380,000
	Snow Flower Cave	Henan	250,000
	Taiji Cave	Anhui	200,000
	Tanglong Cave	Hubei	200,000
	Tianquan Cave	Sichuan	350,000
	Wolongdong Cave	Yunnan	250,000
	Yaolin Cave	Zhejiang	370,000
	Yuhua Cave	Fujiang	300,000
	Yunfu Panlong Cave	Guangdong	200,000
	Zhijing Cave	Guizhou	150,000
	Zhiyundong Cave	Yunnan	500,000
CZECH REPUB.	Bozkov Dolomite Cave	East Bohemia	75,000
	Konìpruské Caves	Central Bohemia	125,000
	Chynovská Cave	South Bohemia	40,000
	Zbrasov Aragonite Caves	Central Moravia	50,000
	Javoricko Caves	Central Moravia	60,000
	Mladec Caves	Central Moravia	20,000
	Na Pomezi Caves	North Moravia	60,000
	Na Spikaku Caves	North Moravia	15,000
	Punkva Caves	South Moravia	195,000
	Balcarka Cave	South Moravia	40,000
	Katerinska Cave	South Moravia	60,000
	Sloupsko-sosuvske Caves	South Moravia	45,000
FRANCE	Grotte d'Arcy	Yonne	180,000
	Aven Armand	Lozère	100,000
	Grotte de la Balme	Isère	60,000
	Abîme de Bramabiau	Gard	40,000
	Grotte de Grandes Canalettes	Pyrénées Orientales	40,000
	Grotte de Choranche	Isère	150,000
	Grotte de Clamouse	Hérault	150,000
	Grotte la Cocalière	Gard	100,000

	Grotte Prehist. Foissac	Aveyron	18,000
	Grotte de Fontirou	Lot et Garonne	40,000
	Grotte des Demoiselles	Hérault	150,000
	Grotte du Grand Roc	Dordogne	130,000
	Grottes Isturitz Oxocelhaya	B. Pyrénées	90,000
	Grotte Lacave	Lot	150,000
	Grotte Limousis	Aude	26,000
GEORGIA	Novoafonskaya	Abkhasia	700,000
	Navenakhevi	Terjol	20,000
	Sataplia	Tskhaltubo	100,000
GERMANY	Barbarossahöhle	Thüringen	200,000
	Dechenhöhle	Sauerland	200,000
	Erlebnisbergwerk Merkers	Thüringen	70,000
	Feengrotten	Thüringen	200,000
	Hermanns and Baumannshöhle	Harz	260,000
	Kluterthöhle	Westfalen	30,000
	Historisches Kupferbergwerk	Hessen	120,000
	Nebelhöhle	Schwäbische Alb	100,000
	Teufelshöhle	Franken	200,000
	Wiehler Tropfsteinhöhle	Bergisches Land	60,000
HUNGARY	Abaliget Cave	Baranya	70,000
	Anna cave	Bükk Natl. Park	20,000
	Baradla Cave	Aggelek	180,000
	Buda Castle Cave	Budapest	50,000
	Szt. István Cave	Bükk Natl. Park	60,000
	Lóczy Cave	Veszprém	10,000
	Miskolk-Tapolca Cave	Veszprém	100,000
	Pál-Völgy Cave	Budapest	40,000
	Szemlö-Hegy Cave	Budapest	10,000
INDIA	Vaishno Devi	Jammu	490,000
IRAN	Ghar Alisadr	Hamadan	400,000
ITALY	Grotta dell'Angelo	Campania	80,000
	Grotta di Castellana	Puglia	250,000
	Grotta di Collepardo	Lazio	10,000
	Grotte di Frasassi	Marche	350,000
	Grotta Gigante	Venezia Giulia	85,000
	Grotta di Is Janas	Sardegna	10,000
	Grotta di Ispinigoli	Sardegna	40,000

