Performance Appraisal of Sportshall and Swimming Pool Buildings in Greece

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Στους γονείς μου,
Μαρία και Παναγάγγελο
και στον αδελφό μου,
Στρατή

Abstract

The selection of the best performing constructional system—among a diverse selection of alternatives—for long spanning (25–60m) sportshalls and swimming pools in Greece initiated this research. Decision making, concerning selection of the constructional system, is difficult in this sector of construction as was explained in the "Long spanning Structures" conference (Nov. 1990, Athens, Greece). Among the reasons is the availability and cost of locally produced concrete and reinforcing bars in contrast to imported steel and timber, the availability of structural codes and the frequency and strength of earthquakes.

The research objectives set were to develop a model to appraise the performance of sportshalls and swimming pool buildings and to evaluate the performance of such buildings. Following discussions with Greek building professionals, the research hypothesis was formulated as: "*The General Secretary of Sports (GSS) evaluation system is effective for the appraisal of 25 to 60 metres long spanning sportshalls and swimming pools in Greece*".

From literature, it has been found that most building appraisals end up at the level of data analysis and draw conclusions on the individual aspects they investigate. These approaches usually focus on a fraction of the problem, examining it very deeply and theoretically. Their drawback is loss of comprehensiveness and ability to draw conclusions on an overall level and, consequently, being applicable to the existing conditions. Research on an inclusive level is sparse.

In this research, an inclusive appraisal approach is adopted, leading to the identification of three main variables, resources, user–human satisfaction and technical; consequently to a combination of quantitative and qualitative data. A model of quantification, is developed which is of vital importance if the problem of incompatibility of data is to be solved, overall relation of findings is to be achieved and holistic conclusions are to be drawn. This model facilitated the construction of an overall index of performance by measuring the performance of each building as a whole through its components' performances and comparison to the others in the sample.

Case studies are conducted on a sample of ten existing buildings in order to assess the effectiveness of the evaluation system used by the GSS through the performance of the various alternative constructional systems implemented. The conclusions drawn do not support the initial hypothesis, demonstrating the limitations of the GSS evaluation methodology. Problematic natural lighting specifications, lack of passive energy systems specifications, low priority (relative importance) of the roof's waterproofing and heating systems design, justify the need for revised GSS briefs and fine tuning the GSS model of evaluation.

All three constructional systems (based on timber glue laminated, steel trusses and tents) have similar performance and, therefore, are appropriate in Greece. However, the particularities of their implementation (such as cladding, lighting, heating, energy conservation, colours etc.) are key issues in constructing well performing buildings. The applicability of reinforced concrete framed structures is questioned and prestressed reinforced concrete use is not justified due to the high capital costs and technology involved (except for the foundations and vertical loadbearing structure were it performs well in both technical and economic terms).

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Chapter 1 Introduction

1.1. The Problem

There is a global problem of evaluating and assessing the appropriateness, effectiveness and, in general, the performance of the various constructional systems used in buildings. This problem is equally applicable in Greece, though, as evident from the following paragraphs, it is more apparent in long spanning buildings.

It is essential to present the conditions existing in Greece in order to facilitate a better understanding of the problem. In short spanning buildings, ranging from dwellings to hospitals and office blocks, spanning up to 15 metres, in-situ reinforced concrete frames with non-loadbearing brick walls is the dominant constructional system. Among the reasons for this preference is the low cost of the materials which are produced locally, the availability of labour and the high cost of imported structural materials. The lack of a tailor-made codes of practice for steel and timber, architects' and structural engineers' lack of knowledge on how to design steel, timber and tension structures and management and operatives' capabilities are also critical.

In long spanning buildings, of over 25 metres, there is no dominant constructional system nor structural material. Various opinions and arguments from architects, building engineers, contractors and theoreticians have led to a long lasting debate. Amongst the constructional systems argued for and adopted in Greece during the last twenty years are steel space frames, space decks and trusses, tension structures, timber (Glu-lam) beams, fabric tents and prestressed reinforced concrete.

The importance of the debate, together with an increasing need for long spanning buildings to house exhibitions, conference and sports halls, warehouses and swimming pools, forced the Technical Chamber of Greece to organize a Scientific Seminar on Long Span Structures (Athens, 1990). The chairman of the seminar, Hatzistergiou, in drawing the conclusions, highlighted the following problems:

- availability and suitability of structural materials
- need for new building standards
- import of know-how on a permanent basis
- quality control
- educational needs of the engineers.

However, it should be noted that these problems are not new for Greece. Kalogeras (1974) in his article "The construction environment in Greece; an appraisal" referred to similar issues. He argued that the—not ideal—state of affairs in construction (not specifically in long spanning buildings) mainly was due to three factors:

1. poor communications between the client-user, the architect and the contractor in *identification of user needs, establishment of a comprehensive building brief, interdisciplinary co-operation and contractor-architect relationship,*

2. lack of organised building research and

3. absence of technological innovation due to the present structure of the building industry.

The first factor mentioned by Kalogeras was not considered in the seminar, implying that communications between client-user and the designing team are improving. However, the other two factors were discussed in the course of the seminar and their importance highlighted by the chairman. This confirms the existence of **a problem of objective evaluation methods for the assessment of various constructional and structural systems used; and in long spanning buildings in particular**.

This problem is quite broad and, in an attempt to narrow it down, the types of buildings spanning over 25 metres are examined. These include sportshalls and swimming pools, conference halls, cinemas and theatres, exhibition halls and, finally, industrial buildings and warehouses. The design and evaluation criteria for these building types vary substantially; conference halls, cinemas and theatres having one group of mutually related criteria and sportshalls, swimming pools and exhibition halls another.

An attempt to identify the most suitable building type for the research included an assessment of the relative importance of the various types for the Greek construction industry, availability of data, number of buildings built per type and future trends. Therefore, discussions and interviews were conducted in Greece with architects and building engineers as well as academics. The conclusions drawn are presented briefly.

There is a need for conference halls but only a couple of buildings have been constructed in the last decade. Furthermore, the lack of a board or committee responsible for the construction of such buildings makes predictions of the construction future impossible. Similarly, the existing exhibition halls are either public or private developments involving diversified objectives which militates against the establishment of a single model for assessment. As far as auditoria, cinemas and theatres are concerned, the most important project within the specified span range is the "Hall of the Friends of Music". Although the construction of it began in the late 70's, a considerable delay occurred and it was finally completed in 1990. There is no provision for similar projects in the future, although a few short spanning (20–25 metres) theatres and auditoria are, currently, in the design stage or under construction.

Regarding industrial buildings and warehouses, it was found that the diversity of objectives and the availability of data are the two main restrictions for research. The first poses the greater problems as some buildings are designed simply to protect goods from weather conditions, whereas others, like factories, are built with design criteria more close to those of exhibition halls.

The last category is sportshalls and swimming pools. Korbas (interview 1990), architect member of the Design Department of the General Sport's Secretariat (DDGSS), pointed out that the vast majority of these buildings are General Sports Secretariat (GSS) developments; the few privately financed buildings do not span over 25 metres. The existence of this public board (DDGSS) is critical in obtaining data on design criteria and building construction facilitating the objective modelling of such buildings. Additionally, there are a large number of existing buildings and a programme for the construction of new ones.

Korbas (1990) explained that during the last fifteen years, the objective set by the GSS was to construct covered sports and training halls, as well as swimming pools of various sizes all over the country, very often under difficult conditions and limited budget. As this objective has been achieved, the new one set is "*to build medium spanning halls, in the region of 45 metres, large enough for three attached training terrains or a large one for official games, providing seating for approximately 1500 spectators*". In order to have a sufficient sample of buildings and objective data it was decided to examine sportshalls and swimming pools.

1.2. Aim of the Research

The aim of the research is to investigate the performance of the various constructional systems used by the GSS for long spanning sportshalls and swimming pools in Greece and to devise an objective evaluation method for their assessment.

1.3. Research Objectives

Three main objectives are set.

Objective 1. *Define performance of buildings and evaluate building appraisal methods and techniques***.**

Therefore the following factors are considered:

1. <u>Building Performance</u>

   Definition and analysis of the performance concept in general (literature review).

   Discussion of the application of the performance concept in buildings.

   Analysis of previous research on building performance; their aims and objectives.

2. <u>Building appraisal</u>

   Literature review; definition of building appraisals and application's objectives.

   Investigation of the methodologies implemented.

   Problems identified. Evaluation of the appraising methods.

Objective 2. *Develop a model for appraising the performance of sportshalls and swimming pools in Greece.*

The steps to be followed are:

1. Determination and evaluation of the performance requirements for sportshalls and swimming pools in Greece.

    G.S.S.; its structure and objectives.

    Analysis of the procurement methods used by the GSS.

    Identification, classification and weighting of independent, intervening and dependent variables according to the GSS.

2. Model appraising sportshalls and swimming pools.

    Identification and development of the main variables; parameters affecting this process.

    Analysis of the main variables and development of measurable indicators.

    Classification and weighting of the variables.

    Development of the analytical tools (questionnaires, interviews, measurements, etc.)

Objective 3. *Evaluate the performance of sportshalls and swimming pools buildings in Greece.*

1. Application of the model to a sample.

    Select a representative sample.

    Data collection (field work).

2. Data analysis, production of results and drawing of conclusions on:

    Performance of the buildings in the sample

    Performance of the research variables

    Design considerations on constructional systems

    Comparison of the *('idealised' but still feasible)* research appraisal system to the GSS one. Identification of shortcomings in GSS appraising system.

1.4. Scope of the Study

The long spanning sportshalls and swimming pool buildings, the focii of this research, can be further classified in three categories of diverse needs and considerations according to their span. The **small**, hardly reaching the span range set in the research objectives and thus discarded from further analysis, the **medium** (25–60m.) and the **large**, over 60 metres.

Medium halls have a great range of diverse solutions and different constructional methods implemented. A great variety of structural solutions have been implemented such as steel space framed beams, 3D trusses and space frames, various forms of fabric and pneumatic structures, tents, inflated balloons etc. Glu-lam structures are close to their upper limit, at least for the technology applied in Greece, not exceeding 40 metres. Reinforced concrete structures have been used, though rarely.

Large spans are very rare. Two of the three architectural contests on sportshalls and swimming pools are for such buildings (Palai de Sport, Olympic Swimming Pool complex) spanning over 100 metres. Although it would be very interesting to examine these two examples, the lack of other buildings, and the fact that the GSS is not forecasting any other similar projects in the near future, makes the category inappropriate.

Therefore, considering the variety of constructional systems and materials, the number of buildings available and the argument that this span range is most likely to be used for future GSS designs, medium spans are examined.

1.5. The Research Hypothesis

The Design Department of the GSS (DDGSS), in order to select the appropriate design for each building it is constructing, is following an evaluation method based on the design proposal combining the budgeted costs and the expected quality. However, once done, no appraisal of the existing buildings take place that would improve the existing evaluation method and subsequent buildings through feedback from actual cases (Markus 1972, Preiser 1991). Therefore, the research hypothesis is that:

The GSS system is effective for the appraisal of 25 to 60 metres (long) spanning sportshall and swimming pool buildings in Greece.

1.6. Methodology

The initial consideration is the development of a theoretical background upon which the whole research is based, enabling better understanding of the particularities of the topic. The research model is developed by analysing the Greek conditions and executing a preliminary study on both public and private sector buildings. In order to test the model and draw conclusions related to the hypothesis and objectives set, field work is carried out on a representative sample of buildings in Greece. The findings of the subsequent analysis facilitate the drawing of overall conclusions. The simplified flow chart of Figure 1.1 presents the methodological steps of this research.

In this study, a sample of Greek sportshalls and swimming pools is assessed; the process has been accomplished by measuring the performance of each building as a whole through its components' performance and by comparing it to the others in the sample. Consequently, the first step carried out is the analysis of the performance concept and its application in buildings. The research focuses on cost, technical issues, human and user needs, functional requirements and criteria and performance requirements.

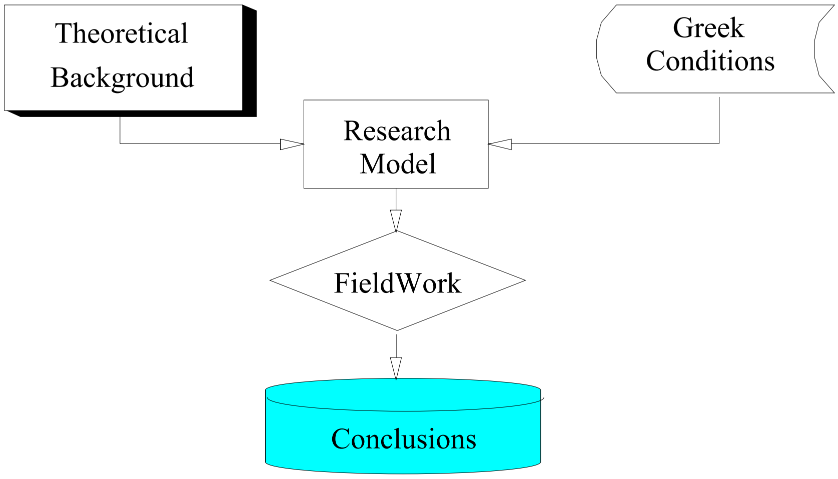


Figure 1.1: A Diagrammatic Model of the Research Process

Three distinct performance concept approaches were identified through the literature; cost dependant, quality dependant and cost-time dependant. The research objectives do not justify any of these approaches individually and, therefore, the development of an inclusive approach is pursued.

The appraisal of buildings is defined through the analysis of various methodological approaches reviewed in the literature. Their applicability problems (Bishop, 1978), are discussed and ways forward suggested. Model and framework developing theoretical approaches are presented focusing on the models presented by the Building Performance Research Unit (BPRU, 1972), Social Services Building Research Team (SSBRT, 1976) and Preiser et al (1988).

The development of the research model started by examining the Greek construction environment. The four procurement systems used by the GSS are investigated and their particularities discussed. The GSS's own model of evaluation in the proposal stage is analysed, its main variables identified and their relative weighting considered. Additionally, the briefs for sportshalls and swimming pools are examined and lists of general and structural remarks as well as functional criteria are constructed and presented in the appendices.

The empirical methodology of the research is based on both literature and the GSS model. The parameters considered are presented, followed by the establishment of the three main variables; resources, human user satisfaction (HUS) and technical. Subsequently, the indicators of these variables are identified and ways of measuring them are developed leading to a mathematical model of quantification.

A representative sample of buildings in Greece is selected and the field work carried out. This includes data collection from four stages of the building life; briefing, construction design, construction and in-use. Data related to the first two stages are gathered through interviews and analysis of plans and briefs as found in the GSS design department.

As far as the construction data are concerned, the GSS engineers, acting as building supervisors during the construction, are questioned. The final stage of data collection involves researcher's observation, users questionnaires and the buildings' managing committees questioning.

The analysis of the collected data reveals problems of data transformation and incompatibility which are solved by the calculation of present values for all cost related issues and the use of standard scores and rankings for the overall classification of the buildings. Tables presenting the results of this analysis facilitating the drawing of conclusions are included in the appendices.

Finally, the results from the analysis of each building are discussed explicitly and overall conclusions are drawn. Figure 1.2 summarizes the process of the research methodology.

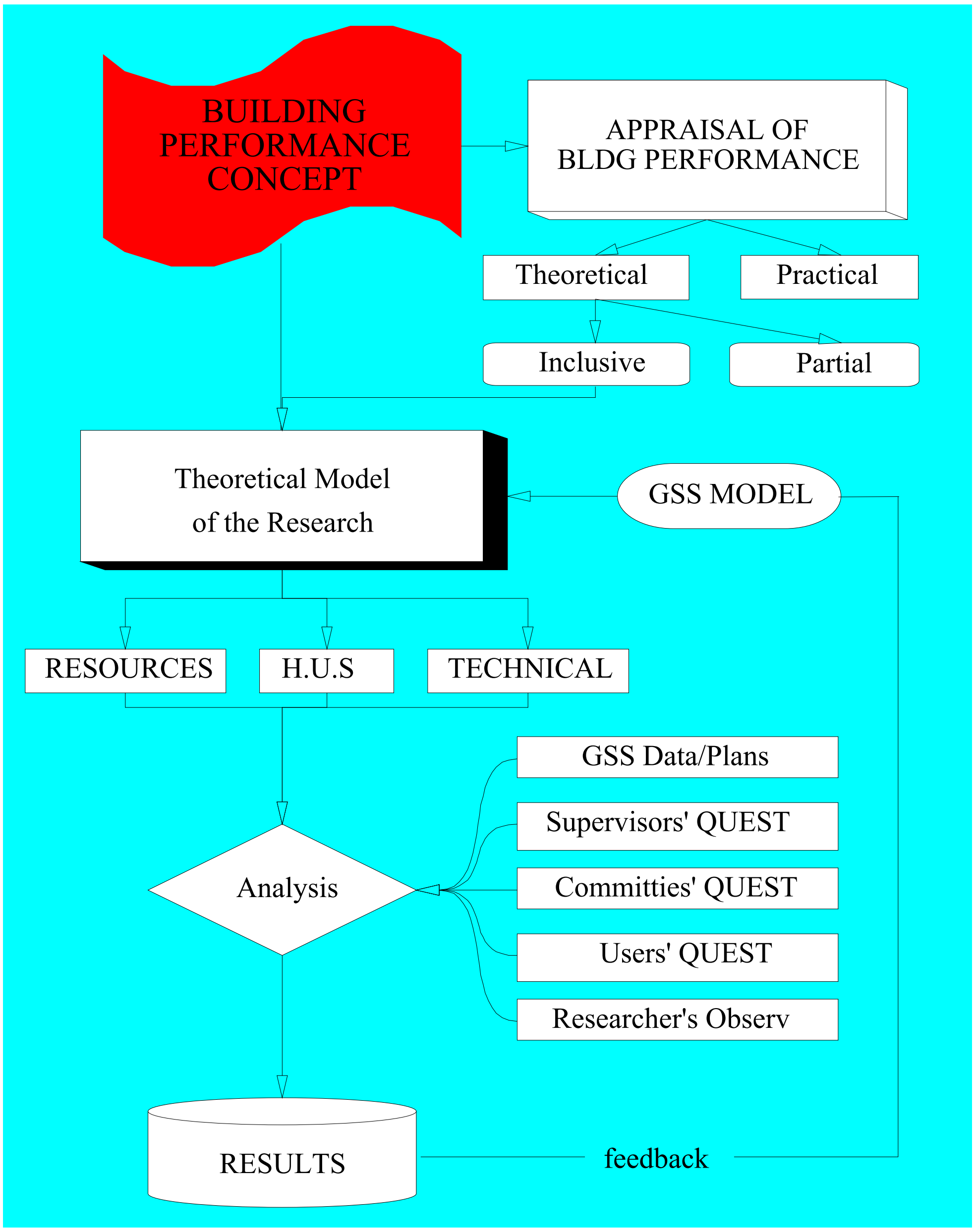


Figure 1.2: The Research Process

Chapter 2 Performance and Appraisal of Buildings

2.1. Building Performance

2.1.1. The Performance Concept in Buildings

The problem of decision making during building design, in terms of structural materials, subassemblies and constructional systems used, is an old one (CIB W60, 1975) and as Preiser et al (1988) argue still hasn't been solved. This decision making problem is closely related to the evaluation of the building elements in order to identify their properties and subsequently their applicability for certain needs. The same problem exists as far as evaluation in use is concerned; according to Shibley (1982) '*Buildings need constant adjustments to the needs of their users*', which leads to a continuous need for assessment evaluation and fine tuning of the building objectives, following users' feedback—feed forward to use Markus' (1972) terminology.

Up to the 1960's, new products', materials' and constructional methods' applicability and suitability for certain uses were assessed by comparing them to well–known ones, used extensively in the construction at that period. To be considered further as alternatives, the new products should be as good as the ones already applied, at least in all essential properties (CIB W60, 1975). This is the so–called prescriptive method in design. However, this procedure is not acceptable nowadays; it is very difficult, and in certain aspects highly subjective, to argue whether a product's properties are necessary or satisfactory (Green et al, 1990). As Preiser et al (1988) state, up to the 1960's the criteria (if existing at all) for assessment were the designer's experience, personal preferences and finally economic (without really considering the long term in–use implications, or heating etc.) and tradition related.

Therefore, the need to measure properties and values of structural materials, subassemblies and building systems objectively was highlighted by many researchers and practitioners. Gradually this led to discarding the traditional prescriptive approach in the design stage in favour of the performance based approach. It was mainly during 1960's (Preiser et al, 1988) that the concept of performance was introduced in its current form and by the late 1970's was used throughout the architectural profession. Nevertheless, it was only during the 1980's that the performance concept was accepted and widely used in the building industry (Preiser et al, 1988).

Due to the importance of the issue, RILEM, ASTM and CIB organised a joint symposium, 'Performance Concept in Buildings', that was held in U.S.A in May 1972. In this symposium, many interesting opinions and ideas were put forward. Among these was Preiser (1972), who highlighted problems related to the performance concept as it was perceived then:

> "The performance of buildings is commonly measured in economic terms such as return on investment, or in otherwise readily quantifiable terms, such as amount of time required for maintenance, heat transfer, acoustic properties, or durability of materials. '*Behavioural cost*', which might be defined as

> dysfunctional aspects in the human organism caused by elements in the social and the designed environment, traditionally has escaped rigorous measurement and quantification. It became evident only through indirect indices such as statistics on pathologies, absenteeism, job turnover, etc. It is suggested that, in addition to the commonly used performance measures, building performance (should) be based on normative user behavior that is explicitly stated in building program specifications."

Karlen (1972), in the same conference, drew attention on the two different approaches to the definition and use of performance concept. The first one is "behaviour in use" which means the behaviour of a thing (e.g. a building, building element or component) in its environment under its exposure to different agents. The second one is the output of a process, a transformation by activities or by function. Following this second interpretation, it is possible to go back to the original expressions—to perform an activity or to perform a function. As Karlen explains, the function of a building is related to the function of all the parts of the building and furthermore the function concept is related to the system concept. The relation between system and function can be expressed by a model, which yields the performance of the whole (system performance) as a result of the performance of the parts (subsystem performance).

Apparently, the greater percentage of researchers and academics have focused on the systematic approach to the performance concept. Among them Sneck et al who, in the joint RILEM–ASTM–CIB Performance Concept symposium (1972), argued that:

> "The application of the performance concept to buildings is considered as a total treatment of the problem where the influence of all aspects has to be accounted for. The performance concept implies that solutions are wanted which give optimal service under the influence of all factors affecting them in use."

The International Council for Building Research, Studies and Documentation (CIB), had been involved in the application of the performance concept in buildings since the late 1960's; the first pieces of work were conducted in Scandinavia. Various commissions were assigned to investigate aspects of performance. During the 5th CIB Congress in 1970, J.Dick, Director of the Building Research Station, reviewed current experience against an international background and highlighted problems faced in adopting a performance approach. He concluded arguing that although the performance approach has certain advantages in facilitating technical innovation and the introduction of scientific methods in buildings, it is not '*a ready–made panacea for all building technology problems*'. As the debate was continuing and the problem of defining terms and approaches was increasing, the CIB commissioned W60 on the performance concept (1975); its first report, mainly definitions and an agreed terminology, published in Building Research and Practice (1975) clearly defined performance and its concept:

> 'As a term to characterize the fact that products must have certain properties to enable them to function when exposed to stresses the word *performance* has been chosen.
>
> Use of the performance concept implies an attempt to define how a result aimed at should be able to *perform*—without resorting to a description of what the result *should be*.'

The new notions and approaches in the performance concept, during the 1980's and 1990's can be identified through the definition given by Preiser et al (1988), that focuses on the subject from a slightly different viewpoint:

> 'In the performance concept, the *behaviors, qualities* and *accomplishments* of people and things are *measured* and *evaluated*.'

2.1.2. Analysis of the Performance Concept

Ware (1972) analyzing the performance concept in a systematic way argues:

> 'The performance concept is an integral part of the systems approach. It provides an organized procedure by which it is possible to state the desired attributes of anything without regard to the specific means to be employed in achieving a solution.'

As he explains, these desired attributes are not dependent on particular materials, devices or systems and derive from the questions:

> Who is the user?
>
> What are the users needs?
>
> Where do the needs exist?
>
> When and for how long do the needs exist?

Consequently performance specifications are developed in order to describe the needs. These have the form of declarative statements. In order to quantify these statements, performance criteria are developed. These state a measure, or a range of measures, of the needs and usually involve a numerical statement of the requirements. Furthermore, in order to know whether the criteria are met, performance evaluation techniques or tests are developed. These include physical tests, simulations or expert judgements. Concluding, the combination of performance requirements, criteria and tests for a given system constitute the performance specifications.

Rosen (1973) commenting on the joint RILEM—ASTM—CIB Performance Concept symposium, quotes a participant's view on the stages of the performance approach in buildings:

> 'Without prescribing—and thus delimiting—the means of delivering the performance wanted, the performance approach makes possible the formulation of a statement of what is expected from a material, component or system in terms of performance itself. *This statement identifies a requirement, quantifies this in the form of criterion and sets the method or methods of assessing a candidate solution for compliance with the criterion.*'

Haider et al (1972) suggest another systematic approach to building performance. The concepts of need, resources, value system, performance criteria and information are identified.

> "A design problem situation usually begins with the realization of a need, which quoting from Hall (1962) is *'a state of tension or imbalance in the*

environment which tends to discharge in behavior aimed at relieving the tension or restoring the balance'.

Resources are the human, physical and financial capabilities of the society to fulfil its needs and wishes. These are analyzed further in long term (political, economic and social systems) and short term (capital available, time, talent, technology and natural resources).

The value system can be developed in five contexts; these are functional, technological, perceptual–aesthetic, sociological and economic. Each context has a set of criteria and each criterion corresponds to some particular characteristics of the building or of a sub–system of it.

'Information is the medium of design activity'. As they explain all stages of the design of a building, from the realization of need up to the construction documents, information is received, recalled, collected, created and converted."

Bearing in mind the arguments already presented by Ware, Rosen, Sneck and others, a systematic approach is attempted. Beman (1972) stresses that the performance path can be used throughout the hierarchical levels of design, '*from user needs and requirements up to performance specifications, while determining performance requirements and criteria, and establishing proper evaluation methods*'.

Blach's and Christensen's (1976) methodological framework for the application of the performance concept in buildings is presented in figure 2.1.

They argue that:

'If the aim is an operational performance specification, the work procedure must encompass a functional analysis, formulation and evaluation of properties relating to "in–use conditions" and development of evaluation methods.'

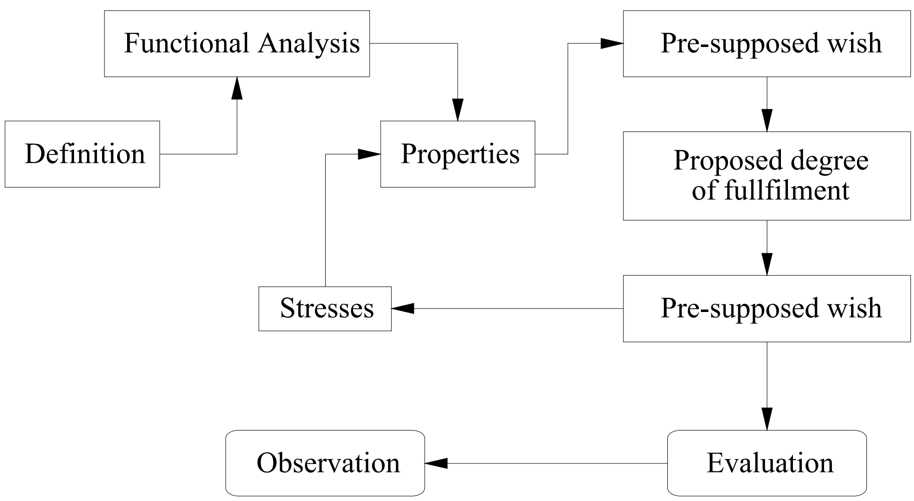


Figure 2.1. Application of Performance Concept; Methodological Framework by Blach and Christensen.

The analysis that follows is partly based on the Blach—Christensen model; aspects from the classifications and analyses already presented are incorporated as well. The framework shown in figure 2.2, is used in the analysis of the performance concept for this particular research.

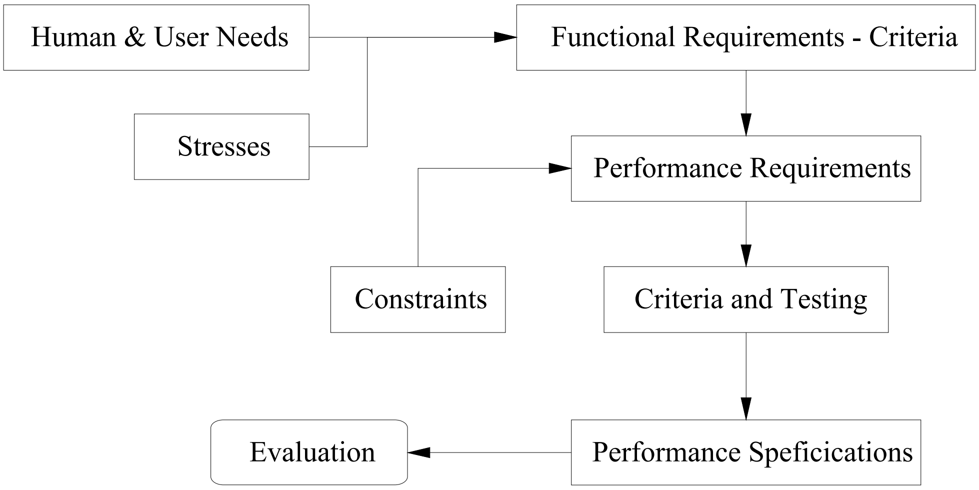


Figure 2.2: Performance Concept; Research's Application Framework.

2.1.3. Application of Performance Concept in Buildings

Human and Users' Needs

The CIB W60 report (1975), stressed that the performance concept takes as its starting point a recognition of needs expressed in terms of human and user's requirements. Therefore, in order to apply the concept of performance in the design of a building, identification and analysis of these needs should be the first step.

The importance of identifying user needs is also highlighted by Brill (1970) who argues that it is possible to assure the users' satisfaction with the surrounding environment if we find a way of assuring '*a good fit*' in physical, psychological and social terms. The systematic application of performance concept helps decision makers to design and procure buildings responsive to those needs and wants. He stresses that:

> 'If user needs are explicitly stated, and form the value structure of the design brief, and user satisfaction is both the goal and the basis for post–facto evaluation of the results, we ought to be able to assure a "good fit", a useful social instrument and a healthy market.'

Furthermore, as Rosen (1973) explains, '*One must be capable of understanding the needs of the user so that he can translate the requirements into a set of criteria by which he can specify materials, components and systems that will perform on the basis of life safety, structural adequacy, durability, environmental conditions and interaction of the parts that make the whole"*.

Nevertheless, the formulation of a comprehensive definition of needs is not an easy task. As Blach et al (1976) argue, the words usually used for short description of needs often are restricting, implying '*...a series of preconceived, "linear" thoughts based on how things always used to be*'. On the contrary, approaching the design via the performance concept is aiming at the adoption of '*...unbiased, "lateral" thinking*', that, as Brill (1972) argues, eventually leads to innovation. Concluding one should be aware that the words used for defining a need should not, unconsciously, lead towards the already well known or towards some marginally improved versions of them (Blach et al, 1976). Another common pitfall is to formulate very general definitions that on the one hand lead to solutions with a wide range of application but on the other become uneconomical; the effort involved in developing and improving the material to be able to perform in various conditions is increasing its cost.

Following the CIB W60 classification, human needs mainly are concerned with safety, health and comfort and are considered in every project, remaining quite the same in all buildings.

On the contrary, the so called user needs vary substantially. In many building types, such as public sector developments, speculative oriented projects, office buildings etc, the decision making (if they could be called so) groups involved are more than one mainly because the owner and the user are different. In these cases, as King (1972) argues, '*Weighing the comparative importance of the conflicting interests of the user–client and the owner–client is the most subtle area of decision making and the toughest*'. Furthermore, financiers', neighbours', community's or even future users' needs are considered in this category.

Generally these needs are grouped in five categories (CIB W60, 1975): *technical, physiological, psychological, sociological and economical*. Blachere (1966) gives a quite similar classification of the user requirements:

> '...those which are demanded by man—qua living animal: physiological performances; then those demanded by thinking man: psychological performances; those of social man: sociological performances; and finally, those of homo economicus: economic performances.'

As he states, the three first can be listed under a common heading: fitness for habitation whereas the last can be split into durability and cost.

Functional Requirements and Criteria

Having identified the various needs, the next step in the application of the performance concept in buildings is the development of functional criteria. To achieve this, the functional requirements, presenting the ways we want a product or solution to perform, should be identified first.

Functional requirements are the first stage in the process of matching needs and solutions (CIB W60, 1975). These are the qualitative and non–numerical statements of function as a design aim (*e.g. the room should be warm enough for the occupants or there should be enough natural light to read during daytime*).

Similarly to what was argued earlier, as far as needs were concerned, it is helpful to analyse and reach at the simplest way of expressing the primary function of an object or sub–assembly (Blach et al, 1976). In this way, out of each such functional requirement, several functional criteria evolve. It has to be stressed that the functional criteria considered in the design stage of a project are not only the ones already mentioned, stemming from the user requirements and needs. Human requirements and government regulations impose extra functional requirements aiming mainly to the public's health and safety.

A systematic approach, encompassing as many relevant aspects as possible and leading to the formulation of functional criteria, is the best way to ensure that solutions will function well (Blach et al, 1976). Nevertheless attention should be drawn to the fact that over detailed analysis resulting in a list of more than 15–25 items per assembly or object is going to have exactly the opposite result as it will discourage comparisons of various alternatives. A similar systematic approach should be followed for the presentation of the functional criteria so that the ones related to the most important requirements will be listed first followed by the less important ones.

According to the performance definition by the CIB W60, earlier in this chapter (page 10), functional criteria are highly related to the <u>stresses</u> to which the parts and subassemblies of a building are exposed. These are undesirable or destructive stresses interfering with normal use as well as stresses related to the normal use of the building. Blach et al (1976) argue that in order to assess the performance of various products and subassemblies it is crucial to be able to specify the whole range of stresses that each product may come upon, at least in a qualitative way, although a quantitative approach would be advantageous.

Performance Requirements

As Meyer et al (1972) explain, performance requirements are the non—prescriptive part of the whole set of requirements for buildings. According to them, performance requirements are objective, qualitative or quantitative statements describing a level of expectation relative to behavior of physical building elements.

<u>Performance requirements</u> are in fact the evolution of the functional requirements. In order to incorporate functional requirements in the building brief, they must be converted in more specific quantitative design aims (CIB W60 1976):

> '...indicate the numerical values—levels of performance required within various degrees of precision, and associated with the necessary units of measurement of test methods and taking into account the given conditions.'

So far, following the formulation of the functional requirements, the highest imaginable quality, '*pressuposed wish*', is prescribed. In fact, functional requirements are the 'utopic' part of the performance approach as they are neither attainable nor operational (Blach et al, 1976). However, these utopic requirements must be prescribed in any project as a pilot model of how solutions should perform and as an initiative for further research and development.

The most important issue is the criteria based on which the conversion will be conducted. These are the various restrictions and limitations that bring the whole process back to 'the harsh [redacted]eality'. Pena et al (1972) identify the groups involved in the decision making, and cons[redacted]uently imposing restrictions, and their 'role' in the design process:

The administrative group whose concern is to:

1. Reduce the time spent in planning and construction
2. Control the cost

[redacted] Quality control

The professional group (designers) concerned with:

1. The opportunity for innovation in the building as a whole
2. The inherent human values

[redacted] The visual quality of the building

The client user group concerned with:

1. The hope of greater satisfaction of its needs
2. Learning how their needs can be met

[redacted] Occupying and testing the finished building

The client owner group concerned with cost reduction and cost control.

Markus (1972), explains that early in the analytic stages, the designer discovers a number of legal, semi–legal (Code), cost and other constraints. While designing it may be discovered that several constraints are 'mutually exclusive' whereas others have to be broken if a solution is to be feasible. He argues that the feasibility study will realistically present the number and the size of these constraints.

The CIB W60 report (1975) on the other hand, specifies two main groups of restrictions; the given conditions and the transferred requirements. It should be stated that the most frequent restrictions are those of resources either in economical or technological (know–how) terms. The already discussed legislation and building regulations can also restrict the development of performance requirements.

Performance Criteria and Testing

As Rosen (1973) quotes from a participant of the RILEM—ASTM—CIB Symposium:

> 'The question is whether it is possible to define quantitatively all the necessary properties of a material, and whether there exists reliable methods of test which can measure the properties. It is contended that neither of these conditions exists to any useful extent, that in many cases they are never likely to exist, and that the instances in which they appear to exist are deceptive.'

Apparently, the complexity of the tests needed to establish performance requirements, is quite often making the whole process impractical for wide implementation by the designing practices.

The double importance of the testing methods and their improvement is discussed by Blach et al (1976). These on the one hand facilitate the improvement of the built environment, by opening new possibilities for using the technological know–how and on the other help in the evaluation of the newly developed solutions based on the performance concept. As they explain, the test methods (simulation of the stresses considered in the functional and consequently performance analysis) are roughly classified in three categories:

[redacted] Testing in the laboratory. This is considered as the most satisfactory testing method although the most difficult, time consuming and costly one. Starting with, some primitive experiments are needed to reproduce the real stresses. An attempt to simulate the stresses and to measure them is following. The next step is to decide on the magnitude and character of the simulated stresses and to validate the measuring method's reliability. Finally, the test methodology is described extensively [redacted] that other researchers can use the method as well.

Calculation methods are used when a good correspondence between a mathematical and a physical model exists. In this case, physical testing can be replaced by recognized calculation methods which, although they are simpler, give [redacted]ilar valid results.

Subjective judgment. This is used in cases where neither laboratory testing nor calculation methods can be applied. Therefore, the evaluation is made by recognized experts on the specific field.

Product and Performance Specifications

Having developed the criteria and the testing methods, the final stage in the application of the performance concept is the performance specification writing. Brill's (1972) definition of both prescriptive and performance specifications is quoted:

> 'Traditional or "prescriptive" specifications are a way of assuring that what is procured will be identical to some "model" which has given satisfactory performance in the past. Prescriptive specifications often prescribe the materials of which the object is to be made, the dimensions it must have, the finishes and the shapes, how it shall be installed and, in many cases, who shall make it.
>
> Performance specifications state in precise terms the characteristics desired by users of a product's of system's performance without regard to the specific means to be employed in achieving the results.'

As he explains, the latter have, since late 1960's, been used as mechanisms for procuring building sub–systems (notably M & E) and evaluating their performance.

Mainstone et al (1969) in a paper published by the BRE argue that: '*Performance specifications are concerned primarily with ends not means. They make explicit the performances required of an artefact and provide a basis for assessing objectively those that are achieved* '.

Finally, Architects' Journal (1985) defines performance specification as,

> '...a means of defining the required performance of a whole building, or a component of it, with the means of achieving the requirements being left primarily to the supplier or contractor.'

2.1.4. Benefits from the Application of Performance Concept in Buildings

Brill (1972), supporting the performance approach, states five reasons for the development and application of the performance concept in the building industry:

> ***'User satisfaction.*** *The users' opinions and requirements are usually underconsidered in the design of buildings, although we all agree that we build in order to satisfy the needs of the people that are going to use them.*

Information–rich procedures *due to the amount of information available to the designer prior the decision making.*

Innovation. *Through the performance concept, any solution that meets the specifications stated is accepted, thus the building industry is permitted to explore alternative solutions compared to those that are regarded as models now.*

Increased cost–effectiveness. *The performance information available, enable the manufacturing industry to reduce the costs of their products by reconsidering their quality and performance aims and focusing on the basic performance characteristics.*

Evaluation and feedback. *By stating the performance explicitly in terms of criteria and testing methods, it is possible to conduct objective evaluations. Furthermore, having the requirements, criteria and test methods we can examine their correctness, a feedback of the design process.'*

The performance concept has been accepted and widely implemented due to its many advantages and benefits over the traditional prescriptive approach. As Preiser et al (1988) state, first of all the performance concept approach has increased objectivity as subjective opinions are replaced by more objective measures of performance.

Clarity of measurement is another benefit as well as enhanced communication. The latter is due to the simplicity, standardisation and clarity of the relevant criteria and measures used that consequently allows them to be discussed with all participants in the building process. Innovation stemming from the development of a range of alternatives that meet the performance requirements set needs mentioning. Aid in decision making and advanced professionalism are the last benefits that they account.

2.1.5. Previous Research on the Topic

Having defined and analysed building performance, it is interesting to review how it has been used in the past.

A first consideration is that *the performance concept can be either the aim of a research or the means to reach the research's aim*. The first is when performance specifications and analysis of certain aspects is required and the second when evaluations, assessments or appraisals of buildings are needed.

Building performance has been investigated and researched a lot in the past especially during the 1960's and 1970's. Lately researchers became more keen on applied research and consequently the current studies are on evaluations, appraisals and post–occupancy evaluations (POE).

Aims of the previous studies

The **aim** of previous studies is the main indicator for further analysis. Therefore, a first classification should be based on them; three main categories where identified:

The performance concept. This has been quite general and needs further analysis. Dealing with the performance concept may be in three different areas.

- Identification of problems related to building performance.
- Investigating and setting performance requirements and criteria for specific building types.
- Setting performance specifications for particular building types.

Evaluation of buildings in the design stage. The performance concept is used for analysis and evaluation of proposed solutions. Following the evaluation of the alternatives, the most appropriate solution is considered for construction. A further analysis based on the evaluations' methodologies would be beneficial; two categories were identified:

- Partial evaluation, dealing with only particular aspects of building performance. These are chosen according to the views, sometimes quite arbitrary leading to a biased view of the subject. In some cases the brief or client are aiming the scope of the evaluation to a particular aspect.
- Inclusive evaluation, dealing with all aspects of performance in a structured and systematic way. Usually scarce and difficult approach to the subject, needing a lot of time and effort.

Appraisal of buildings in use. In this case the performance concept is used for the assessment of existing buildings. This is achieved in various ways presented in the second part of this chapter.

Objectives of previous research

Following the main classification of the previous research based on their aims, an other one based on the main dependent variable should be considered.

Three main approaches have been identified to which the building performance concept is applied; **Cost** dependent approach (analysis of economic factors and considerations), **Quality** dependent approach and **Cost-Time** approach (relatively new trend due to implementation of more advanced economics and the changes in the financing methods followed).

2.2. Appraisal of Buildings

2.2.1. Definition

There is a confusion as far as the terms evaluation and appraisal are concerned. It is widely believed that they both imply a process by which various solutions to a particular problem are tested and selected—that is prior to the actual implementation. Furthermore, evaluation is closely related to some sort of scores or values. These terms have been defined and used extensively in the social sciences. However, when applied in buildings, each one has a totally different meaning (Bishop, 1978).

Manning (1968) argues that:

> 'To appraise buildings' performance it is first necessary to measure some property or properties of that performance, then to compare those measurements with a suitable yardstick. This might be the owners' or users' stated requirements, the architects' intentions as defined by his formal instructions (drawings, specifications, and so on), the Building regulations, codes of practice, established physical standards, or other buildings. This comparison must next be evaluated to decide whether it is acceptable or not and if this can be done—its value rated on a scale.'

On the other hand, King (1972), argues that the evaluation of the quality of a building has been a subjective issue. By establishing performance criteria, quality is related to measurable objectives more than ephemeral issues and this facilitates decision making. He also stresses that weighing the relative importance of the user–client and the owner–client objectives–interests is the toughest area of decision making.

The concept of appraisal, as analyzed by the Building Performance Research Unit (BPRU, Markus et al, 1972), is related to the establishment of the quality or performance of a solution and incorporates three basic steps:

> *"**Representation** in which the solution is modelled in a suitable way. This representation may be verbal, mathematical, visual or even full–scale (a building in–use is a full model).*
>
> ***Measurement**. In this step the performance of the model is obtained on as wide a variety of counts as necessary. To list but a few—costs, environmental conditions, flexibility, space utilization are among the aspects involved.*
>
> ***Evaluation,** when the measured results are evaluated. Techniques that are applicable are: cost–benefit analysis, aesthetic and value judgements, comparisons with the ideal, average or statutory performance standards found in the analysis etc."*

As is stated in the Social Services Building Research Team (SSBRT) (1976) report: *'Evaluation, it appears, includes two concepts, the primary one being that of comparison of measurements against criteria, and the other of choice between alternative solutions, again judged against criteria.'*

The clearest definition of appraisal of buildings is given by Bishop (1978):

> 'Appraisal is the process by which completed buildings are assessed, judged or evaluated by the client, the users (if distinct from the client), the designers or by a combination of any of these.'

On the other hand, Shilbey (1982) argues that building evaluation is the means towards the adjustment of buildings according to their users' needs. As he explains, to "put value on" a building is central to architectural design. When buildings are not evaluated, design '*becomes action without reflection*' and furthermore building owners are left to guess the performance and consequently the value of their buildings (Green et al, 1990).

Another name given to appraisals, during the late 1970's, is post–occupancy evaluations (POE). Preiser et al (1988), point out that the philosophical and theoretical foundation of POE is the performance concept. According to them, POE is:

> 'An appraisal of the degree to which a designed setting satisfies and supports explicit and implicit human needs and values of those for whom a building is designed.'

As they further explain, in their more rigorous forms, POE's follow a systematic approach where all user groups are represented and all important design elements are examined. Figure 2.3, facilitates understanding of the relation between the performance concept and the POE of buildings.

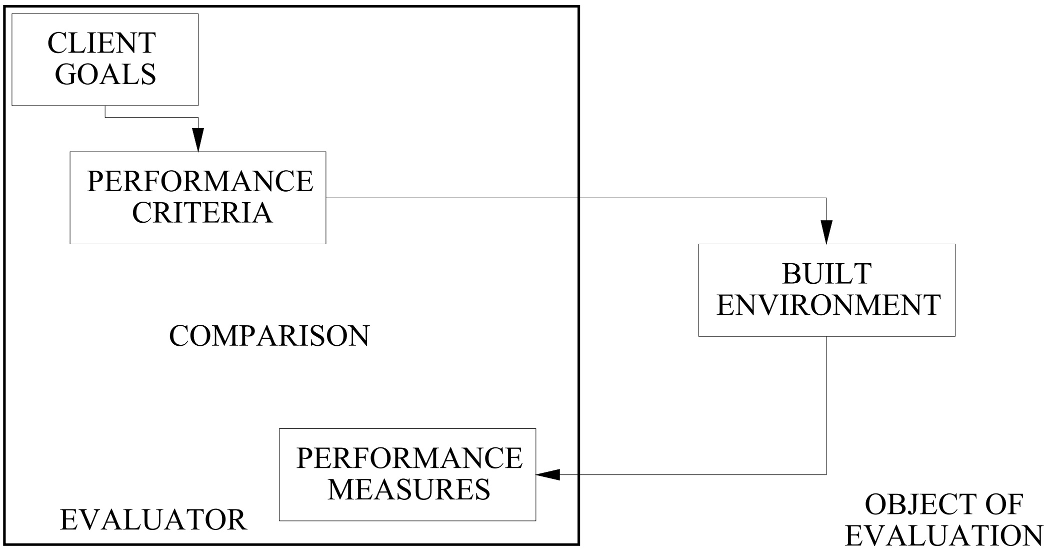


Figure 2.3: Post Occupancy Evaluation (POE) and Performance Concept (Preiser et al, 1988)

2.2.2. Aims of Appraisals

It is essential to establish the importance of carrying out appraisals before proceeding to systems and methodologies implemented. During the early 1970's, many researchers supported appraisals and argued on their importance. Rabinowitz (1976) stated the belief that *'appraisal is the primary method through which better buildings can be designed''*— implying that future buildings be designed based on the 'feed forward' of the appraisals, an approach introduced by Markus et al (1972). Similarly, SSBRT report (1976) states that:

> 'The purpose of appraisal techniques is to provide information about buildings in use to be fed back into the design process.'

Furthermore, according to Bishop (1978), appraisals facilitate the implementation of cost—benefit analyses, crucial for the effective use of financial resources which are becoming more restricted, especially in the public sector.

Friedmann et al (1978) note several reasons for the development of 'design evaluation programs' (appraisals of completed buildings): to *extend our understanding of human* *behaviour* (documenting the transactions of people and the built environment) and *the design process* so as to include evaluation and the development of a feedback mechanism. To *provide a body of information that will be used for the education of new designers*. To *obtain the data required for the analysis* of the ability of public policies and programmes which support and constrain the design of a range of environmental settings. Finally to develop a capability for the prediction of *user satisfaction* and *environmental fit for environmental impact assessment* in its broadest definition.

According to Bishop (1978) the two main aims of appraisals are **to influence future practice and to add to a body of building type knowledge**. As he states, '*appraisal is surely about testing whether the designer's properties (objectives) are reflected successfully in the building and about whether the designer's priorities were right in the first place*'. Zimring et al (1981), generally agree with Bishop identifying two main purposes: immediate feedback for a given project and development of information for future designs. On the other hand, Manning (1987), mainly dealing with environmental appraisals, states that appraisals in general have at least three main purposes:

> 'to learn from existing buildings and their users how buildings actually perform and are used, so to provide knowledge for use in the formulation of user requirements for proposed new buildings; to evaluate the possible consequences of design alternatives, enabling choice of the most appropriate; to check, in a completed building, whether and to what extent the conditions predicted to result from design action did in fact occur.'

Figure 2.4., illustrates the relation between the building process and appraisal of buildings while presenting the benefits of POE's as well.

Architects seem to be the group mostly interested in appraisals. Bishop (1978) points out that, although most of the appraisal studies carried out are conducted by architects, little is done solely for architects. In fact they should be as much for the clients and users of the buildings as for the designers.

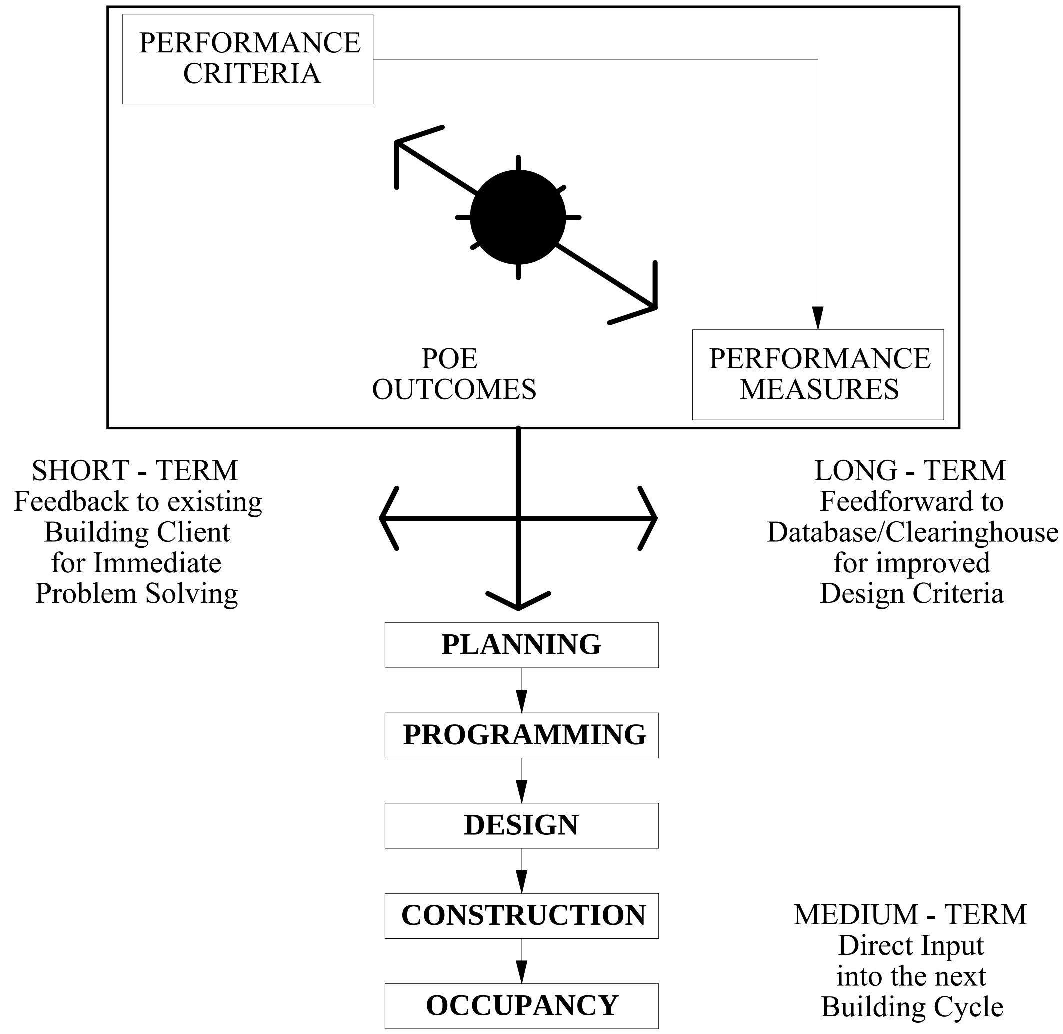


Figure 2.4: Benefits of Post Occupancy Evaluation—Relation Between Building Process and Appraisal of Buildings (Preiser et al, 1988).

Manning (1987) is also arguing that there doesn't seem to be any ready method through which the conclusions of an evaluation of a building can be applied to another. That is against the belief that building appraisals should enlighten and improve the design process in general. He explains that, in general, the existing appraisal methodologies are just providing specific knowledge of the performance of particular aspects of particular buildings.

Summarizing, it should be stated that appraisals, being deep and narrow, are mostly suited to repetitive building types—buildings of which a large number with similar requirements and objectives are built. Therefore, they are against one–off solutions and in favour of system building.

2.2.3. Methodologies Implemented

The SSBRT at Oxford Polytechnic has done a considerable amount of research on the various approaches followed in appraisals of buildings. This research, published in 1976, reviewed all the methodologies applied up to the mid 1970's. Further classification and evaluation of the various approaches was made by Bishop (1978) and Preiser (1988). The presentation that follows is, to an extent, based on these works with Figure 2.5. demonstrating graphically this classification.

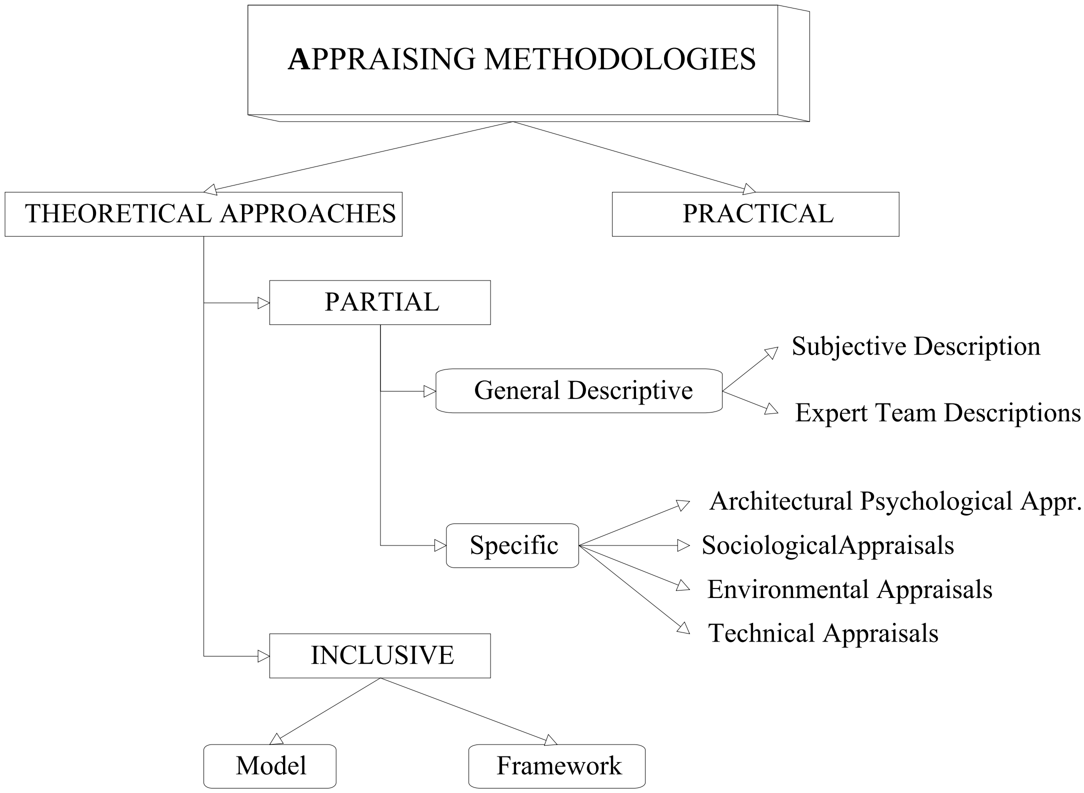


Figure 2.5: Building Appraisal Methodologies Implemented

The first and broadest classification established is according to the general approach to the subject: **practical** or **theoretical**.

Bishop (1978) states that there is a major gap between them. Theoretical works mainly are conducted by architects, sociologists, psychologists, academics in general. They often involve complex theoretical methodologies requiring a high level of experience, time and resources which are short in most of the practical approaches. Nevertheless, theorists (Hillier et al, 1972) claim that these methodologies may be used by the practitioners without much difficulty.

Practical approaches

These are designed and carried out mainly by local–regional government and client departments and occasionally by practices. These works are mainly technical and maintenance oriented with a relatively small number incorporating environmental or psychological (in terms of aesthetics etc) factors.

Theoretical approaches

Two categories are identified in respect of their approach to the problem. The **partial** approach concentrates on, and specializes in, aspects of clearly identified problems and, generally, is quite selective. The **inclusive** approach proposes an overall and inclusive model, usually approaching the problem in a systematic way, seeking to appraise at a holistic level.

Starting with the **partial** approaches, a further classification by SSBRT facilitates understanding; that is <u>general</u> and <u>specific</u> approaches.

General–descriptive approaches partially appraise various aspects of buildings in a non systematic way and are further subdivided into:

<u>Subjective descriptions</u> by individuals usually conducted by architects although, depending on the building type, doctors, heads of schools etc have been employed. The quality of these appraisals depends on the appraiser—they are not based on any methodology or framework and there are no measurements made unless some particular physical ones are specified.

<u>Descriptive appraisals by expert teams.</u> These appraisals are more comprehensive as they are conducted by a group of building professionals and users. Usually this group includes an architect, a client, a user, a consultant and a member of the original design team to facilitate comparisons. In that way the building is assessed from different view–points.