	Grotta del Nettuno	Sardegna	180,000
	Grotta di Oliero	Veneto	30,000
	Grotta di Pastena	Lazio	40,000
	Grotta di Pertosa	Campania	60,000
	Grotta di Su Mannau	Sardegna	20,000
	Grotta San Michele	Sardegna	3,000
	Grotta di Smeraldo	Campania	100,000
	Grotta di Su Marmuri	Sardegna	10,000
	Grotta di Toirano	Liguria	200,000
	Grotta del Vento	Toscana	60,000
	Grotta di Is Zuddas	Sardegna	50,000
NEPAL	Mahadev Cave	Pokhara	> 200 000
	Bat Cave	Pokhara	10,000
NEW ZEALAND	Waitomo Caves	North Island	400,000
	Blackwater Rafting	North Island	12,000
	Te Anau Caves	South Island	12,000
	Metro, Te Hahi & Babylon.	South Island	5,000
PUERTO RICO	Cavernas del Rio Camuy	Arecibo	140,000
RUSSIA	Kungurskaya Ledjanaya Cave	Perm	200,000
	Bol'shaya Azishskaya Cave	Krasnodar	25,000
SLOVENIA	Postojnska Jama	Postojna	800,000
	Skocjanske Jame	Matavun	50,000
SLOVAK REP.	Belianska Cave	Tatra Natl. Park	90,000
	Bystrianska Cave	Low Tatras	30,000
	Demanovska Liberty Cave	Low Tatras Natl. Park	135,000
	Demanovska Ice Cave	Low Tatras Natl. Park	50,000
	Dobsinka Cave	Slovak Paradise Natl. Park	75,000
	Domica Cave	Silicka Plateau	25,000
	Driny Cave	Lesser Carpathiana	40,000
	Gombaseka Cave	Silicka Plateau	15,000
	Harmanecka Cave	Greater Tatra	20,000
	Jasovska Cave	Jasov	22,000
	Ochtinska Cave	Revucka Highland	28,000
	Vazecka Cave	Vazec	30,000
SPAIN	Cueva de Nerja	Malaga	500,000
	Cueva del Tesoro	Malaga	50,000
	Cueva de Valporquero	Leon	70,000

SOUTH AFRICA	Cango Cave	Oudtshoorn	250,000
SWEDEN	Lummelundagrottan	Gotland	80,000
TURKMENISTAN	Bakhardenskaya Cave	Bakharden	40,000
U.K.	Cheddar Caves	Somerset	260,000
	Dan-yr-Ogof Show Caves	S. Wales	80,000
	Kents Cavern	Devon	115,000
	Peak Cavern	Derbyshire	120,000
	Poole's Cavern	Derbyshire	390,000
	Treak Cliff Cavern	Derbyshire	82,000
	White Scar Cave	Lancashire	66,000
UKRAINE	Adjimushkay cave	Crimea	220,000
	Bair Cave	Crimea	60,000
	Krasnaya Cave	Crimea	50,000
	Kristalnaya Cave	Ternopol	70,000
	Mlinki Cave	Ternopol	25,000
	Mramornaya Cave	Crimea	200,000
	Nerubajskoje Cave	Odessa	50,000
	Pecherskaya Lavra Caves	Kiev	1,800,000
U.S.A.	Cave of the Winds	Colorado	> 100,000
	Carlsbad Caverns	New Mexico	> 100,000
	Crystals Caves	Bermuda	> 100,000
	Fantastic Caverns	Missouri	> 100,000
	Howe Caverns	New York	> 100,000
	Inner Space Cavern	Texas	> 100,000
	Lost Sea	Tennessee	> 100,000
	Luray Caverns	Virginia	> 100,000
	Mammoth Cave	Kentucky	> 100,000
	Marvel Cave	Missouru	> 100,000
	Meramec Caverns	Missouri	200,000
	Moaning Cave	California	100,000
	Natural Bridge Caverns	Texas	> 100,000
	Penn's Cave	Pennsylvania	80,000
	Rio Camuy Cave Park	Puerto Rico	> 100,000
	Ruby Falls	Tennessee	> 100,000
	Sea Lion Caves	Oregon	> 100,000
VENEZUELA	Cueva del Guacharo	Monagas	100,000

According to Zhang & Jin, (1996) there are about 800 show caves in the world. If it is assumed that the caves listed in Table 1, with much more than 25 million visitors, are a reasonably representative sample of all show caves, since they are 150/800 = 19 % of the whole, a global number of more than 150 million visitors per year may be evaluated.

By assuming a budget per person as reported in Table 2 the total amount of money spent to visit the show caves is around 2.3 billion US$. The number of the local people directly involved in the show cave business (management and local services) can be estimated to be several hundred per cave, i.e. some hundreds of thousands of individuals in the world.

By taking into account that there are several hundred other people working indirectly to each person directly connected with a show cave (Forti & Cigna, 1989), a gross global figure of about 100 million people receive salaries from the show cave business, i.e. it can be roughly assumed that behind each tourist in a show cave there is about one employee directly or indirectly connected.

In addition to show caves, it must be considered also the existence of karst parks, which include a cave within their boundaries. As reported by Halliday (1981) the number of visitors of three top karst national parks in USA (Mammoth Cave, Carlsbad Caverns and Wind Cave) amounted to about 2,500,000 tourists each year. Therefore karst parks give a further increase to the number of people involved in the whole "karst" business.

Table 2 - Rough estimation of the annual direct and local budget of a show cave per each visitor (US $).

Direct income		5
Other local income:		
	Souvenirs & snacks	1.5
	Meals	5
	Transportation	2
	Travel agency	2
TOTAL		**15.5**

There are many other human activities which involve a larger number of people; nevertheless the figure reported above is not negligible and gives an indication of the role that show caves play in the global economy.

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