Four approaches were identified as **specific** (dealing with only a particular aspect of building performance) by the SSBRT: <u>Architectural Psychological appraisals</u> that isolate one of the most important aspects of building performance, the human satisfaction. The main idea is that buildings are judged by their users and not by the visits of some professionals who, furthermore, are not spending enough time in the building collecting information and analysing the building thoroughly to be able to draw valid conclusions. As SSBRT (1976) state, there is a tendency for many of these studies, mainly the more sophisticated, to measure small problem areas in the search for scientific validity which may lead to applicability problems of the research as a whole as well as to the drawing of valid conclusions (Broadbent, 1973). Furthermore the methods of statistical analysis are complex and sophisticated (Canter, 1968).

<u>Sociological appraisals</u>, in which techniques taken from market research have been applied in particular by Jameson (SSBRT, 1976). Jameson (1971) argues that traditional sociological methods are inadequate (especially the sample survey and the direct questioning) as they tend to describe the world as it is and that such descriptions are not value free. Therefore he accepted value judgements as a standpoint, and tried to relate the methodology to certain testable hypotheses to explain the results and to put forward useful recommendations. SSBRT report (1976), highlighted the contrast between Canter's (architectural psychology) approach and Jameson's (sociological) approach in that the latter, with simpler strategies, gives results much more valid and usable, though a little general, than the first one.

<u>Environmental appraisals</u> are further classified into three main areas:

Environmental building performance appraisals, measuring the efficiency of the building enclosure in relation to the three main environmental aspects heating, lighting and acoustics. Bishop (1978), notes that the validity of such works is debatable on the grounds of human behaviour that upsets the rational models set.

To overcome this problem, *human comfort appraisals* have been developed, their main aim being to determine how people behave or respond to different levels of heating, lighting and sound. These appraisals employ the methodology of sociology and/or psychology in terms of semantic differential scales or questionnaires to discover human responses (Humphreys, 1976).

- *Systems performance appraisals,* which are concerned with evaluation between different technical means of achieving various environmental standards.

Technical appraisals. As Bishop (1978) states, these are more straightforward research than appraisals as the buildings are judged against the established criteria of safety, health or legal standards. In reality, private practices and individuals are the ones most likely to execute technical appraisals and in these cases formal comparisons to standards are rare. It is mainly according to the appraiser's experience that everything is judged. Structured technical studies of whole buildings have been undertaken by the Pilkington Research Unit (Preiser et al, 1988), the BPRU (1969) and Rabinowitz (1976).

As far as **inclusive** approaches are involved, there is no clear classification. Appraising a building at a holistic level leads to an increased number of variables under examination, as well as complicated relations between them (Preiser et al, 1991). Therefore, as SSBRT report states, a systems approach to such an appraisal is providing the means of analysis and the basis for proposing models to explain problems.

It is appropriate to define the system concept in general prior to presenting its implementation in buildings. Ackoff (1969) defines a system as: '*any entity, conceptual or physical, which consists of interdependent parts*' and Thomas (1974): '*...a grouping of parts viewed as a whole, such that, because of the interrelation of the parts, the group has overall properties which are not apparent from the individual parts.*'

Application of a systems approach to buildings involves the explanation of parts and their relationship to the whole and, quoting from SSBRT (1976), '*...thus incrementalist studies can be undertaken of the sub–systems (the parts) and related back to the complete system*'. In a systems approach, the study area is the first that needs identification, the remainder (the surrounding–what is outside) being 'the environment'. The most important problems of a systems approach to appraising buildings, relate to the identification and evaluation of the boundary type and the actual drawing of the boundary between environment and system. Considering that, on the one hand, a building is affected by its surroundings and, on the other, is affecting it, in general, it is an open system—in contrast to the closed ones where no interaction between the system and the environment exists.

The next step in the systematic inclusive appraisal, is the analysis of the building into sub–systems and each sub–system into smaller ones. The first such classification was described by Sir Henry Wotton in Elements of Architecture (1624):

> *'Well building hath three conditions Commodity, Firmness and Delight'*

Zunde (1982) interpreted and analysed this argument and came up with the following classification:

Commodity was interpreted as function and resources. Function is assessed in terms of the space and comfort requirements for the occupier (activities) and the relationship between spaces for convenience of use.

Firmness incorporates the technological aspects of a building; suitability of materials for their purpose, understanding and adoption of advantageous methods of manufacture, assembly and construction.

Delight deals with the aesthetics in general via environmental performance, external appearance and adaptation to the environment; cultural or symbolic aspects.

During the last decades, many attempts to produce models of the building system in terms of either the design process or the appraisal have been made. From a first analysis of six such approaches, as conducted by SSBRT in 1976, the main sub–systems are quite similar and can be classified under the five particular headings of **environmental**, including the internal and external 'climate' and the possible constraints imposed by the site and its immediate surroundings; **activities**, incorporating human activities, perceptions and attitudes within and around the building; **technical**, where the performance of the fabric and building structure is included; **costs—resources**, time, labour, money and materials; **cultural and symbolic**.

This model is compatible with Sir Henry Wotton's analysis. The aspects considered remain the same and only the classification of the headings changes. As SSBRT (1976) stress, this classification is approximate and in each approach the boundaries between the subsystems vary. However, two different appraising approaches are identified.

The model approach, is a formal attempt to express clear and testable relationships between the sub-systems (that have been identified already).

The framework approach, is an informal attempt where the relationships between the sub-systems either are assumed or linked very loosely.

A large number of evaluation and appraisal models have been developed over the years. However, in the following section the ones relevant to the particular study only are presented. These include:

Hillier and Leaman who argue that buildings act as 'modifiers' of various phenomena and that establishing the way that these modifications occur is essential for appraising the resulting buildings (Hillier and Leaman, 1972). They explain that buildings act as modifiers of: Climate (affecting the site, surrounding, interior etc in terms of heat, light and sound), Behaviour (affecting the way people use the buildings, behave in them), Resources (affecting the stock and supply of materials and labour and creating economic effects) and finally Culture (affecting the values and meanings attached to the building).

Rabinowitz who analyses the building in three main elements (Preiser et al, 1988): Technical health, safety and security aspects of building occupancy. Functional occupants' ability to operate efficiently and effectively. Behavioural, psychological and social aspects of user satisfaction and general well–being.

Building Performance Research Unit (BPRU) approach is, according to SSBRT, the only really inclusive and systematic one, where each building is divided in four sub–systems: Environmental system (spatial and physical) both within and outside of the building. Building system (constructional elements, services, contents). Activity/Behaviour system (identification, work flow, communication, control, etc). In general, the various activities occurring within the building. Objectives system (production adaptability, stability). The structural and constructional fabric of the building and site.

A measure of cost is related to each sub–system. SSBRT report (1976), criticizing the BPRU model, highlights the problem of its implementation to buildings. The studies '*...stop short at the level of problem identification*' unable to give any explanation as to the nature of the relationships between them. Concluding on the BPRU model, SSBRT (1976) state that its importance is due to the theoretical background developed and in general the body of knowledge that it produced more than from its immediate results.

Friedmann, Zimring and Zube (1978), suggest an social based POE analysed in five elements: Users (not only people working or living in the building but could be the passer-by or others affected). Building itself (both the typical architectural considerations and description of other qualities such as visual privacy, amount of auditority, etc.). Social–historic context (the forces that influenced the building design, i.e. societal pressures to create an energy efficient building or the increasing demand for housing for the elderly). Design process (who makes decisions—the various participants' roles in creating the final design i.e. client, users, designers, bankers, etc.). Neighbourhood (how well the building fits in its physical context and how the building is affected by its surroundings. Neighbourhood is examined both from an aesthetic and a social viewpoint).

Finally, **Boyd's and James's** (1988) appraisal is a POE as well. They identify four main headings: Phase (phase of the delivery process where issues originate). Component (the component in the fabric of the facility to which the issue relates). Zone (the spatial zone in the facility where the issue has arisen). Behaviour (the nature of the impact of the issue on the organisation and the users of the facility).

2.2.4. Problems Identified

In general, **theoretical** approaches are dealing with issues related to the methodology followed and the tests to be carried out, whereas **practical approaches** are more aware of the existing conditions and issues such as who does a particular appraisal, when this appraisal should be done and why to do them (real purpose of the appraisal). In fact, according to Bishop (1978), theoretical approaches only briefly refer to the above mentioned issues. He points out that this, on the one hand, is increasing the gap between the theoreticians and practitioners, and on the other leads to '*the worrying thought that the operators of the theoretical approaches actually believe they are being objective and neutral* '. Another problem identified by Zimring et al (1981) is related to the academic initiated research. Many of these theoretical approaches use technical language and specialised concepts '*intended for the evaluator's peers rather than for the practitioner'*.

While analysing the theoretical approaches earlier, two major groups were identified: the partial and the inclusive. As far as partial are concerned, in order to obtain a global view of the relationship between building and user, the '*subjective experience of a building and the objective observation of those using it must both be taken into account*' (Canter in SSBRT, 1976). Following the analysis of the descriptive appraisals, it is apparent that they are giving only a partial view. The same applies to all specific appraisals (sociological, psychological, environmental and technical), although as SSBRT report (1976) states '*they have a tendency to follow the law of diminishing returns*'.

As far as the inclusive approaches are concerned, the SSBRT (1976) argue that they don't appear to be entirely feasible. That is mainly due to the fact that these appraisals don't do exactly what they are aiming to. Nevertheless, as they explain, having the opportunity to structure a series of investigations and think clearly and comprehensively about a building as a whole is very important. Concluding from the above observations, Bishop's (1978) statement that partial approaches are '*all depth and no breadth*' whereas inclusive are '*all breadth and no depth*' has some validity.

Having identified and discussed the specific problems of the various appraising methods, some general problems that apply equally in all appraisals should be discussed.

Boyd et al (1988) explain that appraisals have been and are always going to be unpopular, unless something changes drastically. They are invasive, expensive and time–consuming and, furthermore, the beneficiaries are not the ones that bear the cost of the appraisals. They suggest that if POE is to remain a viable appraising method, they must become cheaper and simpler which is, in fact, incompatible with fundamental appraisal's objectives. Nevertheless, they believe that attempts towards cost–effective information, broader aims and feedback of the information gathered should be made.

Manning's (1987) comment *'...the quality and authority of an evaluation is influenced by the amount of time, the depth and amount of professional or research competence and experience that is committed to the task'* is especially apparent in a graph by Bishop (1978) (Figure 2.6.). This is relating effort and results in a general viewpoint—not necessarily in terms of accuracy and effectiveness of the appraisal but mainly in terms of confidence that can be attached to the work.

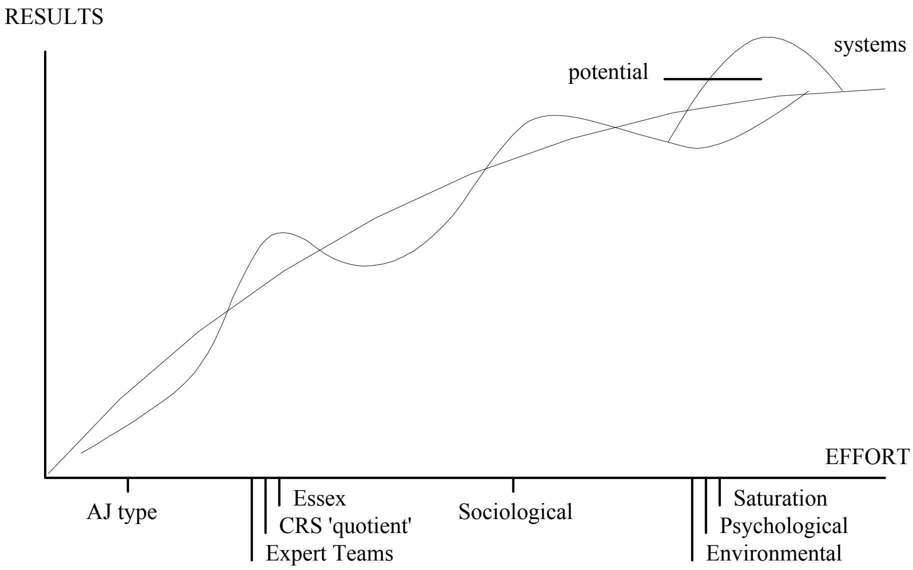


Figure 2.6: Effectiveness of Appraising Methodologies (Bishop, 1978)

2.2.5. Evaluation of the Approaches—Conclusions

Concluding as far as **theoretical** approaches are concerned, few additional comments should be made. Firstly, partial approaches rigorously examine a narrow section of the whole building performance issue leaving many more aspects and variables untouched. On the contrary, inclusive approaches, being systematic, analyse all aspects and present a holistic view of the building. Unfortunately, they tend to be all breadth and no depth (Bishop, 1978) and unless undertaken with great care cannot produce significant results.

The majority of theoretical approaches are of the *framework* type (SSBRT, 1976), identifying some variables and measuring each one individually. This approach fails to develop an overall measure of building performance or any form of model for the quantification of the results. Consequently, comparative assessments of buildings cannot be carried out. Among the reasons for this failure is that these methods were developed to be used in a wide range of buildings with varying specifications and requirements. In order to apply these methods and develop a model of quantification, the relative importance and the relationship between the variables has to be established. As these relations vary for each building type and existing conditions, data banks of substantial size should be developed. This is a laborious and time consuming process that has not been tackled rigorously yet and—considering the indicators available—never will. Furthermore availability of data is poor and most important the type of information collected (especially the cost related ones) are not sufficient for the planned analyses.

During the 1970's and 1980's, researchers developing computer programmes for the appraisal of buildings (Orbit, PACE, etc.) faced this problem of variables' evaluation and were forced to focus on approaches suited to particular building types that subsequently needed a restricted database. Consequently, more focused (and therefore partial) appraisals evolved. These are usually carried out on a building in order to address certain problems, suggest solutions and, consequently, facilitate the improvement of future buildings.

Only a few methods, the so–called *model* appraisals, reviewed in the literature actually develop a model, BPRU being one of the better established and widely known (SSBRT, 1976). This model is inclusive but focuses on particular building types (has been applied in school buildings), although the team that developed this model argue that it can be modified and applied in various building types. The important characteristic of this approach is that the building is divided into four sub–systems (building, environmental, activity–behaviour and organisational) and a measure of cost is related to each sub–system.

Another model is that for the assessment of expected performance effectiveness developed by Crise (1975). This model is focused on industrialised buildings and examines them in terms of technological and economic performance capabilities. It is not an inclusive model but the two points that make it worth noting are its application and classification of the techno-economical variables. It is applied in the pre-selection stage, assessing various building proposals in order to select the best performing building. An explicit classification of techno-economical variables is presented in three levels and following the calculation of the relative effectiveness indices for the two first levels the overall effectiveness index of each industrialised building is calculated.

Theoretical framework approaches are not totally compatible with the research's aims as they do not provide an integrated mathematical model that some public sector's departments do. However, their appraising methodology for the particular aspects on which they focus, facilitates the development of the research's methodology.

On the other hand, *practical approaches* are highly specialised on the type of buildings assessed. The criteria set and the models developed are suitable for specific building types only. As these are mostly conducted by public sector departments, the criteria set are mainly related to the use, function and maintenance costs of these buildings. They are more technically oriented than the highly theoretical inclusive approaches that practising architects and engineers accuse of complexity and inefficiency (Bishop, 1978).

2.2.6. Current Situation of Appraisals

Summarising from the above analysis, the two main properties of a successful appraising methodology of buildings in use are **being systematic** thus not obtaining fragmented information–knowledge and **being inclusive–holistic** (not carrying out a partial assessment of an existing situation). These are the key issues for a widely accepted and applied methodology as they facilitate accurate modelling of the buildings.

Additionally, such an appraisal should be applicable—practical in the way of implementing its methodology. The highly theoretical approaches developed by academics, using complex technical language, have feasibility drawbacks not to mention limitations on the validity of their conclusions (Zimring et al, 1981).

The above mentioned characteristics are exploited by the latest appraising methodologies developed by Friedmann et al (1978) and Preiser et al (1988) and to a lesser extend by Boyd et al (1988) and Rabinowitz (Preiser et al, 1988). All these appraisals are development and evolution of the SSBRT and BPRU methodologies of the 70s.

Problems responsible for the failure and consequent abandoning of certain evaluation techniques are their being too specific (not enough issues tackled in order to draw conclusions). Consequently, limited confidence and or validity could be attached to the conclusions drawn from such methods. Typical examples of such methodologies are the various psychological, sociological and environmental appraisals [Canter (1968), Jameson (1971), Hillier et al (1972)] together with practical and technical approaches [Broadbent (1973), Pilkington Research Unit, Smith (1976) etc].

Appraisals of buildings by teams of experts have tended to be specific and limited in scope; hence, such appraisals now are used relatively infrequently. Subjective descriptions are still used extensively in the architectural press although their arguments and judgements are neither scientific nor objective.

However, there is still a need for answering specifically focused questions (on technical, environmental, etc issues) and this need is covered by some of the partial appraisals. Usually, such appraisals are carried out on a small scale within public sector departments or private companies and, consequently, neither their results nor the methodologies implemented are published.

Chapter 3 Sportshalls and Swimming Pools in Greece

3.1. Construction in Greece

3.1.1. Introduction

To enhance an inclusive approach to the construction of sportshalls and swimming pools, the construction environment in Greece since the beginning of the century is presented and analysed.

Among the issues analysed are those of the main structural materials and constructional methods used, labour availability and costs related issues. The government's role in construction is discussed also. Finally, the particularities of the construction environment in Greece are analysed, focusing on earthquakes, climate, pollution and political situation.

3.1.2. History and Evolution of Structural Materials in Greece

Cement Industry and its Evolution

The cement industry in Greece was founded in 1911 and for the first ten years the production was simply satisfying the country's needs ranging between 10 to 37.5 thousand tons per year (Hatzinikolaou, 1987).

However, the large immigration move from Middle East in 1922, led to a construction boom that increased needs and consequently the production of cement. During the years preceding the Second World War, the production was further increased (Hatzinikolaou, 1987), reaching a peak of 334,000 tons in 1939 with the first exports (7.2%). The production remained at these levels until the beginning of the 1950's.

Kalogeropoulos, chairman of Heracles (one of the two biggest Greek cement manufacturers) argues that '*Greek cement is more efficient(?) ...Greek manufacturers have lower labour rates and a low cost export operation with quarries next to dry cement plants by the coast. The Greek government subsidies are irrelevant; the Greek manufacturers receive a 12% export and 5% interest subsidy*' (Fishlock, 1986).

According to Hatzinikolaou (1987), Greece is in the top three exporting countries in the world but with the biggest percentage of exports compared to the total production. This is a drawback as the Greek cement industry is totally related to the export market. As he explains, the decrease of the domestic demand combined with a substantial reduction in cement prices abroad (nearly halved from 1979 to 1986) led the Greek cement industry to an '*over-production crisis*' from which is now recovering.

Iron and Steel Industry

Greece has been a traditional exporter of iron ore since ancient times. As stated by 'Halyvourgiki Co.' (1969), from 1900 until the beginning of the First World War, Greece exported iron in considerable quantities with a maximum of over 850,000 tons in 1907. The exports were resumed again from 1925, to reach a peak in 1938 (350,000 tons). It is estimated that from 1869, when the mining industry in Greece was revived, until 1938 a total of 14 million tons of iron ore were exported. After the Second World War production reached a maximum of 431,000 tons in 1957 and then tapered off to become almost nil in 1963, following the influx in the world market of higher grade ores from the contemporary deposits with high iron contents.

The above was the iron and steel production outlook until the mid 1970's; of the total production, only 19% is structural steel in the form of reinforcing bars and there are no data available for the way that the flat steel products (17% of the total) are distributed. Nevertheless, as Table B.3. in Appendix B shows, the production outlook has not changed drastically during the last fifteen years.

It is notable that, while Greece was producing iron ore it had no industry to process it and, therefore, exported the whole production. On the other hand, when the Greek iron ore stopped being used, the first industry processing iron ore was founded. This helped keep the cost of the material high. Before 1960's, the final product was imported while nowadays the crude material is imported. Table B.4. presents the structural activities in terms of raw, structural steel and steel products separately to facilitate comparisons.

Timber

According to Loizos (1948) the timber used in Greece, following Second World War, was either pine imported from Sweden, Servia, Romania and U.S.A. or native pine, oak, beech and chestnut. Timber was never used as the main loadbearing structure of a building; it was used in roofs and floors whereas walls were always made out of loadbearing masonry or bricks. However, small timber beams were inserted in masonry to increase its strength in earthquakes. Lately, most of the timber used is imported from Sweden, Africa or the USA; native timber has a small percentage of the market.

Considering the span restrictions imposed by timber, the only form related and applicable to long spanning roofs is the glue laminated (Glu-lam). Examples spanning over 25 metres can be seen throughout the country, made out of beams fabricated in the two Greek factories using local timber.

Other structural materials used

Masonry has been used extensively in Greece since the classical era. However, marble and stone has stopped being the main structural material since the cement evolution of the beginning of the century; after 1960, their use is almost exclusively decorative. Their main use as loadbearing structure has been replaced more effectively and economically by reinforced concrete. Consequently, all the specialised masonry builders were forced to work with concrete ending a very long tradition and craftsmanship.

As far as plastics and composites are concerned, Pikoulis (1973) explained that the greater progress is in timber laminates whereas plastics are used scarcely. Fibreglass laminated beams had been used in prefabrication during the late 1960's and the Greek Tourist Organisation has implemented them in lightweight covers and small buildings. In the early 1970's, composite beams spanning 5.25 metres over a steel factory in Volos were fabricated and in 1973 a fibreglass laminated roof, spanning over 11 metres, covered the Ypati spa (Pikoulis, 1973). Various short spanning applications of the composites can be listed from the Greek construction environment but none in long spans.

Fabric tents is another structural form used in Greece. Using the tension concept, various polyester fabric tents coated with polyvinyl chloride (PVC) have been constructed in the last fifteen years. The forms implemented are supported by central arches, cone–shaped or suspended. They have been applied to swimming pools, theatres, temporary exhibitions, hotels and other leisure centres. In most cases they are only protecting from the sun and rain, although in some cases they are creating a more controlled environment. Some of them span up to 35 metres, with most examples in the 10-20 metres region. The short spanning examples are usually designed, fabricated and constructed in Greece by a few specialised architectural practices. However the larger ones are designed jointly or even sometimes exclusively by European firms.

3.1.3. History and Evolution of Constructional Methods in Greece

Until the beginning of the twentieth century the structural materials used in Greece were marble, stone, brick and, occasionally, timber (Kalogeras, 1974). Iron and timber, hardly used as a skeleton frame material, were used in beams for floor and roof structures, whereas marble and stone formed the loadbearing solid structure of the buildings (Marmaras, 1985). This had a negative impact on the buildings designed in terms of fire and structural safety (earthquakes are very common in Greece) as well as function, especially in high rise buildings (Kalogeras, 1974).

Following the beginning of the twentieth century, substantial changes took place. Reinforced concrete was introduced in Greece; it was first applied in two bridges in Athens in 1902 (Marmaras, 1985). During the first decade of its implementation, it mainly replaced the arched and timber framed floors and roofs and partly the steel beams used in floors and roofs; actually it was not used as a surface structure at all. Gradually, circa 1920, it formed surface floor structures and combined them with reinforced concrete columns and beams. As Biris (1974) explains '*...long span and high rise (4-6 storeys) buildings were able to be constructed since*'. The first examples were the two cinemas built out of a reinforced concrete frame in the centre of Athens between 1916-20: 'Esperos' and 'Attikon'.

In the inter-war period, construction activity flourished. One of the reasons was the immigration from Asia Minor that increased the population of Greece substantially. This problem was more apparent in the capital Athens, where the population almost doubled. Another reason was the ambitious school buildings programme organised by minister G. Papandreou (circa 1924). In fact, the whole first generation of the National Technical University architects and engineers worked and experimented with modern architecture in this school programme (Bourdakis et al, 1985). In the first case, stone loadbearing structures were used mostly for the construction of the relatively small immigrant's houses, whereas reinforced concrete was used extensively for the larger school buildings.

Furthermore, Kalogeras (1974) stated two factors that fostered the implementation and approval of the modern architecture by the architects and the people and, subsequently, of the reinforced concrete structures in Greece. These were the new Building Regulation edited by the DoE (1929) and the 4th CIAM conference (August 1933). As he explains, the first enabled the creation of high rise housing buildings and the latter presented and analysed the modern movement and its ideas to the Greek engineers facilitating the adoption of their methodology and structural logic.

As Marmaras (1985) argues, the advantages of reinforced concrete structures, mainly in high rise housing buildings (4 to 6 storeys), that highlighted and secured its dominance during the inter-war and early post-war years in Greece were:

- flexibility and safety in design, function and fire protection.
- cost; following reinforced concrete's implementation, constructional costs were reduced by 20–40% and the loadbearing members' volume by two thirds (structural steel members were imported, from Belgium and Germany and, therefore, were expensive—in an effort to keep the cost low, steel was not used for the whole frame of the building, stone and marble was used instead which increased the weight of the building, while reinforced concrete frame with thin columns and walls made of non-loadbearing, lightweight bricks was far lighter).
- speed; together with the structural materials, the methods of construction changed as well; that led to faster buildings, which also were cheaper and easier to design.

The construction activity ceased during the Second World War only to recover following the rapid economic growth of the country in the mid 1950's. By the late 1950's–early 1960's, construction activity in Greece, and, particularly, in Athens, reached a new peak. As Kalogeras (1974) explains, this led speculative developers (mainly contractors) to build high rise dwellings. By that time, the labour availability and cost, together with the material cost, were two more factors that strengthened and ensured the use of reinforced concrete in Greece.

Loyer (1968) identified the problems of existing needs, programmes, means, temperament and climate that enhanced the implementation of reinforced concrete in Greece. As he explains, the curtain–wall of the modern movement together with the steel structure and prefabricated concrete panels never managed to influence Greek architects and engineers and therefore was never applied.

According to Loyer (1968), 'The problem is common to many Mediterranean countries, hence certain involuntary architectural similarities:

- *concrete structure of timid design, with short spans and a multiplicity of supports*
- *complete absence of metal elements and accompanying consequences in the mechanical installations*
- *great importance of partition walls and facing materials, dictated by the climate.'*

3.1.4. The role of the Greek Government

Government Activity

A Technical Chamber of Greece (T.C.G.) report (1976) explains that, due to traditional patterns, the average Greek citizen of the 19th century and of the beginning of the 20th (until about the First World War) expected very little from the state in terms of help for a house:

> 'Problems of external politics, internal party politics, problems of internal security, economic problems and various legal and administrative problems absorbed all government's energies leaving no margin whatsoever for a concept of public housing and, moreover, entertainment building as a broader state responsibility. As a result, housing and all the other building enterprises in this period developed entirely as a private responsibility.'

Indeed, housing was not considered by the government as a state's responsibility at all and, therefore, only a negligible percentage of houses was built by the government until the inter-war period.

Since 1920's and until the early post-war period, a series of large scale emergencies forced the state to intervene in the field of housing and develop ambitious and large scale housing programmes. These emergencies included a overwhelming number of refugees, followed by a series of destructive earthquakes. Then the Second World War and the ensuing Civil War caused extensive damage to the whole nation, whereas more earthquakes followed by floods, storms, population redistribution etc. increased the housing problem (TCG, 1976).

As a result, the Greek government developed a policy of viewing housing as a responsibility related to emergencies only. This approach strained the already poor budget of the government to the extent that any 'normal' housing programme would be totally unrealistic. Additional problems were those of the local market of building materials and equipment, of builders and contractors, as well as of building labour force that were insufficiently developed.

Concluding, the bulk of the construction activity in Greece during the last century was initiated and conducted by the private sector; public sector developments were focused on emergencies and infrastructure work (road construction, water supply, drainage, land reclamation, schools, hospitals, etc).

Legislation

In 1929 the new Law on 'Horizontal Property' was launched. This law enabled the wide spread of high rise houses, asserting a forthcoming living standard and dwelling improvement, particularly in Athens. As Kalogeras (1974) explains it was not long before the city was filled up with six to seven storey high buildings resulting to inhuman conditions for the occupants in the long run.

In the course of the century, this law was slightly improved and a series of legislative acts on structural requirements considering the earthquakes problem were launched. These were all abolished when the General Building Legislation (GBL) was issued in 1985. This law obliged building engineers to use computer programmes for the structural analysis and subsequently dimensioning of the structural members, forces etc. The only drawback was that it focuses on reinforced concrete skeletal structures. Consequently, if an engineer designs a steel or timber structure this legislation doesn't apply and German, French or British ones must be implemented.

Procurement Systems

Another issue that holds an important role in the Greek construction is the public sector's procurement methods. According to a National Statistical Service of Greece analysis (NSSG, 1986-7), private sector's activity is focusing on dwellings and less on commercial establishments. This leaves all large scale developments to the public sector.

The vast majority of private sector's buildings are designed following the entrustment to a designing practice. The construction is assigned following a small scale market research to find the cheapest contractor or to the one suggested by the designing practice.

The public sector is following more advanced and complex techniques for design and construction. The private sector's approach, is hardly ever used; competitions of various forms are carried out to select the designer and constructor instead. Broadly, these contests can be divided into two categories. In the first, the design and the construction is approached separately and there may be one contest for each whereas in the second, design and construction is seen as an entity. In the former, three design variations can be listed. Architectural contest, where architectural practices submit their proposals for evaluation; the design is assigned to the winner. The procurement method according to the legislative act 716 is the second variation, where the design practices are not competing with actual proposals and plans. Instead, their previous history and performance of their past designs is assessed and the current load of work these practices have is considered. A third variation is where the construction department of the particular Ministry designs the project, in which case no contest takes place. As far as the construction is concerned, in all three categories a tendering procedure is followed for the contractor's selection.

Invoice completion and evaluation is the last method used. It is better known as 'design and build' where contractors compete for both design and construction. They submit their proposal's drafts and a detailed invoice for the construction according to which they are assessed and the most appropriate proposal is selected.

The above mentioned procurement systems are the only ones used by the public sector in Greece, though slight variations may occur according to the particular conditions and problems faced.

3.1.5. Particularities of the Greek Construction Environment

Earthquakes

Earthquakes in the region of 5.5 to 6.0 of the Richter Scale are regular in Greece. Thessaloniki (1981, 5.7 R.S.), Athens (1983), Kalamata (1986, 5.8 R.S.), Korinthiakos (1987, 6.0 R.S.) and Pyrgos (1992) are examples of the last decade's major seismic action.

A lot of research takes place in the Greek universities on the topic. National Technical University of Athens (NTUA) has one of the most advanced seismic beds in the world for testing composite beams, steel trusses up to electricity high currency posts and even full scale houses (Pyrobolakis & Kanistras experiment 1988, unpublished report). However, most research carried out is on the disaster prevention by the development of standards and the design of safe buildings based on structural performance criteria.

The Greek practice is contrary to a lot of work carried out around the world, concerning risk factors, injury prevention, counter disruption, speeding recovery and effective training (Durkin, 1989). As Konya (1984) suggests, performance criteria should be developed not only for structural elements but for 'non-structural' as well, such as cladding, glazing, interior systems equipment and furniture. It is particularly important that no pre–event evaluations are carried out in Greece that would identify hazards and determine effective hazard reduction strategies. Such strategies deal with life safety threats to building occupants posed by structural damage, damage to architectural elements, equipment and furnishings and by occupant actions (Durkin, 1989).

Most problems and building collapses arose in rural areas poorly built before 1930s when reinforced concrete structures were not yet fully exploited. These led to the vast majority of earthquake casualties in Greece. On the other hand earthquakes hitting big cities, caused minor damages and especially on buildings that following further analysis proved defective. That includes wrongly specified steel reinforcing bars by the structural engineer or, more often, poor supervision on site leading to the contractor doing 'savings' by reducing the amount of reinforcing bars or even concrete thickness in slabs etc.

Climate

Greek climate is described as sub-tropical Mediterranean (Konya 1984). Seasonal variations are broad with hot summers with abundant sunshine and little, if at all, rain and mild winters with moderate rainfall (reduced substantially over the last decade). Rainfall amounts vary from 500mm per annum to 300mm (in sheltered inland locations). The majority of rainfalls are strong downpours stressing housing installations as well as cities' infrastructure.

Temperatures during summer period are reaching regularly 38 degrees leading to mean monthly values of 25–30 degrees Centigrade (Konya, 1984). Mid-winter average ranges between 7–13 with night temperatures reaching freezing point. On the mountainous area, snowfall is often over the winter months and the average monthly temperature values drop lower than seven degrees Centigrade.

Consequently, the most affected part of a building, the roof membranes, may heat up to almost 80 degrees Centigrade during a hot summer noon and cool down to 20–25 at night. This temperature differential strains the membrane substantially leading to actual times between overhauls of 3–5 years instead of the rated figures of 12–15 (Stoll et al, 1987). Consequently, heat resistance and flexibility of the roofing materials are the governing factors of their performance. The intensive solar radiation is an additional danger for the structures, especially during the summer. The finishes and organic materials seem to be the ones mostly affected (paints, wood, varnishes, fabrics, etc.)

The heavy winters of 1987-89 with greater than expected snowfall in the North of the country led to collapsing roofs and consequently reconsideration of the snow force structural calculations on roofs.

Pollution

Athens population is 38 per cent of whole Greece. About half the nation's industry is in Greater Athens, which includes the port of Piraeus. These factors have led to serious pollution problems in the area of the Athens basin that have forced the state in attempts to reduce it (Sahsamanoglou et al, 1982). Due to the prolonged hot summers of the last eight years no significant improvement has been achieved with the state imposed legislation and ruling; the only solutions being the wind and the rain that have self–cleansing effects on the atmosphere.

However pollution, in the Greek climate, is mainly affecting the humans and to a lesser extend the buildings and the structural materials. That is because the air, although saturated with industrial effluents, is dry and therefore doesn't encourage corrosion (Stoll et al, 1987).

The pollution is a great danger to the ancient monuments as corrosion and staining of marble. Rusting of the metal connecting rods used in monuments' reconstruction and repair work carried out at the beginning of the century is the most important problem faced. Recent restoration work overcomes this problem using titanium elements that are unaffected by corrosion.

It should be noted that pollution outside large cities (Athens, Thessaloniki, Patra, Heraklion etc) is almost non existent. Therefore, material selections restrictions applying elsewhere are governed by the proximity to the sea and the particularities of the site.

Political Situation

The changes and instability of the government since 1974 and the deviations in focus and scope (policy) towards certain issues can be alarming. Consequently, companies are not willing to invest in long term policy planning and are focusing on short term aims that are governed by the current policy of the state (Papatheodorou et al, 1989).

Spencer Chapman et al (1991), discussing the construction industries of the EEC members, define the *Mediterranean model* shared by Italy, Spain, Portugal and Greece. They explain that public procurement procedures are costly and regulated by the law whereas in the private sector the key is personal, company and political relationships. The whole construction system is highly bureaucratic and political with "flexible" regulations and procedures commonly interpreted to personal advantages.

3.1.6. Contemporary Problems

Following the analysis of the construction industry in Greece, it is clear that the construction environment has focused on reinforced concrete structures since 1930's. Admittedly this provided solutions for many problems post-war Greece faced, housing sufficiency, safety, etc, but unavoidably created some new ones. The main problem is that focusing on reinforced concrete prevented the wider adoption of steel and timber structures even is cases where, according to the literature, foreign examples and theorists' arguments, these should be more appropriate.

Some of the issues preventing wider implementation of steel and timber structures, deriving from this main problem, are engineers' know–how, contractors' hostility to these materials, labour availability as well as lack of research, literature and building codes of practice.

Nowadays, University studies in Greece are also focused on reinforced concrete. Consequently, less than 20 percent of the courses' content on designing and structural materials is on steel's and timber's implementation in construction. There are courses to comprehend steel and timber framed structures but they are, usually, optional; only few students attend due to the difficulty of the subjects as well as the fear that the extra knowledge gained will not be applicable.

An obvious consequence is that the Greek structural engineers are practically ignorant of steel and timber structures, not able to design with the speed, ease and certainty that they design reinforced concrete. Many architects complain that structural engineers are not willing to design steel or even simple timber structures and when they do the mistakes are fundamental, largely due to incapability in considering the ways these materials work and react under load; not to mention long spanning roofs where special problems emerge. Considering the unemployment in building engineer's profession in Greece, more than 30% are unemployed or part time employed, it would be expected that the number of specialised structural engineers would be higher than it is currently.

Following discussions and unstructured interviews (1989-1991) with practising architects and engineers, few reasons for the contractors' hostility to using steel and timber were identified:

- lack of experience in using steel and timber
- difficulties in estimating costs, time and, subsequently, tendering
- lack of the essential plant, machinery and the specialised labour.

Nevertheless, more research is needed on this particular field to clearly identify the reasons as well as the consequences of using these structural materials.

There are many qualified welders and even more technical schools for their training. They are all employed in the shipyards although they can easily transfer to the construction industry, provided permanent jobs in factories could be created. On the other hand, carpenters are almost reaching extinction. The admirable 'art' of timber trussed roof construction has been abandoned, concrete is used instead. Only laminated timber is used occupying still a small number of specialised carpenters.

The lack of literature on steel and timber structures, especially in the Greek language, is alarming. The existing ones are translations of foreign books that are not backed up by research on the particularities and problems faced in Greece. Furthermore, the research that has been carried out is almost exclusively on reinforced concrete. The only forms of structure that have been reviewed in literature are steel framed bridges which are neither significantly related to the specific research topic nor helpful when steel buildings are designed. Finally the lack of building codes, bearing in mind the frequency of earthquakes, is the greatest drawback for the implementation of these structural methods in Greece. The application of foreign codes of practice is becoming dangerous and thus avoided (Spencer Chapman et al, 1991)

3.2. Design and Construction of Sportshalls and Swimming Pools in Greece

3.2.1. Introduction—Organisations Involved

Following the presentation of the Greek construction environment in general, the research–related building types are examined in particular. These are indoor sportshalls and swimming pools built in Greece. In the introduction, the problem was identified, justified and the scope of the research was narrowed down to a span range of 25 to 60 metres.

It has already been stated that sportshalls or pools not constructed by the General Sports Secretariat (GSS) are a minority built by private colleges or athletic teams. In reality, as Korbas (interview 1990) explains, more than 95% of the halls, such as all the municipal, educational and most team sportshalls and swimming pools, are GSS developments. Therefore, the GSS approach to the designing and construction of these buildings is analysed, facilitating an initial identification of the requirements and performance criteria.

GSS is a public body, part of the Ministry of Youth and Sports, whose main financial support is from the tickets of the various sport events as well as government and other subsidies. Within GSS, the design department (DDGSS) is organising all the construction work carried out. The need for new halls as well as repairs and extensions of old ones is identified followed by the editing of the project brief, the organising of the competitions, the evaluation and the supervision. DDGSS employees, qualified and experienced architects, building and structural engineers, as well as mechanical and electrical engineers and surveyors, are responsible for all the stages, from brief editing up to the supervision of the projects.

3.2.2. Procurement Systems Used by the GSS

All the GSS related halls are designed and constructed following a contest. That can be either architectural, invoice completion (design and build) or based on the 716 legislative act (outlined in section 3.1.4). Furthermore, there are cases where the Design Department is designing the project and tenders the construction—such projects are usually relatively small in size.

Presenting these four procurement methods used by the GSS, architectural contest, design and build contest, design elaboration following the 716 legislative act and GSS design, is essential in order to identify their criteria and objectives. The flow charts included in Appendix B, explain the whole process in greater detail.

Some Considerations—Narrowing down to the Research Related Procurement Methods

The four procurement systems are not used by the GSS equally and, therefore, the number of buildings built under each of the procurement methods varies. As Korbas (interview,

1990) explained, the most common method is design and build, used in approximately 70% of the number of projects the GSS is assigning, whereas 20% is for the Department's own designs. The assignment of the design (according to the 716 legislative act) accounts for only 8% of the total and the remaining 2% is for architectural contests. These percentages are not representative in terms of cost, as the GSS designs are mostly small scale projects with spans in the region of 30 metres (lately increased to 42 metres), whereas the architectural competitions are for the Olympic specifications sportshalls, spanning over 80 (or even 120) metres and whose budget is much higher than the DDGSS designed projects (see § 3.2.4)

Having set the research span range between 25 and 60 metres, it is apparent that the architectural contests could not be considered further in this research as there is not even a single building in the specified span range. The three research related procurement methods are analysed further in the next section. This facilitates the focusing of the research on a particular procurement system.

3.2.3. Analysis of the Procurement Methods

Design and Build

The great advantage of this procurement system is the existence of a fully comprehensive brief—over a hundred pages long. This brief explains thoroughly the GSS objectives and facilitates the construction of an evaluation model for the existing buildings. On the other hand, the submission of brief proposals in limited time, not thoroughly investigated and checked by the contractors, is a drawback. Nevertheless the submitted plans are backed up with an analytical budget specifying materials, assemblies and their costs and a comprehensive list of materials to be used, as well as maintenance and servicing procedure to be followed.

The adoption of a method (by the GSS) to assess the proposals is very helpful as the GSS objectives can be analysed and assessed easily and objectively. In brief, this method of evaluation incorporates two main variables; the **quantitative one of the proposed invoice** and the **qualitative one of the proposed plan's likely performance**. The evaluating committee first examines the plans' performances and then evaluates them against a number of criteria set. The number of these criteria range between seven and eleven. Failure of a proposal to meet a criterion within the accepted limits set in the brief, leads to disqualification as unacceptable. Finally, by adding the gained marks against each criterion, proposals are awarded with an overall mark—**the total grading**. Next the sealed budget invoice is opened and the **real offer of the competitor** is calculated as in the formula:

$$\text{Competitor's Real Offer} = \frac{\text{Proposed Budget}}{\text{Total Grading}}$$

This leads to the assignment of the **best value bidder**, the contractor with the best 'value real' offer.

716 Legislative Act

The objective underlined in this procurement method is the certainty that the building is designed and eventually constructed, obtaining quality standards reflecting the history and the experience of the designing practice. The initial selection of the designing practice seems quite arbitrary; GSS engineers and architects unanimously agreed that it is a weakness of the law. As has been explained, the 716 legislative act is used in most public sector developments and the GSS cannot modify it. Another weakness of the 716 legislative act is the fact that it is not designs or ideas that are competing but curricula vitae and previous practice; in this way it looks more like assignment of the design to a practice rather than a competition. Although the DDGSS objectives are set indirectly, following the close inspection, evaluation and, finally, approval of the various stages of the work, the quality obtained and the cost limits set for the project are ensured. According to Korbas (interview, 1990), the resulting buildings are usually better than the ones built under the invoice completion due to closer monitoring during design and construction design planning.

GSS Design

This particular method, is restricting the competition to the tendering for the construction only. As was previously explained, and as the flow chart shows, the only people involved in the design are the GSS employees. Consequently, there are no requirements' lists or briefs edited; it is an internal process and everything is designed by the DDGSS. In order to draw some conclusions and identify the objectives and requirements set, the Design and Build contest briefing could be considered instead; the objectives set by the GSS for the D&B, and the ones considered in their designs, are the same.

3.2.4. Focus on the Design and Build Procurement Method

In section 3.2.2., the three procurement methods were evaluated in terms of the number of projects built under each method. However that evaluation didn't consider the size of buildings involved. In order to have a more accurate and reliable measure, the mean building capital costs related to each procurement system are considered through available examples.

In the design and build contests, various examples of sportshalls, reaching up to 70 thousand drachmas (drx) per m^2 at 1985 prices, are listed. For the GSS designs, the costs are lower on average, ranging from 30 to 50 thousand drx per m^2 at 1985 prices. More recent, though fewer, examples following the 716 legislative act show, at constant 1985 prices, a range between 40 to 55 thousand drx per m^2 with the exception of a very large and expensive hall (Peristeri). Consequently, the above mentioned costs further justify the importance of the D&B as it is not only the contractual system used in most cases but also the projects built following this system are among the most expensive.

Therefore, following the presentation of the procurement systems, the relevant importance of these systems and finally the objectives set by the GSS, it is decided to focus on the design and build method. Furthermore, this is the method where the client's objectives are described more exhaustively and, most importantly, an evaluation method is available as a reference and indicator of the GSS objectives and ranking of the considered variables.

3.2.5. GSS Requirements for Sporthalls and Swimming Pools

Having already presented the existing construction conditions in Greece in general, and in the long spanning indoor sportshalls and swimming pools in particular, the requirements set for them by the GSS are investigated. Examining the GSS edited briefs, the general functional requirements were identified through the main user needs. A problem faced was the complexity of these briefs which, in fact, are compilations of functional requirements together with performance and products specifications, descriptions etc. An exhaustive analysis is needed to distinguish them and consequently edit the full list of functional requirements, criteria and wherever possible performance requirements. The design and build briefs start with a general description of the building and proceed to a more detailed list of needs that the building should satisfy. Appendix B presents the general Functional Requirements together with the Structural ones and the Functional Criteria.

3.3. Conceptual Model Deriving from the GSS Design and Build Procurement System

3.3.1. GSS Main Dependent Variables

While presenting the design and build procurement system, two main dependent variables were identified, *cost* and *quality*. *Time* variable could not be included directly, in terms of speed of design or erection, as the model is assessing proposals and not completed buildings. Hence, time is considered indirectly through potential charges on the contractors due to delays in design and/or construction.

In order to formulate and validate the conceptual model deriving from the GSS D&B procurement system, three project briefs were analysed. These briefs included a very expensive and quite large indoor sportshall, a small swimming pool and a medium sized sportshall. As a result, the similarities and differences between the briefs were defined leading to the construction of a representative model.

Cost Variable

The starting point for the economic analysis is the GSS building budget. Each project's budget includes: the *net building costs (nbc)*, incorporating all construction related costs such as structural material costs, labour and plant costs, the *general costs and contractor's profit* and finally allowances for the *unexpected and revision costs*.

General costs include undertaking and presenting the design and construction plans, working details, building permit expenses, on-site electricity and water supplies, protection and safety measures taken during construction. General costs and contractors' profit are fixed by the GSS (as well as for all public sector developments in Greece) at 18% over the *nbc*. Allowances for revision and unexpected costs are related to the possible alterations and changes in the initial design as well as inflation compensation, and range between 7% and 10% over the *nbc* depending on the size of the building. In the preliminary study it was found that 10% is commonly used, which is therefore employed throughout this research. The sum of the above three is the *GSS budget*. The previous are expressed in the function:

$$\text{GSS budget} = nbc + .18 * nbc + .1 * nbc = 1.28 * nbc \tag{3.1}$$

In the bidding process, contractors submit their **overall budget (ob)** which comprises three components, the *net building cost offer invoice (n.b.c.o.i.)*, the *general costs and contractor's profit* and the *allowance for revision and unexpected costs*. The main component is the *nbcoi* based on the contractor's estimates of all construction related works. General costs and contractor's profits are 18% of the *nbcoi* and the unexpected and revision costs are 10% over the *nbc*. The *ob* is expressed as:

$$\mathrm{ob} = nbcoi + .18 * nbcoi + .1 * nbc \tag{3.2}$$

Additional information from GSS engineers, and especially from discussions with Korbas (October 1990), were collected during the preliminary investigation. It was found that the net building cost offer invoice is, on average, 30% less than the GSS. net building cost budget.

$$nbcoi = .7 * nbc \Rightarrow nbc = \frac{\mathrm{nbcoi}}{.7} \tag{3.3}$$

Working on the second function and substituting the *nbc* with $\frac{nbcoi}{.7}$ (third function), the relation between *ob* and *nbcoi* is established as:

$$ob = 1.322 * nbcoi \tag{3.4}$$

Following the relation between *GSSbudget* and *o.b.* will be established. The first function is changing through the third one: $\text{GSS Budget} = 1.28 * \frac{nbcoi}{.7} = 1.83 * nbcoi$. Consequently their relation is:

$$\frac{\text{GSS Budget}}{1.83} = \frac{\text{ob}}{1.32} \Rightarrow \frac{\text{GSS Budget}}{ob} = 1.38 \tag{3.5}$$

Time Variable

Korbas (interview, October 1990) argued that the period assigned to the contractor for the proposal design is insufficient, not exceeding 70 days. He pointed out that, on the contrary, the time period assigned for the construction is sufficient, regardless of the structural method followed. The GSS, in order to ensure that projects runs on time, impose charges for delays occurring in *design completion* (submission of the final construction plans and details) and *overall completion deadlines* (construction completion). These charges are daily and are expressed as a percentage of the *mean daily cost* of the building. The latter is calculated by dividing the contractor's *overall budget* by the contract period specified by GSS for the completion (this period is in calendar, not working, days).

Starting with *design completion*, two deadlines are stated. The first deadline is the submission of the final construction plans and working details for approval and validation by the board of GSS. The period within which these plans and details must be completed and submitted is usually no more than 45 calendar days after the contract signing. Failing to do so leads to a daily charge of 27% of the project's mean daily cost for the first 10 days of delay. For the next five days of delay the daily charge increases to 54% of the mean daily cost of the project. Delay of more than 15 days leads to a break of contract—the runner up is called to build the project.

The second design completion deadline applies if the plans and details submitted by the contractor are rejected by the GSS. In this case, the contractor receives a report pointing out the failures and, possibly, suggesting solutions; there is a ten to fifteen days re submission period. If the contractor fails to complete the corrections on time, he faces a daily charge 38% of the project's mean daily cost for the first 5 days of the delay. That percentage is increased to 70% for the next 5 days; delays exceeding the ten days limit lead to a break of contract. As stated in the brief, the total delay charge for these two *design completion* deadlines may reach a maximum of 2% of the *overall budget*.

As far as *overall completion* deadline is concerned the daily charges are 10% of the mean daily cost of the project. That is charged for delays up to 20% of the contract period specified for completion of the project. When the delay is greater (up to 30% of the contract period specified), the daily charge is increased to 20% of the project's mean daily cost. According to the brief, the charge due to overall completion delays can reach a maximum 4% of the *overall budget*.

The maximum construction delay accepted by the GSS is 30% over the contract specified period. If this is exceeded, the contractor is dismissed. Delays beyond the contractor's responsibility, such as in bad weather conditions, changes in the briefing and additions or modifications while the works are in progress, are not charged and not calculated in the overall delay period. Therefore, it is possible that a project exceeds the 30% delay and the contractor is not dismissed.

Another factor affecting construction is the revision of costs which take place twice a year. This acts as an inflation compensator; annual inflation rate was approximately 20% in Greece in 1989-90. Every January and July a new list of structural materials' prices and labour costs is issued by the government and subsequently the costs of works that will be carried in that semester are revised accordingly. Consequently the contractor's payment is adjusted to compensate for inflation. Discussions with various practising architects and engineers, showed that revision is lower than the actual inflation increase in the market and therefore the contractor's payment is never adjusted in full—in fact some of the prices listed are far from reality. As Pyrovolakis stated (interview 1991) in some timber products the prices listed are anything up to 100% less than the market prices. It should be noted that each assembly's cost is revised according to the official programme of work submitted by the contractor immediately after the contract signing. This means that delayed parts of the work are not revised according to the semester in which they are constructed but according to the semester in which they should have been constructed. Furthermore, GSS does not provide any bonus for faster completion which would motivate contractors to speed up construction.

During the preliminary study, it was reported (DDGSS data) that delays did not occur on the projects assigned during the last decade, although that cannot be argued for previous decades. A brief analysis of the GSS lists of completion, showed that older examples (1970's—1980's) had delays in the region of 20% over the contract specified period. The buildings built during the last fifteen years are of similar size and the technological and design considerations have not changed dramatically to justify the delays of the older examples. As Korbas explained (interview, 1990), the delays of the previous decades were caused by the incapability of the decision makers to discipline and organise contractors and, mainly, the bureaucratic structure of the Greek government and all public sector bodies. The latter enabled contractors to exceed the construction period specified in the brief and, furthermore, manage to avoid the charges and, in some cases, update price revisions to the actual construction semester. However, it should be noted that this happened in the minority of buildings and is definitely not the rule.

Quality

The term quality is used in this model in a broader sense as a few technical issues are dealt with. As explained previously, the number of parameters considered varies, ranging from seven to eleven. Furthermore, the relative importance of each parameter is different—the variations in the grades awarded to each parameter is a clear indicator. A more detailed analysis of the briefs revealed that the parameters with the high coefficients appear in all briefs whereas some minor importance parameters are omitted in the lesser model. It was also noticed that the marginal parameters are more suited to certain building types. Therefore, it was decided to base the GSS conceptual model on the analytical briefs, as all parameters are included and considered.

These eleven parameters are: **aesthetics** (external and internal appearance of the building), **function** (of the building in general, in relation to sports and to its surrounding environment), **loadbearing structure** (overall arrangement, selection, combination of the loadbearing and non-loadbearing members of the building and durability), **lighting** of the main hall, **heating**, **plant room**, **machinery and e/m equipment**, **building materials** and their specifications, **energy conservation systems** (passive energy, etc), **acoustics** of the main hall and finally **repairs and maintenance** (selection of materials and constructional methods facilitating simplicity, flexibility and economy in repairing and maintaining the building).

3.3.2. Weighting of the GSS Main Dependent Variables

In order to have an inclusive view and assess the GSS model at a holistic level, the relative importance of the three main dependent variables should be calculated. This is possible by examining them in pairs. **Cost – quality** is the first pair, **cost – time** the second. Analysis of two pairs is sufficient; the third, **quality – time** can be derived from the relationships determined on the other two pairs.

Cost—Quality relation

Earlier in this chapter, in the analysis of the design and build contest (page 42), the evaluation method employed by the GSS was presented. It was explained that the contractors submit their proposals and the GSS evaluation committee assesses them in order to establish the quality level likely to be achieved in the actual building. Therefore the submitted plans, lists of materials to be used and maintenance and servicing procedures are evaluated through a list of, brief specified, criteria–parameters and *the total grading* of each proposal is calculated. Next the sealed offers are opened and the evaluated offer of each contractor is calculated as:

$$\text{Evaluated Offer} = \frac{nbcoi}{\text{Total Grading}}$$

leading to the assignment of *best value bidder*, the one with the smallest evaluated offer.

The above function is the only one on which the relation between cost and quality can be based. This relation is shown in figure 3.1, where *E.O.* versus *nbcoi* and *E.O.* versus *grading—quality* are plotted together to facilitate comparisons. The *E.O.* is on the vertical axis and cost and quality on the horizontal. It should be stated that all these are measured in ratios and not actual monetary units since grading systems and budgets vary among the buildings examined. Since cost and *E.O.* are proportional, their relation is represented by a straight line, whereas the quality–*E.O.* relation by a curve.

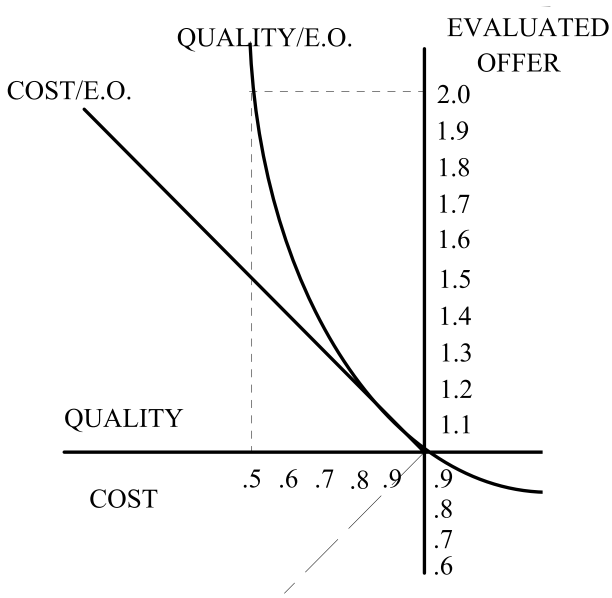


Figure 3.1: Cost–Quality Relation

The (1,1) point is where the maximum grading and therefore quality and the maximum contractor's offer—*nbc*—is. The minimum acceptable quality rating (.5) is the limit of the graph on the left hand side. As far as quality–*E.O.* relation is concerned, the curve is clearly showing that quality is affecting the *E.O.* much more when the quality level is low than when it is high. The two limits of this curve, for maximum and minimum acceptable grading, present the range limits of the *E.O.* to quality relation. For maximum grading this relation is one to one whereas for minimum grading quality's importance is doubled.

In order to calculate the cost quality relation the mean *E.O.* is needed. That is achieved by setting the average percentages that the preliminary study identified in both cost *nbcoi* and quality grading. The *nbcoi* average (focused on the winning and running-up proposals is .7 of the *nbc* as stated in function 3.3 (page 45). On the other hand, Korbas (interview 1991) explained that the grading of the winning proposals is in the region of ten percent less than the maximum. Consequently the $E.O. = \frac{.7 * nbc}{.9 * grading} = .78$

Therefore the cost–quality relation is established as:

$\frac{COST}{QUALITY} = E.O. = 0.78$ **This means that the cost–quality ratio is 1 : 1.28.**

Cost—Time relation

Usually time is measured in terms of the period spent designing and constructing a building. The GSS, in their model, measure time in terms of delays over certain deadlines.

In order to enhance comparability among various buildings, delays are expressed as a percentage of calendar days delay over the contract time specified.

The aim of this analysis is to establish a formula evaluating time in terms of cost. Therefore investigation of the time factor in terms of potential/actual delays and the consequent charges is needed. In the analysis presented previously (pages 45-46), two types of delays were considered by the GSS; design and construction. The first are short term ones, up to 25 days, but can reach a maximum charge of 2% of the *ob*. The latter are long term delays for up to 30% of the contract period and up to 4% of the *ob*.

The formula, according which the charges are estimated, is of special importance for this relation. As Korbas (interview, 1990) explained, design delays are scarce and furthermore design delays data are almost impossible to obtain. Consequently, the time—cost formula is based on construction delays only. As stated earlier, the daily overall completion delay charges are not fixed. They are 10% of the daily cost and then double when delays reach the 20% of the contract specified construction period. Therefore, based on the available information and sample, it is decided to consider only the 10% charges as that percentage is almost never exceeded.

This, in effect, means that **the daily delay is charged with .1 of the daily cost**, leading to a **cost time relation of 10 to 1.**

Overall Relation

As a conclusion, the overall relation, based on the sectional ratios, is established. The partial results are: $\frac{COST}{QUALITY} = 0.78$ and $\frac{COST}{TIME} = 10$

Starting with, the quality to time relation is:

$$\left.\begin{aligned} \frac{COST}{QUALITY} = 0.78 &\Rightarrow COST = 0.78 * QUALITY \\ \frac{COST}{TIME} = 10 &\Rightarrow COST = 10 * TIME \end{aligned}\right\rangle \Rightarrow 0.78 * QUALITY = 10 * TIME \Rightarrow QUALITY = 12.82 * TIME$$

Following the sum of the three is calculated:

$$COST + QUALITY + TIME = 100 \Rightarrow (10 + 12.82 + 1) * TIME = 23.82 * TIME = 100 \Rightarrow TIME = 4.2\%$$

Consequently:

$$COST = 10 * TIME = 10 * 4.2\% \Rightarrow COST = 42\%$$
$$QUALITY = 12.82 * TIME = 12.82 * 4.2\% \Rightarrow QUALITY = 53.8\%$$

Concluding:

Cost weighs 42% of the total.

Quality counts for 53.8%

Time is only 4.2% due to the rarity of overruns and the method that the construction duration is specified (section 3.3.1. and 3.3.2.)

3.3.3. Weighing of the GSS Quality Parameters

In order to obtain a complete chart including all independent variables and their relative importance the evaluation of the quality parameters is needed. The GSS model incorporates a chart assigning grading values to all eleven parameters. As each parameter is of varying importance, the maximum and minimum grading differs. Analysis of this chart led to the evaluation of these parameters and the construction of Table 3.1.

Parameter	*GSS grading*	*mean*	*%*	*o/a %*
Aesthetics	20–10	15.0	15.6	8.4
Function	25–15	20.0	20.8	11.2
Loadbearing Structure	20–10	15.0	15.6	8.4
Lighting	6–3	4.5	4.7	2.5
Heating	9–4	6.5	6.8	3.6
Plant Room	5–3	4.0	4.2	2.3
Machinery, e/m eq.	12–7	9.5	9.9	5.3
Building Materials	84	6.0	6.3	3.4
Energy Conservation	5–2	3.5	3.6	1.9
Acoustics	5–3	4.0	4.2	2.3
Repair & Maintenance	10–6	8.0	8.3	4.5
Total	125–67	96.0	100.0	53.8

Table 3.1: Weighting of the Quality Parameters

In Table 3.1 the GSS grading, as a reference point, is in the first column showing how GSS conceives the relative importance of the parameters. As a maximum and a minimum grading is stated, the mean grade value is calculated (second column of the graph) to facilitate relating the parameters in single numbers and not ranges. The third column shows the relative importance of these eleven parameters calculated through the mean GSS gradings. The final column presents the co-efficient factor of each parameter at an overall level where cost and time variables are also considered.

In the next chapter the GSS model is compared to various models reviewed in the literature and its compatibility with the form, structure and function of the research's conceptual model is examined.

Chapter 4 Empirical Methodology

4.1. Research's Methodological Approach

4.1.1. General Considerations—Aim of the Research

The evaluation methods presented in the second chapter are applied either in an advanced stage of design, facilitating decision making on particular problems, or in the appraisal of already existing, and often recently completed, buildings; identifying problems, suggesting solutions and feeding–forward to the design of future buildings (Markus, 1972). Comparison between buildings is very rare in these models; it is mainly comparison between alternative solutions to specific problems (structural, environmental, etc.) that matter most.

On the other hand, the GSS model (Chapter three) is based on the evaluation of proposals which are exclusively in a draft plan stage but have developed 'clear' ideas (GSS briefs, 1985-1990) on the constructional methods, materials used etc. The time period in which these proposals are made is very limited. Consequently, the whole evaluation plan attempts to identify (reveal) the virtues of each proposal and the areas of potential problems; in a few words, the expected performance. Nevertheless, a model of quantification has been developed to measure the performance level of each proposal.

As stated in the introduction, *the aim of this research is to investigate the performance of the various constructional systems used by the GSS for sportshall and swimming pool buildings in Greece and devise an objective evaluation method for their assessment*. Consequently, the methodological approach followed in this research facilitates the appraisal of already built and, sometimes, quite old buildings. Therefore, a model is constructed aiming at an overall measurement of building performance and facilitating the comparison between buildings of different constructional systems.

4.1.2. Appraising Methodology

This study deals with existing buildings leading to the adoption of an in–use evaluation approach. This evaluation examines and investigates all aspects affecting building performance; in other words, it is a holistic one. According to Bishop (1978) and the SSBRT (1976), holistic evaluations employ the systems concept. Various appraisals of this type have been presented already (BPRU, SSBRT, Rabinowitz, GSS etc.) that are subdivided further into framework and model appraisals. Yet, as stated previously, only the approaches developing a model of quantification are considered.

Three such approaches have been discussed in the previous chapters; BPRU, SSBRT and GSS—although, as Bishop (1978) explains, the second one has not exactly developed a model of quantification, it is a very well structured and organised framework. Another approach, having a clear model that rigorously investigates the variables and their relations, is the Crise (1975) one. His model, assessing the expected performance of industrialised housing systems, is not an inclusive one as it does not consider sociological, psychological and environmental issues at all. Nevertheless, Crise approaches the variables globally and develops an analytical and detailed model for the assessment of the alternative systems.

An issue examined in this particular research is the interaction of people and buildings which, as Markus et al (1972) explain, is very important in measuring building performance. In order to measure this interaction, it is necessary to collect empirical information about what people actually do and say in regard to their environment. Therefore, the environment–activity interaction qualitative parameters of this particular research (aesthetics, acoustics, heating, lighting etc.), are measured through the subjective users opinion. Their opinions together with the researcher's observations provide a more suitable measure than the 'rigorous and highly scientific approaches' applied in many partial theoretical appraisals reviewed in Chapter Two. That is mainly due to the need to compromise between a highly inclusive approach and a partial focused one; the diversity of the buildings' objectives also affects this decision.

Limitations—Scope of Content

A problem faced in systematic appraisals is that of drawing *the boundaries* between the system (on which the appraisal is carried out) and the environment (SSBRT, 1976). Researching long spanning buildings in Greece, does not imply that only the structural frame and the roofing are considered; the whole external envelope is included in the analysis. Since buildings modify both behaviour and culture (Hillier et al, 1972) the boundaries are extended to include the immediate surrounding of the buildings by considering environmental conditions such as temperature, air quality, noise, traffic etc. (section 4.3.2).

4.1.3. Parameters Considered—Analysis and Justification

Having set the boundaries of the research, the next step is to identify the parameters considered through a detailed evaluation of the issues tackled in the systematic approaches presented already. This evaluation focuses on appraisals incorporating a model of quantification, BPRU and GSS, and compares them with the stated restrictions and limitations.

The BPRU approach to appraising buildings relates each of four systems (building, activity, environmental and objectives) to a measure of cost or value. However, such an approach is impractical for this research project due to the lack of availability of information—especially cost related information (and resources available). Therefore, *human satisfaction and technological issues are measured qualitatively while quantitative cost measures for resource–related issues are developed.*

The GSS model is the starting point for the research's methodology. In the following paragraphs, GSS model's parameters (briefly presented in Chapter Three) are examined, compared to the BPRU ones (Chapter Two) thus establishing their relevance to the subject and the restrictions–boundaries. Consequently, the research's parameters are identified and listed.

According to the GSS methodology, the research parameters are classified in two broad groups—the resources related and the quality related. The resources include cost and time measures whereas quality includes the four BPRU approach's systems; building, activity, environmental and objectives. The quantitative resources parameters are analysed first, followed by the qualitative ones.

Cost is one of the most important parameters involved in the building industry. As Markus et al (1972) state, *'...the building costs something to build; the environment costs something to maintain (labour, material and energy costs); and activities have definable costs (related to work flow, control, communication, identification) ...objectives have values (production, adaptability, morale, stability), values which are obtained to a greater or lesser degree according to the degree of fulfilment of the objectives'.'* In the previous chapter, building costs were discussed through contractor's reduction, costs overrun and overall cost. However, environment costs were not investigated, neither activities' nor objectives' costs. The last two are assessed qualitatively in the following sections but the environmental parameter is included in the cost analysis in terms of labour, material and energy costs. Labour and materials costs are discussed in the maintenance section, leaving only energy costs in the heating section. Finally, issues related to the environmental performance of the buildings are examined under the quality parameters.

Time parameter considers both building construction and in-use issues. The building construction related issues have been analysed in the GSS model (page 45) and the in-use ones are analysed in section 4.2.2.

The most subjective parameter listed in the GSS model is **aesthetics**. Markus et al (1972), argue that the stages of buildings' appraisal incorporate: *representation, measurement and evaluation* (§ 2.2.1.). Discussing the evaluation methods available to the researcher, BPRU include aesthetic judgement among the more conventional theoretical methods of cost benefit analysis, comparison to ideal and value judgement. In this research, aesthetics play a significant role in the evaluation of the different systems due to variations in elevations, shapes and overall appearance of the buildings. Users are the main source of information backed up by researcher's observation (as a qualified architect).

Function is a parameter analysed in detail by the GSS. Three main requirements were set: space, safety and legislation.

The <u>space requirements</u> relevant to the research relate to the physical properties of the hall, as well as visibility. In terms of physical properties minimum height, seating capacity and overall plan area are the issues considered.

In terms of <u>safety requirements</u>, analysing the structural safety of the buildings under examination is outside the scope of this research. The DoE standards (custom made for reinforced concrete and German, U.S. and U.K. ones for steel and timber) have proved successful through the years—ultimate example are the large earthquakes of the last decade. Consequently, the research only examines the main hall's wall performance as presented in Appendix B.2.3 Side Walls section and in § 4.3.2.

Legislative requirements mainly deal with heating, the already discussed safety and space issues (in terms of maximum height, protrusions, ratio of site area to building area, etc.). Bearing in mind that all buildings are approved by the DoE in terms of safety and space issues, heating is considered only.

Another parameter examined by the GSS is the **loadbearing structure** in terms of industrialisation, prefabrication, simplicity and solidity. BPRU (1972) incorporate this parameter in the building system and, furthermore, do not deal with the above mentioned issues. On the other hand, Crise (1975) analysing the structure of buildings refers to adaptability, standardisation, variety in terms of overall configuration, size and cladding as well as interchange ability of components and sub-systems within the system. He also examines the compatibility with labour force capabilities. This research focuses on the industrialisation, prefabrication of the structure and construction complexity as discussed on the GSS model (Appendix B.2.2.) as these are the factors related to the research's aim.

Natural lighting performance indicates design problems related to the particular building (successful incorporation of rooflights or windows within the building envelope, shape and arrangement of building elements preventing lighting, etc). Additionally, the usage of **artificial lighting** highlights the efficiency (or not) of the natural lighting and is, therefore, a further measure of lighting performance.

In terms of **heating,** all Greek buildings comply with the DoE standards without that presupposing they are performing uniformly. As an example, there are swimming pools in which vapour condensation takes place on a larger scale than others, leading to faster deterioration of the structural materials and finishings and in other halls, during winter, temperatures drop lower than the DoE and GSS specifications. The appraising methodologies presented in Chapter Two assess air–conditioning and cooling of the buildings as well as heating whereas GSS model of evaluation focuses on heating through the examination of the performance of the individual components. This is a serious omission, especially in buildings that suffer from heat more than cold as in sub-tropical Mediterranean climate of Greece (Stoll et al, 1987). Air–conditioning and cooling installations are considered in a separate category together with all other installations and machinery involved in these buildings. Concluding, in-use evaluation is the only feasible method to obtain information on the compatibility and overall performance of the heating and ventilating system.

Machinery and electro–mechanical equipment are taken into account only to the extent that they intervene in heating, ventilating and air–conditioning of the buildings, since water circulation in pools and hot water for the changing rooms are not considered in this research. For example, excessive air–conditioning and heating expenses are signs of poor design in terms of materials chosen for the cladding or shape of the roof, though it is possible that the actual installations and machinery are wrongly selected and installed. The latter can be identified through interviews with the building staff and by correlation of the running cost to HVAC performance figures for similarly constructed buildings of the sample.

The performance of the **building materials** used in construction has an important role in the longevity, economy, aesthetics, safety and maintenance of the buildings. Consequently, materials specifications, design and construction procedures are among the issues examined (Preiser et al, 1988). Considering the scope of the research, certain aspects from the buildings' superstructure are not evaluated. These include flooring, seating, internal walls and partitions, showers, wc, electrical installations and mechanical equipment for circulating and heating the water in pools. Building materials are assessed indirectly through aesthetics, capital and maintenance costs and safety (function parameter).

Main hall **acoustics** (for sportshalls and to a lesser extent for swimming pools) is a parameter that is regarded mainly for the secondary uses of these buildings. Nevertheless, the shape of the roof as well as the properties of the cladding materials used both in roofs and walls have a significant effect on the acoustic performance of buildings (Timagenis, 1988). As Preiser et al (1988) explain, acoustic considerations are rarely found in building codes although there are federal regulations protecting people from noisy environments. BPRU (1972), examining school buildings, argue that reverbation (indicating acoustic absorption by the walls, ceiling and other contents of the hall), noise level, air-borne sound attenuation between adjacent rooms and external noise level must be measured in a comprehensive approach to buildings' acoustic performance. Out of all these issues, these relevant to this research are the reverbation and noise level measurements, as sound attenuation is not applicable in single–spaced buildings. Bearing in mind the low relative importance of this factor in the overall evaluation carried out, these variables are measured from users' opinions.

The last quality–related parameter the GSS consider is that of **maintenance**. An analytical approach to this issue is found in Crise's model incorporating criteria such as: long-term cost savings due to reduced annual maintenance, durability under repeated and cyclical service loads, compatibility with existing labour force capabilities, availability of spares. Preiser et al (1988) point out that as far as appraisals are concerned, the most undervalued source of information is the building maintenance staff who are knowledgeable about the ongoing maintenance of various assemblies and the repair works. Additionally the building managers can provide the repair and renovation records of the building over time.

Concluding with maintenance, the availability of spares, the level of technical expertise needed and any significant failures reported are among the research's main considerations; these are assessed through the maintenance staff and the building managers. Additionally, the latter provide the time–related information: annual time spent maintaining, intervals between regular maintenance and mean time between failures. Finally, data on costs of repair works in an annual average of both parts and labour as well as the costs of regular servicing are collected also.

4.2. Conceptual Model of the Research

4.2.1. Identification of the Main Variables

Following the analysis, justification and narrowing down to the research related parameters, the research variables are identified and structured. The variables analysed already are classified under three headings: <u>resources, human–user satisfaction and technical</u>.

Resources, the first variable, and the most clearly defined, is similar to the resources modifier by Hillier et al (1972) and the SSBRT's (1976) cost–resources heading. This variable incorporates two of the three main variables of the GSS model: <u>cost and time</u>.

These are not only examined in the *provision level* (as in construction costs and time spent of the GSS approach) but *in–use* (HVAC costs, energy conservation and maintenance) as well.

The second main dependent variable to be examined is the **human–user satisfaction**, including the physical environment, discussed in Markus's (1972) environmental system: *"...aspects of the environmental system directly perceived as heat, light, sound, texture and smell"* and psychological. The latter is presented in Zunde's (1982) analysis under the *delight, visual aesthetics* section and Preiser's et al (1988) behavioural elements of post–occupancy evaluation. Essentially, physical environment deals with heating, lighting and acoustics as have been identified and explained previously, whereas psychological refers to the GSS aesthetics as well as the spatial configuration—similar to the functional parameter of the GSS model.

The last main variable of the research is the **technical**, resembling Preiser's et al (1988) category, where structural integrity, durability and general performance of the various building systems is assessed. This technical variable is identical to the SSBRT (1976) technical category and very close to the BPRU (1972) building system. However, only two out of BPRU's three sub–systems are examined; constructional and services. Contents dealing with furniture, plant and equipment, are not considered in this study as they have no relation to the constructional system used. Technical variable is divided in two, building structure and maintenance. Building structure is assessed in terms of the GSS model parameters of origin of building materials and complexity and prefabrication of the building envelope, whereas maintenance, is reviewed as in the GSS analysis (availability of spares and cost of repairs).

Main Variables	Aspects Considered	GSS Parameters
Resources	Cost Time	Cost Heating Maintenance Time
Human–User Satisfaction	Psychological Physical Environment	Function Aesthetics Heating Lighting Acoustics
Technical	Building Structure Maintenance	Building Materials Loadbearing Structure Maintenance

Table 4.1: Main Variables of the Research

4.2.2. Analysis—Indicators and their Measurement

The only purely quantitative variable of the research is **resources**, incorporating cost and time dependent parameters. In order to measure sportshalls' and swimming pools' cost performance, the total costs of each building need to be calculated. The ingredients of the total cost for the life span of a building are the capital and running costs. Occupational charges as well as land costs (Seeley, 1983) are outside the scope of this research. Therefore, capital costs include the construction and the professional fees only expressed through the sum of envelope and services construction costs minus the construction delay fines (if any).

The running costs are more complex and can be divided further into annual and periodic. *Annual costs* include maintenance, operating services and energy (Lee, 1983). Maintenance is defined as '*a combination of any actions carried out to retain an item in, or restore it to, an acceptable condition*' (BS3811:1964) and, therefore, deals with the cost of spares, labour etc. involved in the "preventive" as well as "corrective" maintenance of the buildings. Operating services—a "base cost" of using the building not part of the occupancy costs—are measured through the annual salaries of the personnel and the annual costs of consumables. Finally, energy comprises electricity (lighting, ventilating, air–conditioning etc.) and oil (that all buildings examined use for heating) annual costs.

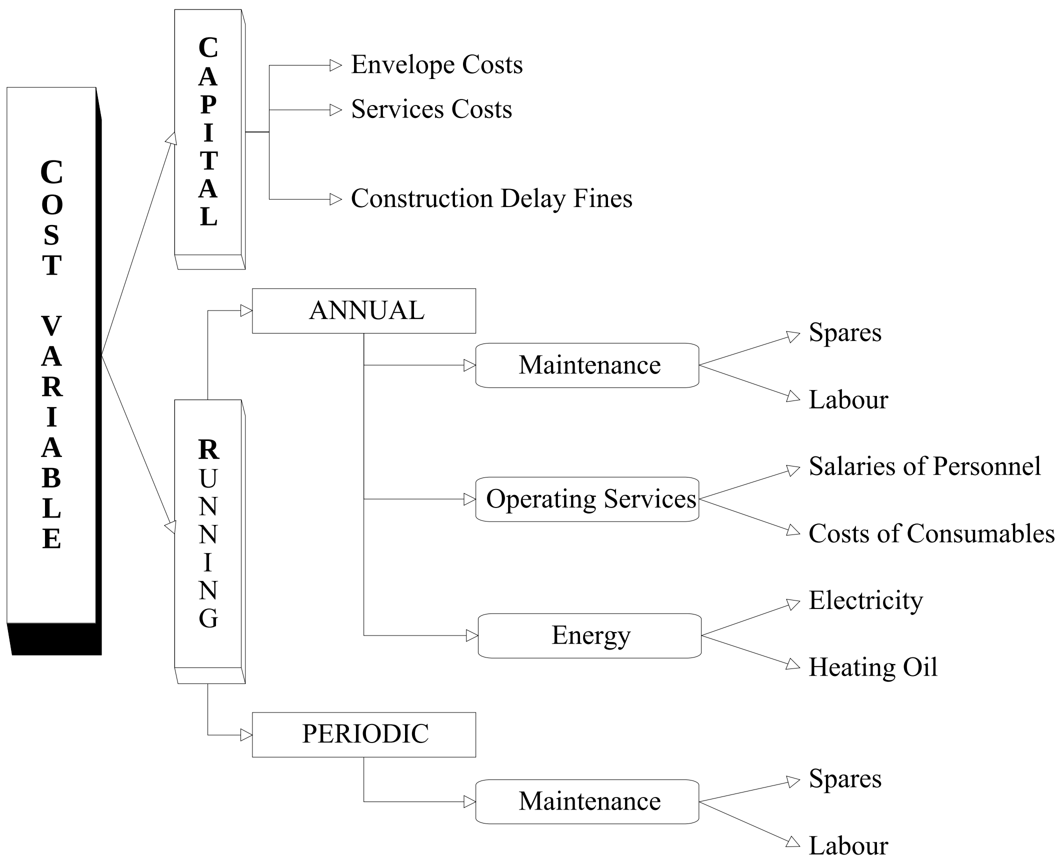


Figure 4.1: Analysis of the Cost Variable

Two more issues considered in the annual cost analysis model are the daily hours of use and the annual duration of maintenance—when the building is not available to the users. It should be noted that these buildings are shut only for maintenance work and not for summer or other types of vacation. The former affects the operation, energy and maintenance costs whereas the latter affects the energy only. Additionally, all cost measures need adjustment for the size of each building by dividing them by the usable building area. Trying to incorporate all these functions together complicated things considerably and led to the following formula:

$$\text{Annual Costs} = \frac{\dfrac{(\text{Maint} + \text{Oper})*24}{\text{Hours Daily Use}} + \dfrac{Energy*24*365}{\text{HoursD. Use}*(365 - \text{Main. Dur})}}{\text{Usable Floor Area}} \quad (\text{drx/m}^2) \quad (4.1)$$

Periodic costs—such as electro mechanical installations refurbishment and/or replacement, envelope members replacement—are maintenance related actions taken in intervals larger than a year and, thus, it is not appropriate to include them in annual costs.

As far as the time measures are concerned, the building's performance is assessed through the construction delays' fines, the annual maintenance duration and the intervals between the periodic maintenance bearing in mind that the intervals vary in regard to the particular assembly (see §5.1.4).

	Cost *(drx, drx/m²)*	**Time**
Capital	Envelope Services	Construction Delay (*drx, drx/m²*)
Annual	Maintenance Operating Services Energy	Maintenance Duration (*days/year*)
Periodic	Structural Electro-Mechanical	Frequency *(years)*

Table 4.2: Resources Indicators

Human–user satisfaction, is a qualitative and highly subjective variable assessed through psychological and physical environment indicators. These indicators are classified in five main categories: aesthetics, HVAC, lighting, acoustics and functionality. The environment–activity interaction qualitative parameters are measured through the subjective users' opinions whereas physical environment indicators are assessed by the researcher (see Table 4.3. and explanation in page 63). It must be stressed that the main source of information are the users—the physical indicators supplement the analysis, facilitating a holistic view of the existing conditions in general, and of the specific data collection day in particular (temperature considerations, physical phenomena occurred, etc.), as well as clarifying issues not explicitly covered by the users' opinions. Thus, in the discussion of each building's performance, psychological and physical indicators are related and compared in order to evaluate and assess the validity of the users' opinions and to enhance the drawing of conclusions. However, the model of quantification is based on the users' opinions and not the researcher's observations.

<u>Aesthetics</u> are measured via users' *appeal of the building* as a whole and *appeal of the hall* alone. The relevant physical indicators are the *shape and size of elevations, colours used* for the first and *main hall's properties in general and colours used* for the second recorded following researcher's observation (see page 63).

In terms of <u>HVAC</u>, users' opinions are monitored. Additionally, the following physical indicators are considered; *temperature considerations* (proximity to the sea, open space or protected by buildings, strong winds, etc.), *air quality* (dust, pollution) and *condensation*.

Users are also questioned on <u>lighting</u> issues focusing on daylight intensity and glare problems. The relevant physical indicators are *the window area, texture and orientation* *and the properties (colour, texture etc.) of the hall's walls* assessed by the researcher and from the plans. Additionally, the buildings' management provide more objective information on how often (if at all) artificial lighting is used during day time—more accurately, what time of the day is the lighting turned on for a set week of the year (to facilitate comparisons).

Acoustics in general, and the noise penetration from the surrounding environment, are also considered through users' opinion. The environment in terms of traffic load, factories and other noise sources that are potential causes of disturbance, are the physical indicators investigated by the researcher.

In terms of functionality, users are questioned on the safety of the buildings and the visibility lines from the seating area, whereas the researcher is carrying out an observation of the whole building in order to identify areas of potential problems such as *the wall's protrusions and smoothness etc*.

	Psychological	**Physical**
Aesthetics	Appeal of the building Appeal of the main hall	Shape and Size of elevations Colours used
HVAC	Heating Air quality–comfort Ventilation	Temperature consideration Air quality Condensation
Lighting	Natural light Glare	Window surface, texture & orientation. Main hall's wall properties. Usage of artificial lighting
Acoustics	Noise level in the hall Echo, clarity of sound	Proximity to noise sources
Function	Safety Visibility from seating	Wall's protrusions, smoothness Potential problem areas

Table 4.3: Human–User Satisfaction Indicators

Technical is the third main variable of the research. Maintenance resources related issues have been discussed in previous sections leaving the building structure and maintenance related aspects to be presented and analysed. The GSS analysis dealt with the loadbearing structure, building materials and maintenance. Focusing this study to the research objectives, the building envelope is examined, leading to the identification of the following indicators; *industrialisation of the building envelope, origin of the structural materials, construction complexity and availability of spares*. Cost related functions are developed for the measurement of the first two indicators, whereas the remaining are measured by questioning the building supervisors assigned by the GSS during the construction (Appendix C.3.).

$$Industrialisation = \frac{\text{Prefabricated Members Cost}}{\text{Roofing Cost}}, \qquad (\%) \qquad (4.2)$$

$$Origin = \frac{\text{Imported Members Cost}}{\text{Roofing Cost}}, \qquad (\%) \qquad (4.3)$$

Industrialisation	Extent of Prefabrication
Origin of Materials	Percentage of imported materials
Complexity	Level of expertise of construction personnel
Spares	Availability of spares

Table 4.4: Technical Indicators

4.2.3. Weighting of the Main Variables

Following the presentation and analysis of the three main variables and their indicators, the relative importance of each main variable must be established. This enables an accurate evaluation of the performance of each constructional system examined to be made. However, it also creates a problem as two major sources of information for this weighting exist. The first is the GSS and the second is the opinion of the Greek architects and building engineers that are currently practising in this field.

In order to cover all cases, and, furthermore, compare and evaluate their various opinions, it was decided to set two weightings, one according to the GSS and another one according to the engineers. Consequently, semi-structured interviews with a small sample of building professionals were conducted in Greece during the pilot study (October 1991). In these interviews the researcher introduced the three main variables briefly and following the engineers were asked to comment on the GSS weighting and, finally, suggest their own weightings.

The engineers questioned, were selected so that they represent a wide age group with various qualifications and specialisation's. Therefore, a relatively inexperienced architect was included as well as a very experienced GSS architect together with another one of 10 years experience. The building engineers questioned were from the GSS as well as a University lecturer with almost 35 years experience. The researcher's opinion (as an architect) is included as well. This questionnaire is included in Appendix C.

The percentages derived from the GSS analysis are:

Resources= 42 + 4.2 + 3 + 1.9 + 1.6 = 52.7

from cost, time, part of maintenance, energy conservation and part of heating respectively. Human-User Satisfaction= 8.4 + 5 + 2.5 + 2 + 3 + 2.3 =23.2

HUS derive from aesthetics, fraction of function, lighting, the remaining of heating, machinery & equipment (part only) and acoustics respectively. Finally,

Technical= 8.4 + 3.4 + 1.5 = 13.3

where these are related to loadbearing structure, building materials and maintenance (the remaining part). Transforming them to a hundred: **Resources are 59%, Human-User Satisfaction 26% and Technical 15%**.

The percentages derived from the interviews of Greek building professionals (architects, building and structural engineers) are **Resources 42.3%, Human–User Satisfaction**

32% and Technical 25.7%. There is a significant drop in resources (by almost a third) and an increase in technical and human-user satisfaction in comparison to the GSS model .

	GSS derived	Greek Prof.
Resources	59.0	42.3
HUS	26.0	32.0
Technical	15.0	25.7

Table 4.5: Relative Importance of the Research Variables

4.3. Data Collection Methodology

4. 3.1. Research Sample

According to Yin (1989), the research method used is selected mainly according to the type of the research and information needed. In this particular research it could be argued that **survey** is the most appropriate method to obtain a wide range of information. However, the diversity of the sources for the data needed (some from the GSS., other from the building site, the building managers and maintenance superintendents) are drawbacks for the implementation of this method. The difficulties faced in collecting information (insufficient data for old buildings, lack of co-operation from some building managers and maintenance superintendents) are also restrictive. The fact that these buildings are spread all over Greece and time limitations for the research, lead to the rejection of the survey method as inappropriate.

Another research method considered is the case study one, though a single case study is rejected in terms of reliability, as any attempt to classify long span sportshall and swimming pool buildings would result in more than five groups (according to the constructional systems used). These problems are avoided with the execution of **multiple case studies**, following a careful classification of the sportshall and swimming pool buildings. This method combines the advantages of case studies (depth of the research) and surveys (variety, all constructional systems examined), is flexible and reaches to reliable conclusions.

The research sample includes three contractual methods (D&B, 716 Legislative Act and GSS design), proportionally represented, as well as the various constructional systems used in sportshall and swimming pool buildings. Furthermore, in one case, identical buildings are intentionally included in the sample to facilitate assessment and testing of the research methodology by examining and calculating the significance of variance among the similar buildings in terms of resources, human satisfaction (although ethnographic research is involved as well) and technical issues. The age of these buildings is selected in a way that maintenance and, generally, service history is available and accessible. A table presenting the buildings analysed is provided in Appendix C.

4.3.2. Sources of Information—Techniques Implemented

In the independent variables' analysis of section 4.2, the following sources of information were identified: GSS, building management committee, building maintenance staff, users and the building itself. However it should be noted that each building is examined in three levels, overall, research related and envelope only whereas information are gathered from all four stages of the building life; briefing, construction design, construction and in–use. The independent variables' sources are listed analytically and related to the above mentioned classes.

	Brief	Constr.Design	Construction	In–Use
GSS	GSS Briefing	GSS plans Technical Report Design Budget	Completion Charts Constr.Supervisor	
Building Management				Manag.Question. Operating Staff
Users				Questionnaire
Researcher				Pers. Observation

Table 4.6: Research Data—Source of Information

Briefing

Analysing the brief enhanced a first approach to the buildings and provided a starting point for the analysis by establishing the *project's budget* and its *issue date*.

Construction Design

The GSS is the only source of information for the construction of the buildings. The **Technical Report** provided a general description of the building, its *use, size, placing, access, materials used* as well as *designer's aims and objectives set*. The **Construction Design Plans** were analysed by the researcher in order to quantify the following independent variables:

- Dimensions of the whole building and of the sports terrain alone
- Area of terrain with the seating and area of all other complimentary spaces
- Average and minimum height of the sports terrain
- Window surface and orientation

Finally, the **Design Budget** provided part of the necessary capital cost related information; GSS budget (both total and analytical), net building cost (*nbc*), envelope cost as well as the issue date of the design budget.

Construction

The information needed from the construction stage of the buildings were collected from the charts of completion of the GSS Construction Department. Additionally, each building has a building engineer member of the DDGSS as construction superintendent who provided all the relevant measures through the questionnaire presented in Appendix C.3.

In–Use

The relevant information was collected from four different sources; the building managers', the buildings' operation and maintenance staff, the users and personal observation of the researcher. The **building managers'** were questioned, as in the questionnaire listed in Appendix C.4, to provide information on the running and maintenance costs.

The **buildings' operation and maintenance staff** were questioned in a general and unstructured way to provide information on problems related to cleaning and maintaining the buildings and on special problems encountered.

The **users' questionnaire** is presented in Appendix C.5. The term users is employed in its wide sense including school children and athletes up to trainers and referees (people old enough and experienced by having used most of the sportshalls existing in the country) as well as spectators. As far as users sample is concerned, it was attempted to have a random sample by questioning users throughout the day so that various age groups, sports, external conditions, lighting conditions, etc. were represented. It was also attempted to carry out the data collection during days that official games were held, so that spectators could be included.

The **researcher's observation,** as explained earlier in this chapter, supplements the users questionnaires data. It was carried out during the researcher's visit to each building by noting remarks on the following issues:

1. Walls' smoothness and protrusions (rated from excellent—poor).
2. Visual obstruction (excellent—poor).
3. Shape of elevations (descriptive).
4. Colours used (descriptive).
5. Noise level of the environment (traffic load, other noise sources, etc).
6. Environmental temperature considerations (near sea, open space, wind's strength, etc.)
7. Environmental air quality considerations (dust, pollution)
8. Vapours' liquidation (excellent–poor).

The researcher is a qualified architect and, furthermore, the only one visiting the whole building sample following the same observation approach in a constant–consistant and critical manner, justifying the objectivity in his comments. Furthermore, these remarks–notes were mainly descriptive statements, with no ranking or any other type of classification attempted, as they were used for the explanation of the users' questionnaires analysis results rather than the analysis itself.

Chapter 5 Data Analysis

5.1. Resources—Cost and Time

5.1.1. Comparability Across the Building Sample

In order to proceed with the cost related analysis, the mean life of these buildings in Greece needs establishment by checking their history. One of the oldest swimming pools, built in Glyfada during the early 1960's, was reconstructed extensively in 1991-1992—actually a new building using the same main structural concept (steel beams and columns) was built. Furthermore, all government initiated or funded cost benefit analyses carried out in the last decade in Greece are considering a life expectancy of 30 years (Papatheodorou 1989, DMP 1990). Therefore, this research is also considering a 30 year life duration.

Another issue, that needs consideration prior to the cost analysis, is the estimation of the real rate of interest in Greece. According to Flanagan et al (1989), the running costs, and consequently their importance on a present value calculation, is highly related to the real rate of interest. The real rate of interest **r** is calculated using the formula derived from Fellows et al (1983):

$$(1+r)=\frac{(1+N)}{(1+i)} \tag{5.1}$$

where **N** is the market rate of interest and **i** the GDP deflator (International Financial Statistics and OECD) for 1960 to 1989. The real rate of interest was calculated as 2.43%.

5.1.2. Rethymno Sportshall—Estimation of Operating Costs

Among the ten buildings of the sample (table C.1), Rethymno sportshall causes certain problems. This is one of the series of steel framed trussed halls the GSS is building currently. It is the first one completed (March 1992) out of over ten under construction in 1992-93. This made its inclusion very important even though there was a lack of operational and maintenance data that, consequently, needed prediction.

Starting with the operational costs, as far as salaries of the personnel are concerned, the number of employees is the same as in the Mets hall. Considering that the wages in the public sector are practically fixed, this enables an accurate prediction of the annual salaries for this hall; 4.41 million drachmas per year in 1985 constant prices.

Energy expenses and consumables are more difficult to predict and, therefore, three similar buildings (in terms of size and usage) were selected for comparison; these are Mets, Loutraki and Byron. Table 5.1 presents their respective costs in constant 1985 prices and in drachmas per m^2. These led to sensitivity tests in order to identify possible overall rankings and performance levels of these buildings (which are presented in table D.2).

Buildings	*Consumables*		*Electricity*		*Heating Oil*	
	thous. drx	drx/m^2	thous. drx	drx/m^2	thous. drx	drx/m^2
Mets	590	262	840	372	5510	2442
Loutraki	600	235	370	145	110	43
Byron	1060	747	390	275	510	360
Reth.(max)	**2071**	747	**1031**	372	**6770**	2442
Reth.(aver)	**1150**	415	**732**	264	**2630**	948
Reth.(min)	**651**	235	**402**	145	**119**	43

Table 5.1: Calculations of Rethymno Operational Costs

Examination of the sensitivity test results, showed that Rethymno is the second performing building after Loutraki Glu-lam sportshall in both minimum and average test results. However, it drops down to third spot in the results of the maximum test which is not really representative as the values for this last test were a compilation of the highest values on all three buildings sampled. Therefore, the analysis proceeded using the average figures.

5.1.3. Calculation of Present Values

The method used for the cost analysis is the calculation of the present value (PV) of the buildings under investigation (Seeley, 1983). The main parameters involved are capital, annual and periodic costs. All costs were transformed into constant 1985 prices using table D.1. Consequently, capital costs were added as such, whereas the PVs of annual costs were calculated as in the formula noted by Fellows et al (1983) using 1985 level cash sums:

$$\text{Present Value (Annual)} = C_A * \frac{(1+r)^n - 1}{(1+r)^n * r} \qquad (5.2)$$

where $\mathbf{C_A}$ is the constant annual cost, **r** is the real rate of interest 2.43% (noted earlier in section 5.1.1) and **n** are the life span in years—30. Periodic costs were calculated following the function (Fellows et al, 1983):

$$\text{Present Value (Periodic)} = C_P * \frac{1}{(1+r)^n} \qquad (5.3)$$

where $\mathbf{C_P}$ is the constant periodic cost, **r** is the real rate of interest of 2.43% and **n** the interval of periodical maintenance.

The annual building costs calculated in function 4.1, together with the capital and periodic costs per m^2, lead to the following function that computes the Present Value of each building. This function takes into consideration, the usable floor area, the impact of the daily usage as well as the annual maintenance duration of the building sample. The construction rate is not incorporated in this function as it is used only as an indicator of the speed of construction (discussed in Chapter Six).

$$P.V. = \frac{Capital + Per.Ma\text{int} + \dfrac{(Ma\text{int} + Oper)*24}{HoursDailyUse} + \dfrac{Energy*24*365}{HoursD.Use*(365 - Ma\text{int}.Dur)}}{\text{Usable Floor Area}} \qquad (5.4)$$

5.1.4. Maintenance Costs

The issues discussed above are straightforward to measure and compare across the sample except for one; maintenance. Throughout the life of the building the fluctuations of the annual present value of salaries, consumables, electricity and heating oil are minimal. However, maintenance costs are related to age and vary substantially throughout the life of a building (Ferry et al, 1991). In order to calculate the PV of the maintenance expenses on the buildings of the sample, periodic maintenance costs were isolated from the annual and examined separately. Therefore, these two different types of maintenance costs are defined and analysed.

Annual maintenance costs include work necessary to keep or restore the buildings to an acceptable standard (Lee, 1983) such as redecoration, painting, servicing of assemblies as well as accidental damages etc. All these may not be exactly annual but are frequent enough to be assumed as such (especially when the cost data collected expand to three years in average per building examined).

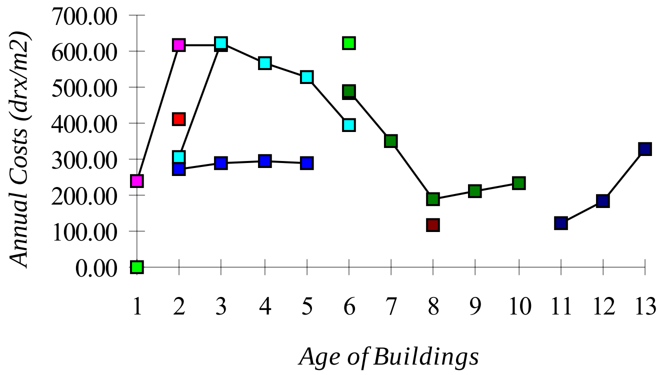
Periodic maintenance is more difficult to define and, consequently, calculate. However, the internal management and organisation of the GSS and the building committees facilitates this process. Each sportshall and swimming pool has an annual budget subsidised by the GSS. This budget is used for all operating, energy and maintenance expenses (§ 4.2.2) with most of the work carried out by the buildings' permanent staff and/or the municipal authorities (since the buildings are, in effect, run by the municipalities). When a substantial (in terms of expenses) problem or need occurs, the building managing committee reports to the GSS. Specialised GSS engineers assess the case and organise the courses of action. This, in most cases, involves briefing and tendering. Consequently, there is a clear differentiation between the annual and periodic maintenance and repairs costs. Additionally, the available data and interviews in the GSS with Korbas and Leandros during 1992-3, show a trend of running the available building stock with the least possible expenses and have planned extensive work carried out at large intervals resulting in spending large sums. It seems that this interval is at approximately 10 years as both Byron and Arta already had one such "periodical refurbishment" (Leandros, interview 1993). Additionally, Patra and Posidonio (closing to their tenth year) are in need of refurbishment of various installations (see Chapter Six on the discussion of these buildings).

Concluding, maintenance in the Greek public sector in general, and these buildings in particular, is perceived by the "run until it breaks" approach described by Ferry et al (1991) rather than regular, planned preventive maintenance. That is particularly true in installations not restricted with a limited standby capacity.

Tent covered buildings need extra periodic repairs (apart from envelope panels, structural frame, etc) concerning the tent itself that needs replacement (see earlier in Chapter 3). Repairs in waterproofing, painting the structural frame and similar are of minor importance and of low relative cost and, therefore, incorporated in the annual maintenance costs. However, the life of tent fabrics hardly reaches 20 years in the Greek climate (Stoll et al, 1987). Following personal observation and discussions with GSS engineers, it was revealed that the sun (ultra violet radiation, heat etc) causes extensive wear on the fabric and, therefore, fifteen years is a more realistic life expectancy for this material (Chapter 6).

Calculation of the Annual Related Maintenance Present Values

Focusing on maintenance, the annual expenditure varies with the age of the building, described as "maintenance profile" Lee (1981). It is high at the first years of the life of the building (especially when the contractor's liability ends) until various minor, or even major, details are sorted out, drops substantially in the coming years only to increase again when materials become older and need attention. This is described as '*the bathtub curve*' (Bargh, 1987). The only problem is that annual maintenance expenditure varies according to the use, type and assemblies of the building.



(*) costs in constant 1985 prices

Figure 5.1: Maintenance Costs for the Sample

Figure 5.1, presents the data collected from the building sample as cost per m^2 (in constant 1985 prices). There seems to be a pattern similar to the previously discussed '*bathtub curve*'. However, the available data are insufficient to enable a mathematical representation of this pattern or the prediction of the maintenance costs over the thirty years life span the research considers. Therefore, certain assumptions are made and, together with the theory and examples of similar research, a method for the calculation of the present value of maintenance costs is devised.

Examining the available data from the sportshalls and swimming pools in Greece, the problem of predicting the maintenance costs for the period of eleven to thirty years was identified. The available data can be used only for the modelling of up to the eleventh year by calculating the best fit curve equation. This equation (5.5), with a coefficient of determination (**r^2**) of 50.2%, standard error of the estimate (**Se**) of 3.370 and prediction intervals lower than 2% was derived from multiple regression calculations using the least squares criterion (using the statistical analysis package MINITAB). (Years 12 and 13 were included in the analysis but the curve was limited to the 11th year due to their high residuals.)

$$\sqrt{\cos t} = \quad 19.9 - 6.49 * year + 0.0135 * year^3 - 39.6 * \log \sqrt{1 / year} \qquad (5.5)$$

In regard to the rest of the effective life span the research examines, attempts were made to predict cost, based on theory and other similar studies. (The use of this particular curve fit equation (5.5) was not possible, as it conflicted with the existing theory reaching values in the tens of thousand of drachmas / per square metre by the year 25.)

The Sports Council of the U.K. was contacted and J.Davies (from the Technical Unit) explained that there are no data banks with maintenance cost figures except for a life cycle cost analysis that the Sports Council had commissioned to Davis Langdon & Everest (1992). This report investigates 12 small to medium sized halls with ages similar to the ones examined in this study. However, the raw maintenance data are very poor as they are hardly covering a year and D.L.&E. are therefore using their own tender price index on a custom made resource based costing model. Bearing in mind the confidentiality of the report, the only figures available were of overall P.V. monetary tables discounted at 6%, that are not in a form comparable to this study i.e. examining the breakdown of running costs over the life of the buildings. The only conclusion drawn from this D.L.&E. research that may be useful for this particular study is that the P.V. of the maintenance costs are on average 30% of the P.V. of the capital costs of a building.

Theory was not very helpful on this particular issue either. The pattern discussed by Lee (1981) is not clearly defined and/or predicted and is affected by the type of building, usage, constructional materials, environment, etc. as well as age. Therefore, it was decided to predict the maintenance costs for the remaining period using a line equation. This line equation, starting from year 11 at cost of 194.83 drx/m^2 (Table D.3), reaches the 30 year limit of the research at a cost that needs to be predicted/estimated. Asserting from the theory, the ending point of this whole curve should be in the 'burn-in' maintenance cost range of the first two–three years (Bargh, 1987, Lee, 1981) in this case in the 500 drx/m^2. The main assumption made in the above argument is that the annual maintenance costs will not exceed or drop below the limits of the first 13 years of buildings' lives. This assumption is justified by the fact that, even in case of a maintenance overrun (quite unlikely as the data from Byron and Arta show), this will be for only one or two years and will not spread over the remaining.

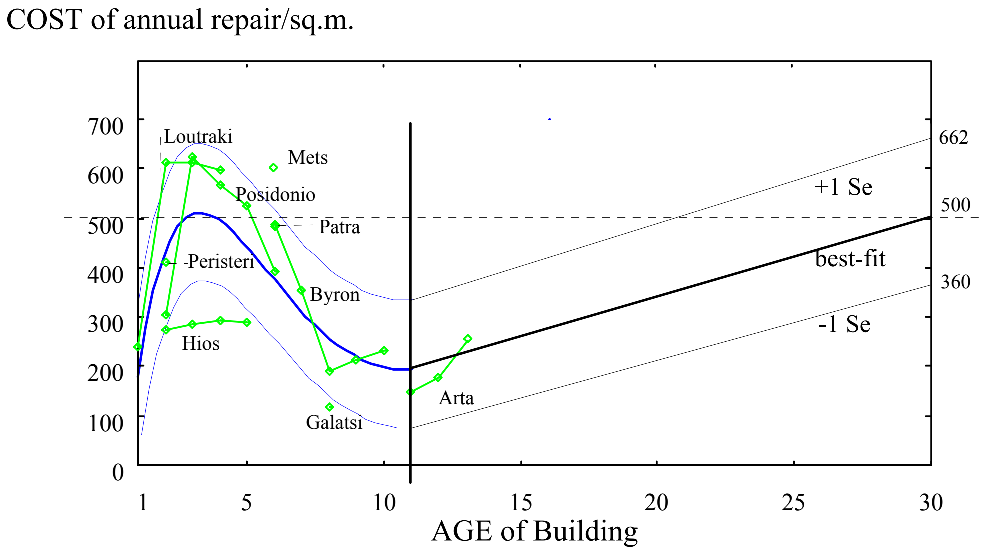


Figure 5.2. Graphical Representation of Maintenance Costs

The linear forecasting approach adopted may yield slightly high discounted maintenance costs (in comparison to a 'true' 'bath-tub' curve). However, bearing in mind the discounting technique used with all costs in Present Values and the inflation rate in Greece, the importance (and, thus, impact) of the maintenance costs decreases as the age of the building increases; which furthermore validates the approach followed. The above are presented in Figure 5.2.

Following the establishment of this "best–fit" curve the residuals are examined in order to verify their randomness and identify extreme cases (Levin et al, 1991). Table 5.2 shows the cases that were outside the ±1 Standard Error of Estimate (**Se**) denoting buildings with either high or low maintenance costs (in comparison to the rest of the sample). Four such buildings were identified. Starting with Loutraki, the high maintenance costs recorded for the second year of its life are not matched with similar data on year one, three and four. Therefore, it was excluded from further consideration. Hios swimming pool, with its innovative design and use of constructional system, showed lower than **–Se** maintenance figures for all four years data. Similarly Galatsi sportshall being quite small and a very simple construction showed low maintenance figures. On the other side of the scale, Mets, the only reinforced concrete building of the sample with high energy running costs showed the highest deviation from the best fit curve. Consequently the buildings of the sample are classified in three groups: the **low (-Se)**, the **average/best-fit** and the **high (+Se)** maintenance ones.

Equation 5.5 is used for the calculation of the maintenance costs for years 1 to 11. Table D.3 in the Appendices presents the predicted maintenance costs per square meter based on the best-fit figures of the sample. Following, the high and low maintenance costs are calculated as **Se** over and under the best-fit respectively.

Building	*Age*	*Actual(1)*	*Predicted(2)*	*Residual (3)*	*Ratio(Se)*
Loutraki	2	614.2	430.68	4.0736	1.208
Hios	2	274.5	430.68	-4.1222	-1.223
Hios	3	286.3	508.40	-5.5772	-1.654
Hios	4	294.1	495.22	-5.0378	-1.494
Hios	5	288.2	441.22	-3.9553	-1.173
Mets	6	620.6	374.57	5.6561	1.678
Galatsi	8	116.6	258.12	-5.1351	-1.523

(1) Actual costs in thousand drx/m^2 of constant 1985 prices

(2) Predicted costs in thousand drx/m^2 of constant 1985 prices

(3) Residual costs in square root of thousand drx/m^2 of constant 1985 prices

Table 5.2 Variation of Maintenance Costs; Cases Outside the ±1 Se.

Rethymno sportshall has no data on maintenance costs. This problem can be solved by examining the buildings of the sample that are similar to it (§5.1.2). Byron and Loutraki are in the average group whereas Mets is on the high. Therefore it was decided to use the average/best-fit maintenance costs for Rethymno as well. Concluding the life cycle maintenance costs figures assigned to the three groups were 9719.3, 6479.5 and 3239.8 respectively. These values are Present Values in thousand drachmas per square meter in 1985 prices.

Calculation of the Periodic Related Maintenance Present Values

In section 5.1.4, periodic maintenance costs were considered in 10 year intervals for all buildings and an extra cost at the mid-life (15th year) for tents only. The ten year interval maintenance costs were calculated as the mean of the recorded ones for Byron and Arta (the only two buildings of the sample that have reached this age). Byron was 1431.7 drx/m^2 and Arta was 1011.0 drx/m^2 leading to a mean value of 1221.3 drx/m^2 in constant 1985 prices. These costs are translated to PV using formula (5.3) for 10 and 20 years leading to a total Present Value cost of 1.7 thous.drx/m^2. Tents' extra periodic maintenance costs were calculated individually for each building according to the tent capital costs.

5.1.5. Overall Resources Analysis

The cost-time variable was evaluated for 30 years of expected life. Table 5.3 shows the Present Value of each building analysed in three sections—capital, annual and periodic—with the relative percentages expressing inclusively relationships between the various alternative constructional systems.

Name	*Present Values*			*Percentages*			*Total*		
	Capit	*Ann.*(1)	*Perd*	*Capit*	*Ann.*	*Perd.*	*P.V.*(2)	*SS*(3)	*Rank*
Peristeri	57.2	189.8	1.7	0.23	0.76	0.01	248.7	-0.05	7
Mets	37.8	186.0	1.7	0.17	0.82	0.01	225.6	0.16	5
Hios	60.9	123.1	7.9	0.32	0.64	0.04	191.9	0.48	4
Patra	24.5	259.3	8.7	0.08	0.89	0.03	292.5	-0.46	8
Rethymno	33.5	100.2	1.7	0.25	0.74	0.01	135.5	1.01	2
Loutraki	35.6	53.5	1.7	0.39	0.59	0.02	90.8	1.42	1
Posidonio	23.8	201.9	8.5	0.10	0.86	0.04	234.2	0.08	6
Galatsi	29.9	152.7	1.7	0.16	0.83	0.01	184.3	0.55	3
Byron	54.0	339.2	1.7	0.14	0.86	0.00	395.0	-1.42	9
Arta	51.7	380.1	1.7	0.12	0.88	0.00	433.5	-1.78	10

(1)annual costs are the total for the predicted 30 years life

(2)Present Values

(3)Standard Scores

(*) rounded decimals may not match exactly; all costs are in thousand drachmas per m^2.

Table 5.3: Cost Statistics for 30 Years of Life Span

5.2. Human–User Satisfaction

The users' questionnaire is the main source of Human-User Satisfaction (HUS) information. Personal observation (by the researcher) and other information collected through the building plans facilitate explanation and validation of the conclusions drawn. Consequently, they are considered in the discussion of the findings and overall conclusions.

5.2.1. Analysis—Data Transformation Within Each Building

The questionnaires' replies (Appendix C.5.) are in a five step scale from very poor to excellent—or else from very unfavourable to very favourable towards the issue under investigation. Consequently, the data obtained are ordinal (Ryan et al, 1985) preventing straightforward relation of them to the cost and time data.

In every building there are two main groups of respondents with the majority of questionnaires completed by **athletes** participating in the various national championships. This was achieved by delivering the questionnaires to the coaches of the teams using the particular sportshall or swimming pool. Athletes' responses can be identified by the frequency of use (essentially daily). The main advantage of their replies is validity, inclusiveness, comparability and lack of ethnographic elements since they are travelling around the country during the course of the championship and have the opportunity to play, and therefore assess, a great range of sportshalls and swimming pools. Conversely, **spectators and occasional users** do not always have a reference point against which to compare and judge the buildings. Therefore, athletes' opinions and assessments are helpful in comparing the buildings under investigation whereas spectators and occasional users opinions are important in identifying certain points where a building fails and of which athletes may be unaware (lighting conditions, etc.).

Response rate from these questionnaires was high. The reasons are the immediate interaction in the spectators' case and the fact that the team's trainer was in charge of the distribution and collection of the athletes ones. The latter posed a few problems in terms of time elapsed from the initial handing in, to reply of the completed questionnaires in some halls. The response rates are presented in appendix D.

Swimming pools cause special problems since they are assessed separately from the sportshalls—the athletes using them are not necessarily aware of the particularities of sportshalls and can compare them only to the other swimming pools they have used. In most cases the same is true for athletes using sportshalls only.

The HUS analysis in each building is based on the replies of approximately thirty respondents and incorporates three sets of analyses; *the athletes, the users and spectators* and, in order to have an inclusive measure, *the whole sample's* analysis. The main analysis is carried out using all users' replies. However, a secondary analysis is carried out using the athletes replies only to enhance inclusiveness and identify special problems and conditions.

The methodology followed is based on the semantic differential technique (Smith, 1975). Scores are assigned to the extreme replies only of all questions; minus one is assigned to the very unfavourable replies and plus one to the very favourable. This approach discards the replies that might impose positive bias, since according to Christie and Geis (1970) the respondents that have no particularly strong opinion on the subject, tend to use the more socially desirable end of the continuum. Consequently, the mean of the scores in each question is calculated giving an interval score within the -1 to 1 range. This score indicates the performance of the building in each particular issue and leads to a general overview of the buildings enabling a rough assessment of the various issues' performances.

These scores need further processing in order to draw more accurate and generalised conclusions on the performance of sportshall and swimming pool buildings. The twelve indicators of the users' questionnaire, measure the five main HUS parameters; heating ventilation air-conditioning (HVAC), lighting, acoustics, function and aesthetics. The evaluation of the relative importance of these indicators is needed for the calculation of the parameters.

Starting with the HVAC, the three questions asked are of equal importance for the research. Lighting is measured through two indicators the natural lighting of the hall and the glare. At first it seems that the former is more important; bearing in mind the extreme sunshine in Greece and following informal discussions with athletes, trainers and spectators it was shown to be appropriate to consider both equally vital for athletes' and spectators' satisfaction. Similarly, acoustics are measured via two indicators of equal importance.

The users' questionnaire analysis lead to the tables D.5 to D.14 of the appendices presenting the HUS means for each building and for each group of users separately. Table 5.4 shows the correlations noting the diversity of the evaluation criteria for these two groups particularly apparent in Peristeri and Loutraki sportshalls.

	All Users Vs Athletes			All Users Vs Spectators		
	R-sq(1)	t-ratio(2)	p-int(3)	R-sq(1)	tratio(2)	pint(3)
Peristeri	92.6	6.12	.9	60.2	2.13	12.3
Mets	95.1	7.60	.5	96.5	9.11	.3
Hios	85.5	4.21	2.5	86.5	4.39	2.2
Patra	97.1	9.95	.2	95.3	7.76	.4
Rethymno	95.3	7.81	.4	91.8	5.80	1.0
Loutraki	93.9	6.81	.6	74.6	2.97	5.9
Posidonio	96.4	8.99	.3	97.7	11.22	.2
Galatsi	96.8	9.50	.2	77.0	3.17	5.1
Byron	96.5	9.16	.3	80.3	3.50	3.9
Arta	81.7	3.66	3.5	88.3	4.75	1.8

(1) Coefficient of Determination (%)

(2) Tests of Significance

(3) Prediction interval (%)

Table 5.4: Correlation and Significance Tests on HUS data

5.2.2. Comparability Across the Sample—Standard Scores

The analysis carried out so far, provides a set of comparable results, based on which HUS performance scores for each indicator of the building sample can be calculated. These scores are in the -1 to +1 range considering 0 as the average indifferent reply. However, this score (0) may be misleading as it is not uniform for all buildings. Therefore, the deviation from the mean (standard scores) is calculated for each indicator across the buildings. According to Chebyshev (Levin, 1991) no matter what the shape of the distribution is, at least 75% of the standard scores fall within the plus or minus two standard deviations and at least 89% within plus or minus three.

5.2.3. Regression Coefficients

The final step in this evaluation process, is to establish the coefficient factors for each main HUS parameter in order to reach overall conclusions on the performance level of each building. Weighting of the main variables based on the G.S.S. model (carried out in §4.2.3), calculated their importance. Transforming them to a hundred, leads to the actual percentages employed in this research. Tables 5.5 and 5.6 present the weighted standard scores of each parameter in each building, together with the weighted total and overall ranking. They present the whole sample and the athletes only analysis respectively.

Name	**HVAC**	**Light**	**Acoust**	**Funct**	**Aesth**	**Weight**	**Overall**
Coeff.	*.216*	*.107*	*.099*	*.216*	*.362*	**Total**	**Ranking**
Peristeri	1.83	2.60	1.95	0.77	1.04	1.41	1
Mets	-0.11	-0.24	0.09	0.48	0.82	0.36	5
Hios	1.03	0.08	-0.38	0.69	0.89	0.67	3
Patra	-0.93	-0.46	-1.14	-0.75	-1.14	-0.94	8
Rethymno	0.44	0.04	-0.46	1.15	0.40	0.45	4
Loutraki	0.27	0.24	1.67	1.25	1.41	1.03	2
Posidonio	-0.11	0.08	-0.46	-0.95	-1.10	-0.66	7
Galatsi	0.19	-0.57	-0.46	-0.08	-0.81	-0.37	6
Byron	-1.44	-0.80	-0.38	-1.36	-0.73	-0.99	10
Arta	-1.66	-0.96	-0.46	-1.20	-0.79	-0.95	9

(*) Rounded Means may not agree strictly.

Table 5.5: Standard Scores of the HUS Variable (all users replies)

Name	**HVAC**	**Light**	**Acoust**	**Funct**	**Aesth**	**Weight**	**Overall**
Coeff.	*.216*	*.107*	*.099*	*.216*	*.362*	**Total**	**Ranking**
Peristeri	1.95	2.74	1.74	1.11	1.11	1.52	1
Mets	0.10	-0.67	0.25	0.33	0.59	0.33	4
Hios	0.62	-0.41	-0.46	0.52	0.28	0.26	5
Patra	-1.01	-0.34	-1.09	-0.86	-1.11	-0.95	9
Rethymno	0.12	-0.25	-0.46	1.17	0.78	0.49	3
Loutraki	0.44	0.08	1.8	1.03	1.65	1.11	2
Posidonio	0.01	0.05	-0.46	-0.96	-0.78	-0.53	7
Galatsi	0.39	-0.54	-0.58	0.18	-0.91	-0.32	6
Byron	-1.35	-0.44	-0.35	-1.05	-0.66	-0.84	8
Arta	-1.27	-0.82	-0.46	-1.47	-0.95	-1.07	10

(*) Rounded Means may not agree strictly.

Table 5.6: Standard Scores of the HUS Variable (athletes replies)

5.3. Technical Variable

In contrast to the resources and HUS main variables, technical is assessed both quantitatively and qualitatively. This approach involves some cost related measurements and the opinion of the GSS building supervisors.

5.3.1. Data Transformation—Compatibility

The approach followed is two-fold. As far as the interval data of industrialisation of the building envelope and origin of the structural materials are concerned, the data obtained are in cost units. Since the calculation involves division of the prefabricated members' cost and imported members' cost respectively by envelope cost, these indicators are pure numbers.

On the other hand, the construction complexity and the availability of spares is assessed through questioning the GSS building supervisors. This is done in a three step scale (highly specialised, specialised and unspecialised personnel) for the construction complexity and a five step scale (very bad, bad, average, good and very good) for the spares availability. This variation in the steps of the two evaluations was due to the results of the pilot study—GSS engineers were unable to differentiate more than three steps as far as personnel's specialisation was concerned.

These interval scores need transformation similar to that performed in the HUS parameters since the data come from one person for each building and not from a 30 persons sample. Therefore, using the semantic differential technique, the scores are transformed into signs as follows: the three stepped scale is assigned -1, 0 and +1 whereas the five stepped one -2, -1, 0, +1 and +2.

Name	**Pref.(1)**	**Imp.(1)**	**Envel.(1)**	**Compl.(2)**	**Spares(3)**
Peristeri	52.7	74.7	98.0	-1	1
Mets	0.0	14.0	30.7	-1	1
Hios	71.7	71.7	101.6	-1	0
Patra	60.0	60.0	60.0	-1	-1
Rethymno	5.4	0.0	24.4	0	2
Loutraki	14.0	0.0	21.3	-1	2
Posidonio	60.0	60.0	60.0	-1	-1
Galatsi	7.5	0.0	11.9	-1	2
Byron	0.0	0.0	16.6	0	2
Arta	14.4	14.4	17.2	-1	0

(1) Present Value in million drachmas (1985 prices).

(2) Scores in a three scale range.

(3) Scores in a five scale range.

Table 5.7: Data of the Technical Variable

5.3.2. Comparability Across the Buildings of the Sample

The first two indicators, rated in a 0 to 1 scale are compared across the sample, calculating the mean, and standard deviation of the buildings' scores. Next the standard scores for each building are computed leading to a new set of results. Similarly, the standard scores of the two qualitative indicators are calculated producing a comparable set of scores.

5.3.3. Regression Coefficients

Based on the GSS analysis, the loadbearing structure is assessed through the industrialisation and complexity of the building envelope. These two indicators, though diversified, are of similar importance; industrialisation is more general but objective while complexity more accurate as a measure but subjective in the way of quantifying.

Origin of the constructional materials is an important issue leading to construction cost reductions—additionally, the lack of transportation expenses makes them competitively priced in similar quality assemblies. The readily available spares is also leading to a long term economy. In an attempt of the Greek government to protect native factories and business, the GSS model of assessment is very keen on the use of Greek materials, rating origin as very important.

Name	**Prefab.**	**Import.**	**Compl.**	**Spares**	**Weight Total**	**Overall Ranking**
Coeff.	*.32*	*.25*	*.32*	*.11*		
Peristeri	-.06	-.65	-.47	.16	-.316	9
Mets	-1.50	.05	-.47	.16	-.604	10
Hios	.40	-.53	-.47	-1.46	-.228	6
Patra	1.19	-1.20	-.47	-1.46	-.232	7
Rethymno	-.91	1.09	1.90	.98	.696	1
Loutraki	.26	1.09	-.47	.98	.312	3
Posidonio	1.19	-1.20	-.47	-1.46	-.232	7
Galatsi	.19	1.09	-.47	.98	.289	4
Byron	-1.50	1.09	1.90	.98	.505	2
Arta	.75	-.83	-.47	-.65	-1.90	5

(*) Rounded decimal numbers may not agree strictly.

Table 5.8: Standard Scores of the Technical Variable

Table 5.8 presents the GSS model deriving percentages transformed in the 1 to 100 scale and the overall analysis of the technical variable showing the Standard Scores, Weighted Totals and Ranking of the buildings.

5.4. Overall Analysis of the Building Sample

In the previous sections, the three main variables of the research were considered individually. However, the scope of this study is to draw overall conclusions. Therefore, a final step is needed in which another variable is imported; the relative importance of these three main variables. In the methodology chapter, this subject was presented and two individual sets of regression coefficients were presented; one deriving out of the GSS analysis and another through a small scale survey of Greek engineers. These coefficients are not totally unrelated but would potentially lead to different results. Consequently, two sets of analyses were carried out—one with the GSS coefficients and one with the survey's.

This analysis involves calculating the evaluated standard scores of each parameter and then, by adding them together, computing the total standard score which ranges from approximately -3 to +3. The results are presented in table 5.9. Table D.15 at the appendices presents the same analysis with the athletes' questionnaires even though the regression tests described earlier in this chapter showed significance in the 1% level for all but two of the buildings. The results of this second test showed a minor variation in the classification of buildings on the lower ranks.

Name	***GSS Model***				***Survey***			
	Res.	*HUS*	*Techn*	*Total*	*Res.*	*HUS*	*Techn*	*Total*
Co-effic.	*0.59*	*0.26*	*0.15*		*0.42*	*0.32*	*0.26*	
Peristeri	-0.03	0.37	-0.05	**0.29**	-0.02	0.45	-0.08	**0.35**
Mets	0.09	0.09	-0.09	**0.09**	0.07	0.12	-0.16	**0.03**
Hios	0.29	0.17	-0.03	**0.43**	0.21	0.21	-0.06	**0.36**
Patra	-0.27	-0.24	-0.03	**-0.54**	-0.19	-0.30	-0.06	**-0.55**
Rethymno	0.59	0.12	0.10	**0.81**	0.42	0.14	0.18	**0.74**
Loutraki	0.84	0.27	0.05	**1.16**	0.60	0.33	0.08	**1.01**
Posidonio	0.05	-0.17	-0.03	**-0.15**	0.03	-0.21	-0.06	**-0.24**
Galatsi	0.33	-0.10	0.04	**0.27**	0.23	-0.12	0.07	**0.18**
Byron	-0.84	-0.26	0.08	**-1.02**	-0.60	-0.32	0.13	**-0.79**
Arta	-1.05	-0.25	-0.03	**-1.33**	-0.75	-0.30	-0.05	**-1.10**

(*) Using all users replies in HUS and the average operating costs in Rethymno Sportshall.

Table 5.9: Standard Scores of the Overall Analysis

Chapter 6 Discussion of the Findings

6.1. Performance of the Buildings

6.1.1. Peristeri Sportshall

This building is built in Athens and is the first of a series of higher than average quality sportshall buildings. This proves to be its major drawback, since in fear of wear, official teams are the only ones entitled to use the hall. As a result it is not used intensively—in fact it is the building used least out of the whole research sample—ten hours on average, daily. It is the only sportshall of the sample installed with a fully operating summer as well as winter air–conditioning. The rest use mechanical ventilation and conventional heating.

The structural frame is a composite one with large concrete pylons supporting a space framed steel roof which incorporates the only natural lighting of the hall. As a result, lighting costs are relatively high since the lights are on for the whole day. The span, 50 metres, is one of the longest as is the usable floor area (over 5,000 m^2). It was completed at the end of 1988 (a few months over the contract specified date) due to changes in the brief in terms of the air-conditioning systems and has been in constant use since.

Users unanimously rated this hall as the best of the sample, far ahead of the second—the Glulam structured Loutraki sportshall. Peristeri is a clear leader both in terms of HVAC and lighting and on the top three on the other HUS parameters. This justifies the extra cost of the air-conditioning system and shows the effects of an unconventional—for Greece—lighting approach. However, further examining of its cost performance shows that these same factors are responsible for its bad cost rating, seventh out of ten. Peristeri has the second highest capital cost in the sample (after Hios pool) and below average servicing costs following the other two pools (where a substantial amount is spent on the pool related installations). Finally, the very poor rating in technical terms leads to the overall fourth place according to the GSS model of quantification and very close to the third building (Hios) according to the Survey's model—where cost has less impact.

Peristeri is a very good overall performer that could do even better if capital cost and, more important, electricity running costs were lower. However, there is a question mark on whether the extra capital cost involved is justified compared to Rethymno hall which easily outperforms Peristeri on cost and technical issues. The larger than average size of the hall should be considered as an essential advantage against the other constructional systems examined.

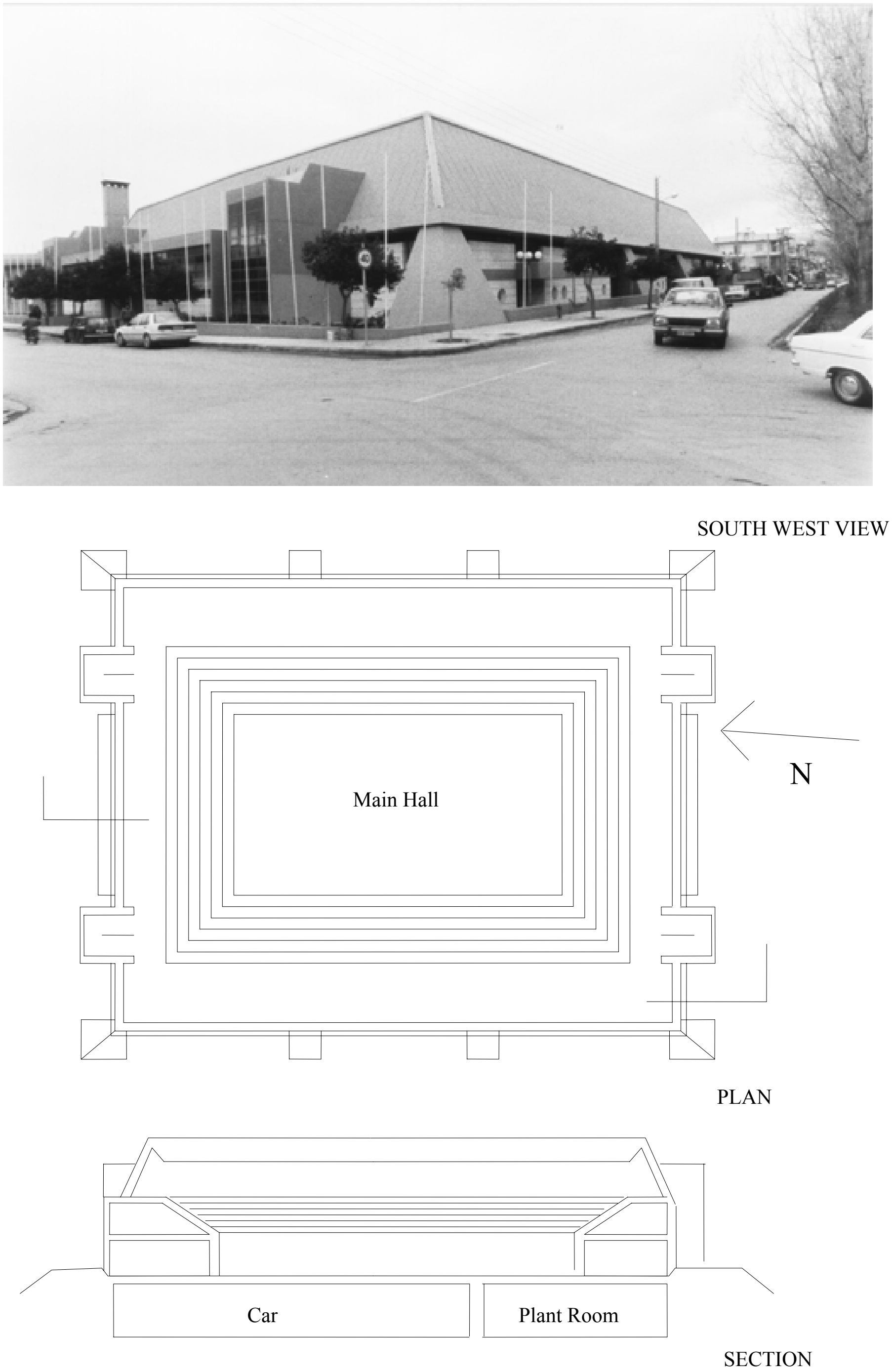


Figure 6.1. Peristeri Sportshall

6.1.2. Mets Sportshall

This sportshall is built in an area of Athens that was lacking a covered hall thus explaining its extensive use—15 hours a day. The site has a slope of approximately 30% and is adjacent to a main road. Therefore, extensive excavation in the solid rock and supportive engineering work was carried out which lasted over a year, having an negative effect on the capital cost.

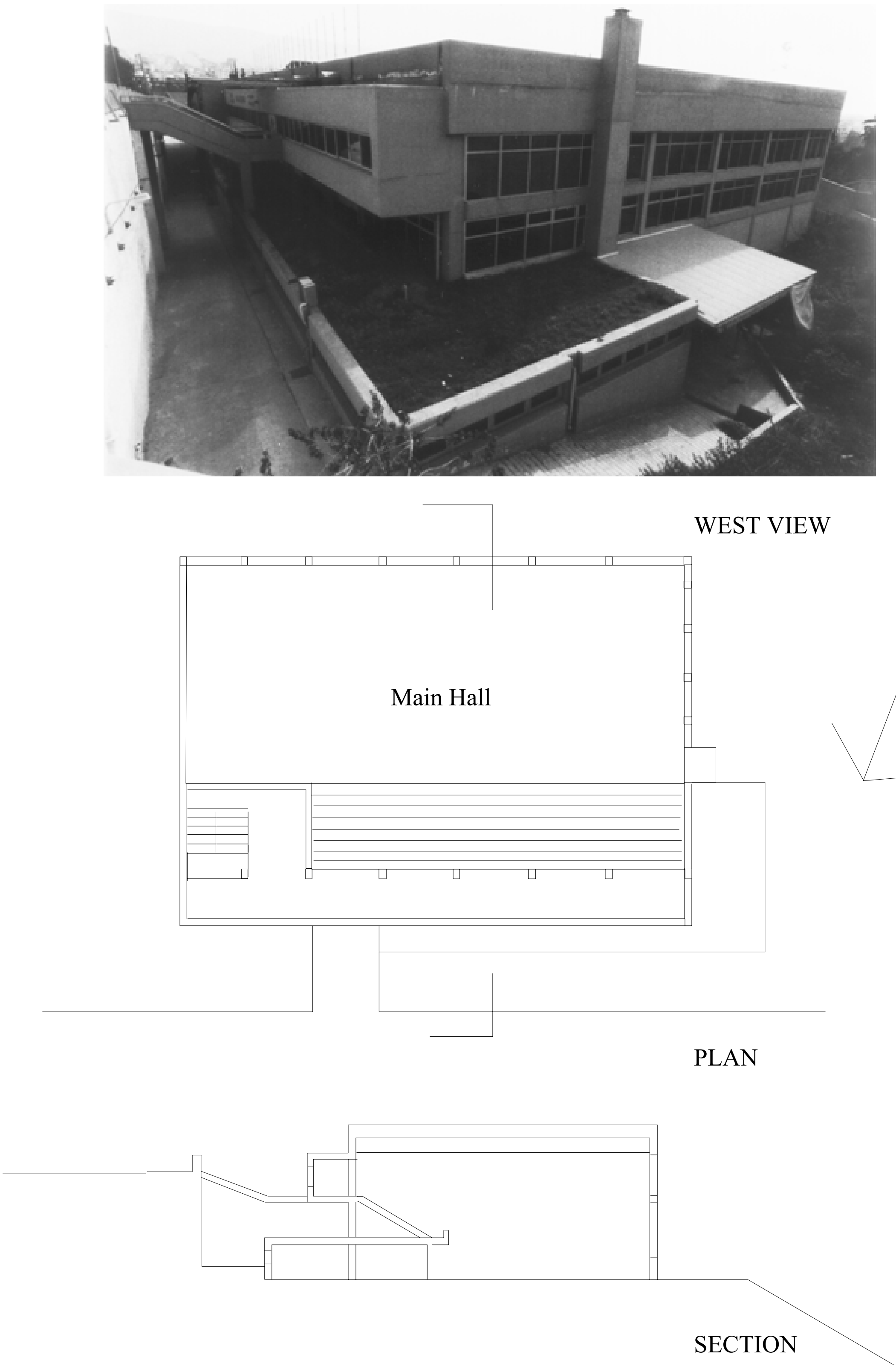


Figure 6.2. Mets Sportshall

The structural frame is reinforced concrete—which is the norm in Greek construction. However, the 34 metres of roof span could not be covered using the techniques applied on housing and office buildings, so prestressed reinforced concrete was used. The technology and the steel bars used where imported thereby increasing the roofing cost to 40% of the whole envelope cost. Half of this amount was spent on insulating and waterproofing the roof—it is the only building that had no problems with water leaks.

Lighting is ample from windows all around the building although there were complaints of glare problems during early afternoon. Heating oil consumption is the highest of the sample while users rated HVAC performance as average; the above imply an old technology or inefficient system. Overall, this building is in very good condition with only minor decoration work carried out on it during its six year life.

Mets' cost performance is average—the two main pitfalls being the roofing capital cost and the heating running costs. As far as HUS is concerned, Mets' performance is also average, with an exceptionally good rating in acoustics and aesthetics whereas HVAC and lighting is fair. In technical terms, it is the worst performer; the prestressed reinforced concrete techniques and the imported insulation and waterproofing of the roof being the main reasons. Following this analysis it is in sixth place overall.

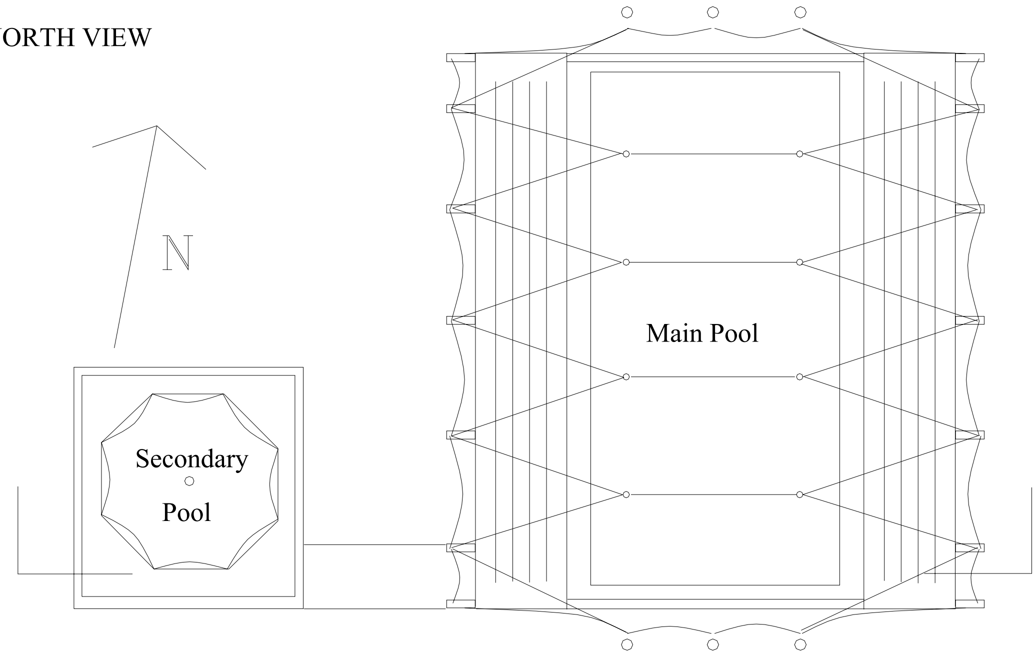
6.1.3. Hios Swimming Pool

This swimming pool is built on a remote island renowned for water sports. It is the second biggest building of the sample following Peristeri both in terms of capital cost and usable floor area. Its high-tech double skin tent is highly admired by the engineering world and especially GSS staff. The whole tent is tensioned by two rows of three columns, while it is attached on the perimetrical concrete structure of the seating and foundation in order to create the double curvature needed for structural stability. The span is the largest of the sample, 60 metres, showing the potential of the constructional system and covering material.

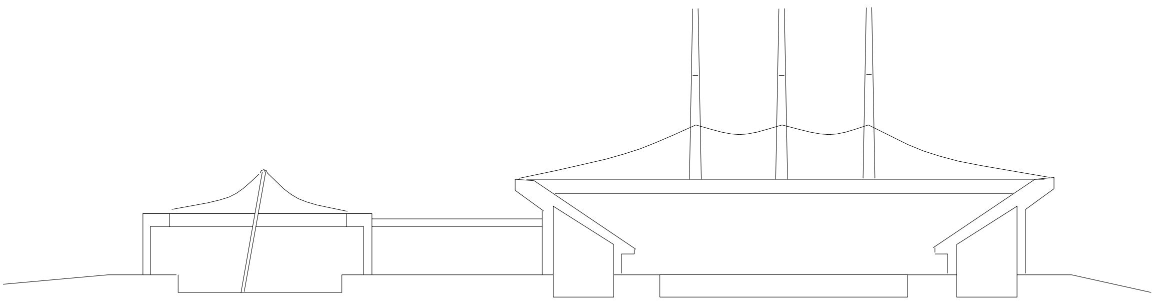
The tent itself, made of PVC coated polyester fabric, was imported from Italy and cost one third of the envelope capital cost. The life of this fabric tent is approximately 20 years (O'Brien et al, 1980). However, examining the two other tent covered pools of the sample, Patra and Posidonio, it is apparent that this estimate is optimistic. Therefore, it was decided to calculate the life expectancy of the tent as 15 years which imposes another substantial expense in the middle of the expected life of the building.

Lighting, in theory, is not a problem as this tent is translucent and additional windows are provided on two sides. However, users rated this building just below average in terms of lighting, as they did on acoustics. Function and aesthetics were above average with HVAC figures being exceptionally high. This can be explained from the quality of the relevant installations and the double skin tent that enables the circulation of hot air between the two skins, creating an insulating cushion during the winter. In the summer, parts of the cover can be removed improving ventilation. The overall HUS performance of Hios was very good in third place. It is interesting to note the results of the correlation tests between the athletes' and spectators' opinions. This was the second lowest of the sample highlighting the different perspective of these two groups (Table 5.4.).

NORTH VIEW



PLAN



SECTION

Figure 6.3. Hios Swimming Pool

As far as the technical variable is concerned, Hios was below average—unsurprising considering the cost of the roof and the imported technology and materials as well as complexity of the structure. In cost terms, the highest capital costs (per m^2) and the 40 days of annual repair led to a better than average rating. Overall the building was in third place, close to the fourth place Peristeri sportshall.

The proximity of this swimming pool to an Electricity Power station—just over a kilometre—led to the installation of pipes bringing hot water from cooling the generators to be used for the hot water needs. Although a complete year's data were not available, the managing committee reported an estimated reduction in heating expenses in the region of 30%. The research is based on the full years' data prior to this installation since the later were an estimation (at the time of the data collection) and could lead to inaccurate calculations.

6.1.4. Patra Swimming Pool

This swimming pool together with Posidonio was built in 1985. Both of them were coverings of existing swimming pools. This explains their relatively low capital cost although certain parts of the surrounding and seating was constructed then. The lack of other covered pools in the city of Patra reflects on the daily use which is the highest of the sample; 18 hours.

The covering is a polyester fabric coated with PVC and is supported on arched steel trusses in contrast to the self supported Hios tent. The whole design is very simple and easy to dismantle and—theoretically—reassemble if such a need arises. In practice, the managing committee doesn't even open the side 'windows' during the summer for ventilation. The reason being that the joints and their details are designed in a way that makes them difficult to operate or even dangerous for the staff. The whole design is French and the steel trusses, fabric tent, ropes etc. were imported. The fabric, which is in stripes of white and red, has been affected by the sun to an extent that it is difficult to identify its colour—it has all become grey accompanied by a reduction in its translucency.

A problem that became apparent in the last two years is the failure of many ropes securing the tent. As a consequence, most of them have been replaced, a process involving a high cost. Additionally the fabric tent needs replacement soon, since lack of heating and proper ventilation of the pool resulted in fungus and mould badly affecting the tent fabric. Finally heating consumption is quite high which is expected in a pool compared to sportshalls (but similar to the other swimming pools examined).

Accordingly, cost performance is poor—the only strong point about it is the low capital costs. HUS performance is among the worst of the sample; the almost identical Posidonio pool—which is maintained better—ranks higher. The condition of the building's interior and mainly the changing rooms and installations take an important role in this deviation which is reflected in the worst score in aesthetics and acoustics also.

In terms of technical performance, the imported structure, with no available spare parts, was major contributor to the bad score. The only positive issue was the extensive prefabrication which facilitated the fast erection (the small size and the existing infrastructure should be considered also). Overall, this swimming pool was rated eighth.

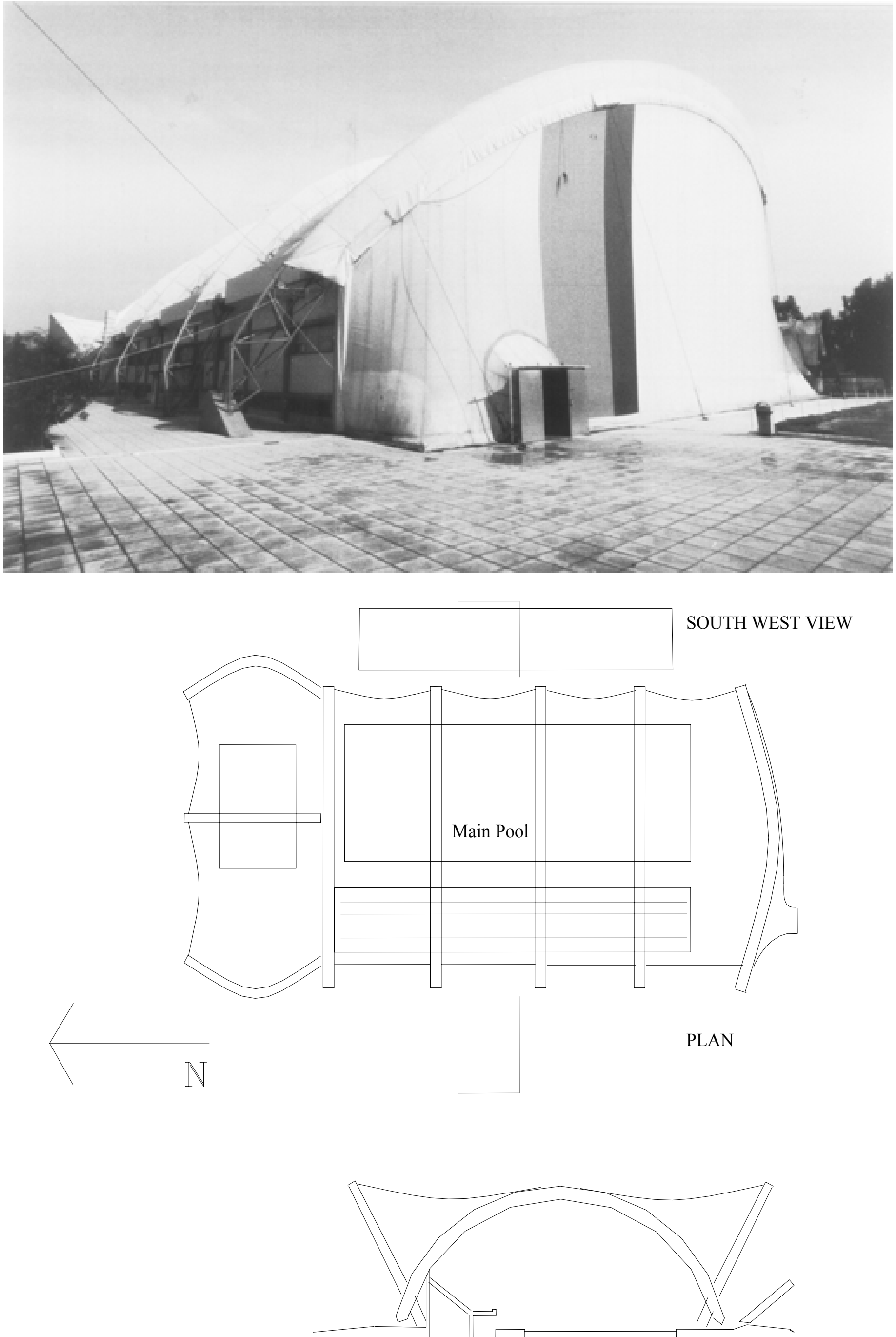
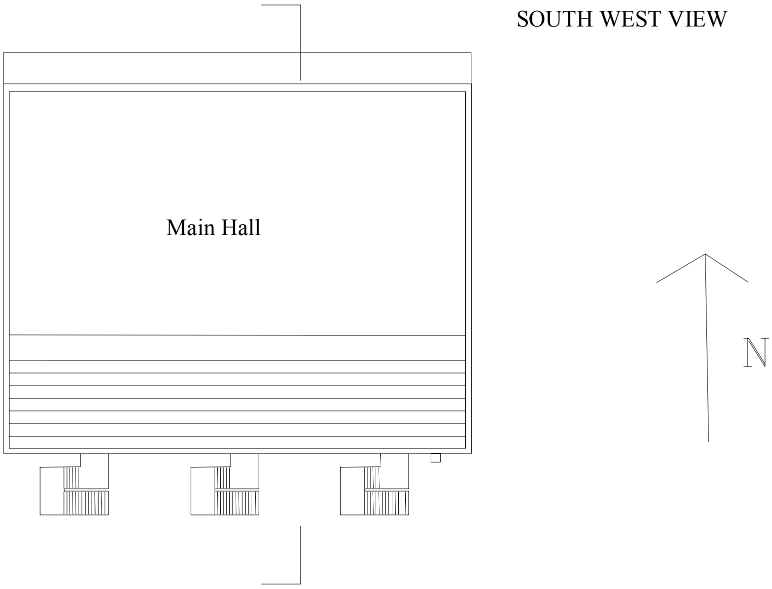


Figure 6.4. Patra Swimming Pool

6.1.5. Rethymno Sportshall

SOUTH WEST VIEW



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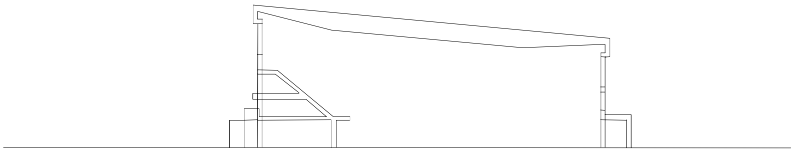

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Figure 6.5. Rethymno Sportshall

This is the newest building in this research—included as a representative of a new series of halls designed by the GSS under the code name T8. These are larger and better equipped than the previous T4 halls, aiming to improve the conditions under which athletes train and provide each city with at least one international specification sportshall. This follows the first objective—set more than ten years ago—to provide every city with indoors facilities. The actual frame concept is quite close to the older T4 series (for which Byron is a representative example) keeping the same structural material; steel. The foundation, seating, columns and perimeter beam are made out of reinforced concrete. The structural beams are inclined inverted trusses spanning over 41 metres. There is ample lighting from the windows on the two long sides of the building, especially on the north, and no rooflighting.

In terms of cost performance, Rethymno was in the second place of the overall cost analysis. Roofing costs were approximately 25% of the total capital cost which is a low figure for a sportshall. Furthermore, all materials were produced locally. The structural frame was not as complex as in other buildings of the sample and the spares availability was very good. All these facts resulted in the best building in technical terms.

However, the HUS performance of Rethymno was just above average. HVAC was rated high—it should be considered that the hall had not completed a year of operation; it opened in spring of 1992. Rating in terms of functionality was very high possibly due to efficient implementation of the knowledge and experience of the GSS personnel on dealing with problems related to movement, seating, changing rooms arrangement and layout, etc. Lighting and aesthetics are in the middle of the scale, with athletes rating the lighting better than the spectators. Compared to the Peristeri, Mets and other halls, artificial lighting is a conservative as well as an economical solution, featuring incandescent lamps and not high intensity discharge (HID) ones. Acoustics were poor although no particular problem was identified during the observation (there were three more buildings scoring poorly on this particular issue). Summarising, Rethymno is rated as the second building overall after Loutraki and ahead of Hios.

6.1.6. Loutraki Sportshall

Built in a small city thirty kilometres to the west of Athens, this hall is, considering the small population of the area, at a low level of utilisation. It is the second least used sportshall; on average 12 hours a day. The structural material used is glue-laminated timber, forming both the beams and columns of the structure. The three–pinned portal frames used span just under 40 metres. Their structure enables the incorporation of rooflights, made out of a specially imported synthetic material, "*isobelek*". The north facing windows improve natural lighting, both quantitatively and qualitatively. Another advantage of this structure is the low cost of the roofing (structure and covering)—less than 25% of the total capital cost.

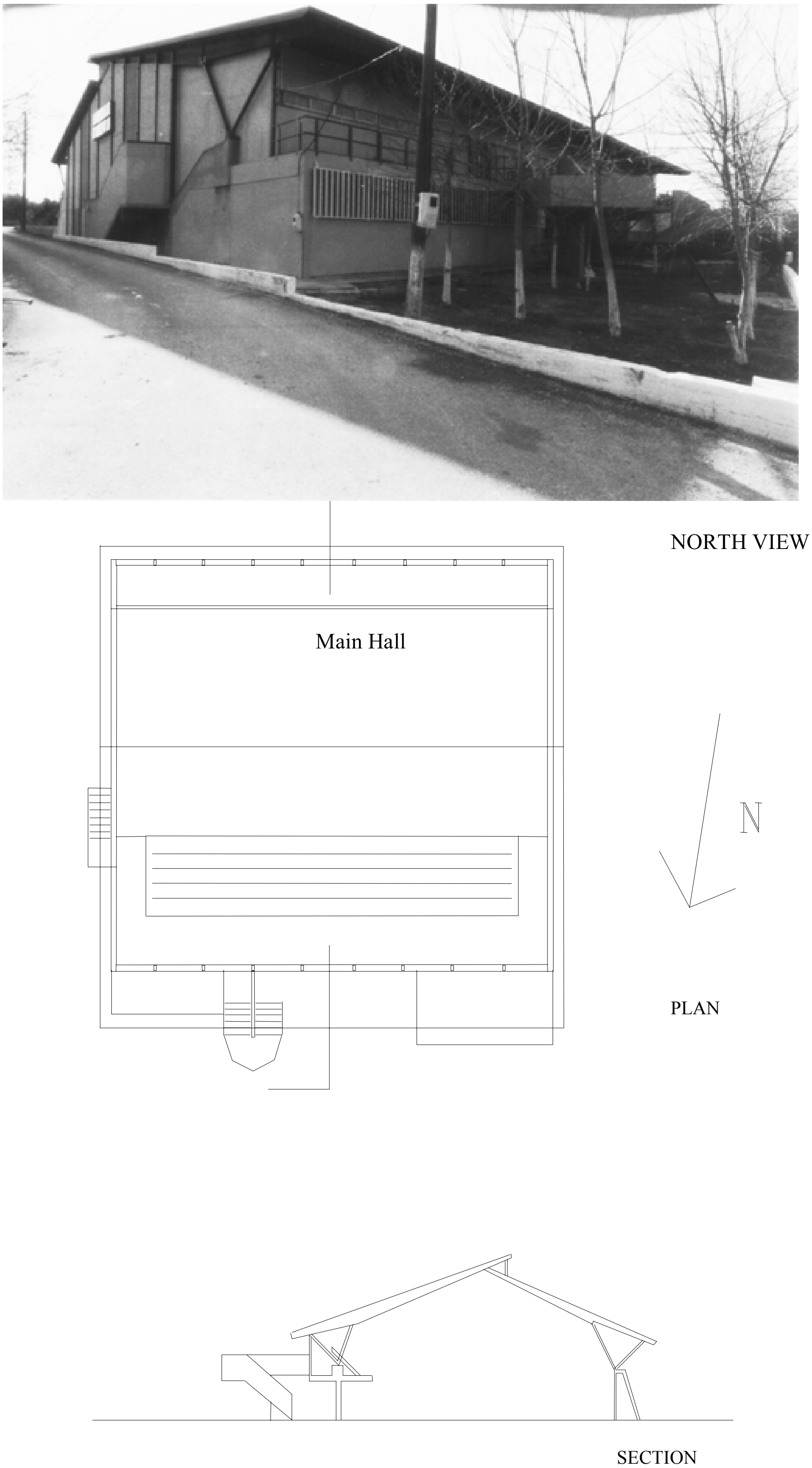


Figure 6.6. Loutraki Sportshall

Loutraki is the only building of the research sample installed with solar collectors for hot water production, reflected in the lowest energy cost figures encountered. The rest of the running costs are very low, especially personnel salaries—there are only two full time members of staff working in cleaning, maintaining and securing the building. Furthermore, the capital costs are among the lowest, leading to a clear lead over the second performing hall (Rethymno).

Users and athletes opinions show the excellent performance of this hall in terms of functionality and aesthetics. This hall has the best kept changing rooms and facilities for the users in the whole sample. Lighting and acoustics performance is very good, reflecting the properties of timber as a structural material (acoustics) and the results of efficient and well designed rooflighting. However, in terms of HVAC, Loutraki is just above average although the personal observation didn't highlight any problems. Ventilation is good from roof mounted fans and remote controlled roof windows. The only problem that could have caused the low HVAC rating is the heating, where the hot air outlets are incorporated in the flooring around the sports terrain. The problem arises through the use of a plastic mat covering all the non-active part of the parquet in order to preserve it. By doing so, these outlets are partially blocked detracting from the proper operation of the system. The overall HUS rating in second place, is satisfactory leaving heating as the only issue that would benefit a redesign.

As far as technical performance is concerned, the very good spares availability, the fair complexity, the high level of prefabrication and the locality of the structural materials used led to the third place, following the two GSS designed steel framed buildings T8 and T4. Concluding, Loutraki is the overall leader of this analysis, ahead of Rethymno sportshall.

6.1.7. Posidonio Swimming Pool

This is the only building that, apart from minor functional details, is identical to another one that has been analysed already—Patra. The reasons for including both these buildings was to enable an investigation of the ethnographic elements in the users sample, test the research methodology and examine variations in the overall state of constructional systems under different climate and management conditions. This pool was built in 1985, by the same company, in similar environment—by the sea-shore. Posidonio is, however, built in a much colder area in Salonika, approximately 500km north of Patra where the weather, and especially the strong and cold wind, is a serious consideration during the winter.

The description of this pool focuses on the differences from the Patra one. These are mainly in one issue; maintenance. The funds available for maintaining this pool are larger and this reflects on the better condition of the tent itself and the changing rooms and installations. Heating and ventilation are used regularly—not only in official games as is the case in Patra—resulting in less fungus and decay of the tent.

Consequently it outperforms Patra in cost, HUS and overall. Technical performance is equal (as the two buildings are identical). In terms of cost, Posidonio is slightly better, mainly because of the lower salaries, running costs and the—by far—shorter duration of annual maintenance period, ten instead of fifty days; that is when the building is not available to the users. However, heating consumption is the highest of the sample.

Following discussions with the managing committee, it was found that the cold weather is the main cause. The annual heating costs since 1986 reflected clearly the fluctuations in

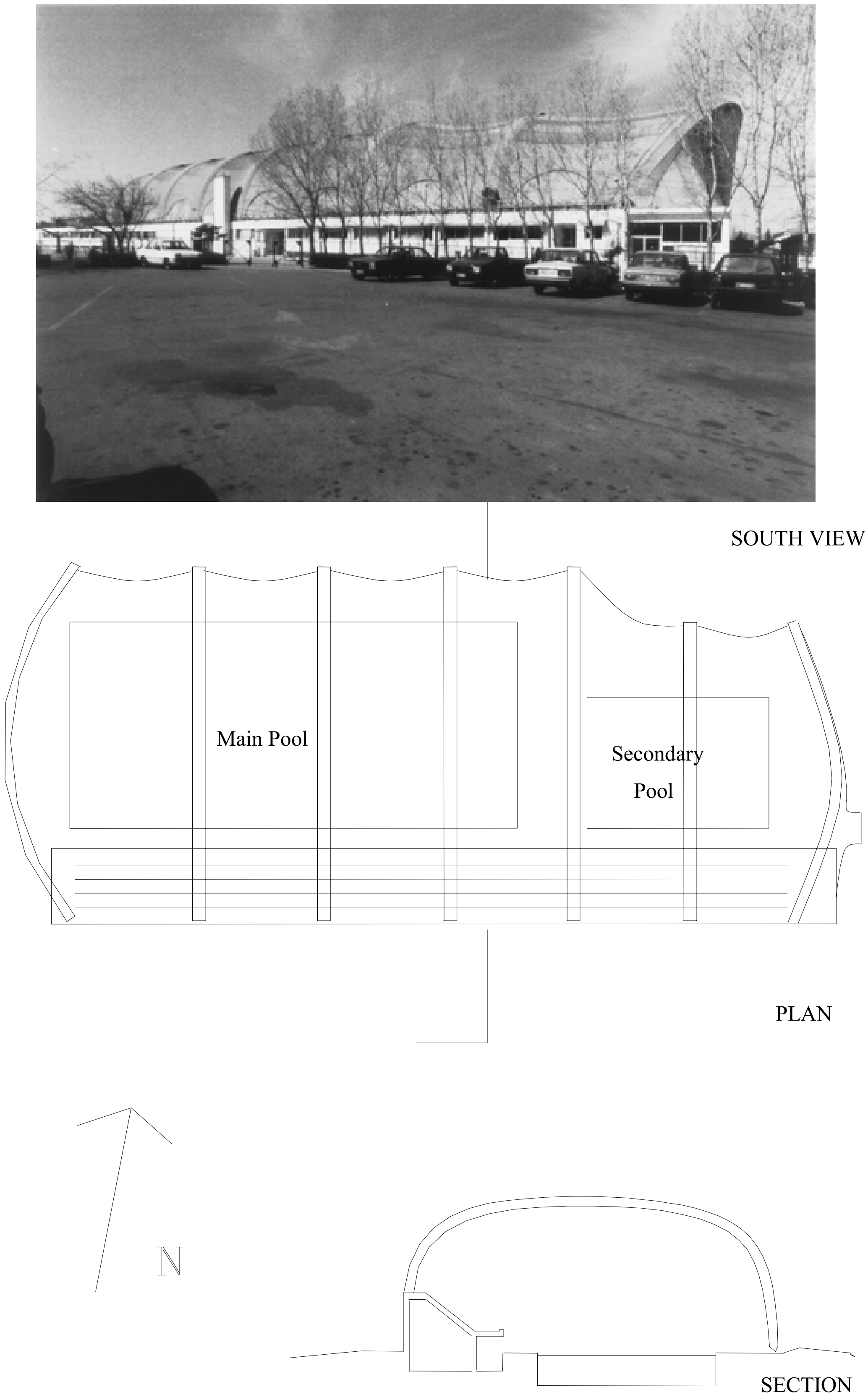


Figure 6.7. Posidonio Swimming Pool

temperature (in particular the extremely cold winter of 1987). The result is a building with running costs marginally lower than Patra, due to better utilisation of the available funds, reflecting the theory that a well serviced building is cheaper in the long run.

As far as HUS is concerned, functionality and aesthetics rating is similarly low for both buildings. In terms of HVAC and acoustics Posidonio is marginally better rated. This is mainly caused by the better overall condition of the building as well as the ventilation and heating. Lighting performance is an exception—it is in the third place together with the other tent Hios. The reason being the better condition of the fabric. (Maybe self cleaned by the strong winds as well as the lower solar radiation). Finally this pool is rated in the seventh place out of ten—just in front of the identical Patra Swimming Pool.

6.1.8. Galatsi Sportshall

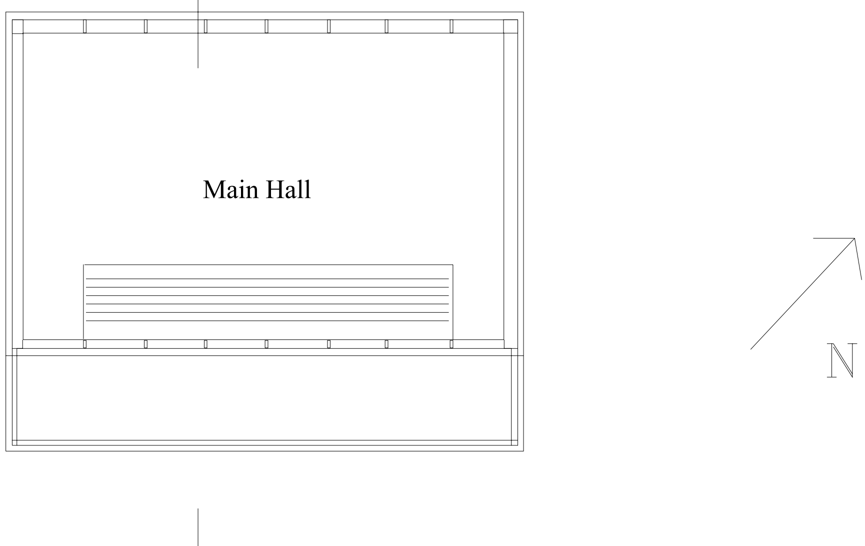
This is the second timber framed building of the sample, using the same techniques as the Loutraki hall. It is one of the older buildings and the shortest spanning one—just 24 metres. It is also the smallest building overall in terms of usable floor area. The designing group is the same as in Loutraki and this is a representative example of their work although during the late 80s objectives changed and spans increased substantially. In contrast to the steel framed buildings, this construction is exclusively out of Glu-lam and timber; reinforced concrete is used in the foundations (sub-structure) only.

It belongs to the batch of buildings built following the previous GSS objectives in terms of size, usage and span (see Chapter Three) and, therefore, is more comparable to the Mets, Byron and Arta sportshalls than their larger counterparts. The building is a very simple structure with Glulam beams running across the 24 metres creating a fixed portal frame.

There is no rooflighting incorporated in the structure—unlike Loutraki—and the translucent synthetic material "*Isobelek*", used in the side windows, has been badly affected by ultra-violet radiation. As a result, the south facing windows are almost black, having a negative effect on aesthetics. The HUS performance of the hall reflects the above mentioned issues scoring poorly on acoustics, aesthetics and lighting. HVAC and functionality are average reflecting the overall impression of the researcher—a dull and un-inspiring hall. Overall, in HUS terms the hall is rated sixth by both users and athletes.

As far as cost is concerned, the low capital cost plus the less than average running costs lead to the third place overall; its standard score is closer to the average halls than to the top two. Technical performance was satisfactory; materials locally produced, average complexity of the construction and good availability of spares. The overall evaluation of the building was average—in fifth place—that would benefit from a better designed lighting system and colours schemes.

NORTH EAST VIEW



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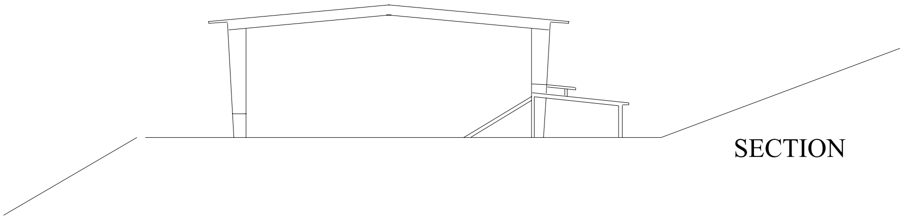

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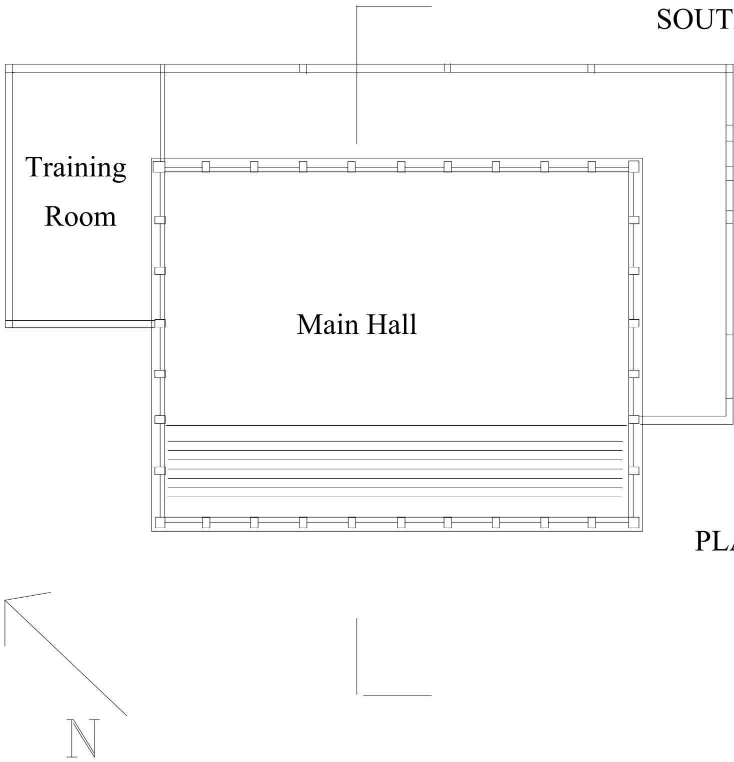
Figure 6.8. Galatsi Sportshall

6.1.9. Byron Sportshall

This sportshall (or precisely "training hall") carrying the GSS design code T4, is the second oldest as well as the smallest building of the sample. Built in a northern suburb of Athens, it is one of a series of similar halls—approximately twenty halls constructed until the mid 80's—selected due to availability of research related construction as well as in–use data from the GSS. The structural frame of the roof is steel trusses spanning thirty metres supported on a reinforced concrete sub- and super-structure. The construction duration was one of the longest in the sample due to soil problems. Half the building is on solid rock and the rest on approximately 25 metres deep gravel and loose ground. Consequently, extensive excavations were carried out until sound ground for the foundation was reached which delayed the construction considerably (over a year).

The cost related performance of the hall is the second poorest of the sample. The main reason is the high capital cost and, most important, the second highest operational costs—30 to 40% higher than the swimming pools—as well as the fifteen days of annual maintenance duration. The very low energy running costs could not improve the overall ranking. HUS performance is similarly poor; the worst according to the users, whereas athletes rated it eighth. Users unanimously rated Byron as the worst building in terms of HVAC and functionality. Serious heating problems were reported by the managing committee. The ventilating system is of limited power with 5 small fans mounted on the top of the window panels only. Lighting was rated as very poor, possibly due to the unusual east–west orientation of the windows combined with the lack of rooflighting and the dense surrounding trees (it seems that spectators are more annoyed than the users.) Finally, aesthetics is the strongest point of this hall—just below average—explained by the extensive redecoration and repair work carried out in 1990-91, in view of hosting an international event. Bearing in mind the simplicity, locality of resources and very good availability of spares, this hall was rated as the second best performing one in technical terms. However, those factors were not enough to improve its ninth position overall.

SOUTH VIEW



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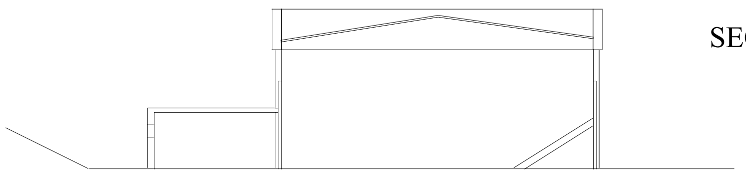

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Figure 6.9. Byron Sportshall

6.1.10. Arta Sportshall

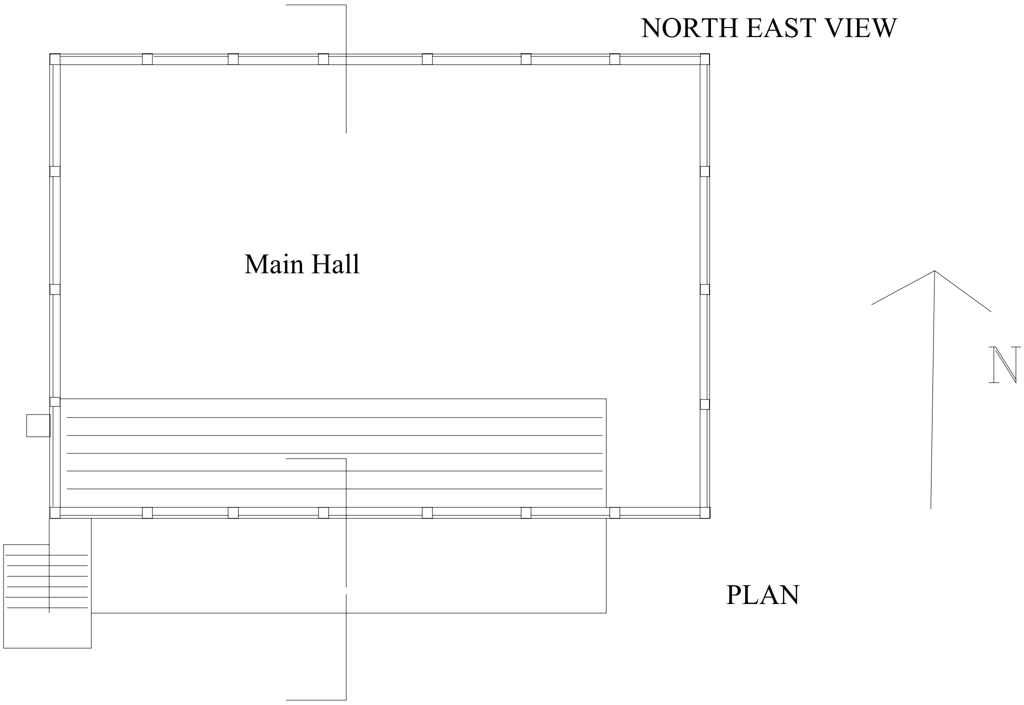
Arta sportshall is the oldest buildings of the sample. Built in 1977-1978 in central Greece and spanning 42 metres, its roof was designed and erected by the German firm MERO. This is a patented space framed system with spherical nodes and specially designed members. The whole roof construction was carried out by a highly specialised German team. The cost of the roofing structure was relatively low compared to the rest of the sample, bearing in mind the size of the hall, at 20% of the overall capital cost. In this building the foundations, columns and the substantial perimetrical beam (2.5 metres deep) were made in-situ out of reinforced concrete by a local contractor.

Structurally, the roof has no problems at all; 14 years after erection and there is not even need for repainting of the structural frame. However, the actual covering and waterproofing have failed repeatedly leading to extensive unsuccessful repairs wrongly designed and/or executed. The main problem is the minimal slope of the roof. As a result there are serious problems of decay and mould in the walls (especially in the changing rooms) as well as the roof. Another problem observed is cleaning the windows. In order to overcome glare–related problems, the designer specified very high–mounted windows which are extremely difficult to clean and, as the personnel explained, they have to set up a whole scaffolding system. The result is that the windows are usually dirty reducing the amount of light and, since there is no rooflighting, the lighting is—partially—on for the whole day. Users rated this hall as the worst of the sample together with Byron hall except for aesthetics and acoustics where Patra, and to a lesser extent Posidonio, were considered as even worse. The heating is used during official games only (as reported by the committee) whereas the ventilation is carried out from only two fans which are insufficient during summer. As a result, windows and doors are opened to improve air circulation causing more problems of lighting, glare etc. The lighting is inappropriate, using fluorescent lamps instead of more powerful ones.

The correlation between the athletes and spectators opinions were the lowest of the sample highlighting the different perspectives of the these two groups (Table 5.4).

In cost terms, analysis showed poor performance especially in terms of operating costs and annual duration of maintenance—fifteen days—longer than Posidonio swimming pool where most of this time is spent in maintaining the pool–related electromechanical installations. Finally, bearing in mind the availability of spares and complexity of the structure as well as its cost and size, the technical performance is average—fifth place. The overall performance of the hall is the lowest of the whole research sample.

NORTH EAST VIEW



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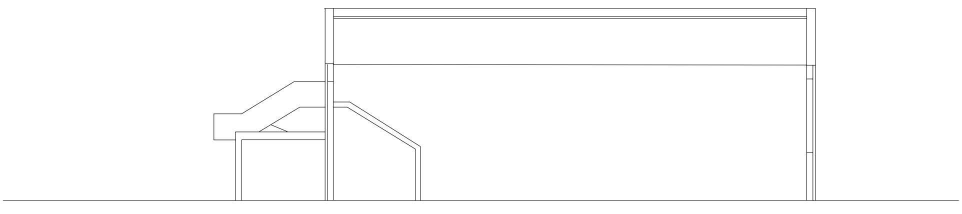

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Figure 6.10. Arta Sportshall

6.2. Performance of the Research Variables

6.2.1. Cost and Time

Capital Costs

Two main categories of buildings according to the capital costs per m^2 clearly emerge from this study. The majority of the buildings in the sample are in the 25-35 thousand drachmas per m^2 range (in 1985 constant prices). The rest are in the 50-60 thousand range which is expected in the Peristeri and Hios case but is unacceptable for Byron and Arta which have none of the features that justify the higher capital costs of the first two (high tech steel space frame, fully air-conditioned or double skin tent with highly specialised labourers). Byron and Arta high capital costs are due to the lower know how and less advanced constructional techniques and facilities available 15 years ago (Kalogeras, 1974).

In the above mentioned classification, pools' high capital costs were expected due to the pool related M&E installations but Patra and Posidonio were just coverings of existing pools and, therefore, do not bear capital costs to the same extent. On the other hand, the fully air–conditioned Peristeri has the second highest capital costs—eight thousand drachmas per m^2 alone were for the HVAC related electromechanical installations.

Examining the roofing cost per m^2 in relation to the envelope capital cost revealed that, for Hios double skin tent, Peristeri space frame and Mets prestressed concrete, roofing costs are almost half their respective total envelope costs. The remaining buildings of the sample, rate roofing costs at approximately one fourth of the envelope costs. It should be stressed that the above capital cost analysis is not a stand-alone representative of the overall cost performance of the building sample—Hios is a striking example being worst in capital and roofing costs and fourth in overall present value calculations—further consideration of running and periodic costs follows.

Annual Costs

The three main ingredients of annual costs are the operational, energy and maintenance costs.

An issue that clearly affected the **operational** performance of the buildings was the number of employees. As an example, Arta, one of the smallest buildings, had the highest number of employees (7 plus management), even higher than buildings triple its size. There was no reason or explanation given by the managing committee (the GSS cannot interfere in the management of a building after the local authorities take over). The opposite is true in Loutraki where two full-time employees and a part timer are responsible for the maintenance and day to day operation of the hall. Compared to an average of four to six employees per building, this number is very low even taking into consideration the relatively non-intensive use of this particular sportshall (12 hours daily).

Consumables, the other operational cost parameter measured, was fairly constant throughout the sample with two exceptions; Patra pool and Arta. The former could be explained as an inability to exclude the cost of pool-related chemicals, etc.—although the managing committee's clerk that supplied the data was asked to specify whether these are included. The latter has no apparent reason and is constant for the period 1988-91 that data were collected.

Energy expenses are markedly higher in pools than in halls due to the need for circulating, cleaning, filtering and, mostly, heating the water which are all energy consuming. However, it was not possible to exclude the electricity or oil costs related to cleaning and heating the pool water. The higher ranked Hios pool, compared to the other pools in the sample, demonstrated slightly better cost performance and very good HUS due to improved design and implementation of contemporary technology. The concrete Mets hall had exceptionally high energy consumption, particularly oil. The literature and the personal observation did not point out any particular pitfalls for concrete structures. On the contrary, bearing in mind the highly specified roof insulation and the thermal properties of the material, it would be expected to prove fairly economical against the simple panels and steel cladding used in many of the competition. Therefore, the poor energy consumption of Mets must be caused by a faulty and/or inefficient heating system.

Finally, another issue highlighting the difference between pools and halls is the **annual maintenance duration** of the buildings. Usually halls are not shut for maintenance and cleaning as happens with pools; all repairs are carried out in off–peak hours of use (usually in the mornings). In all pools up to over a month per year is spent in repairing the electro-mechanical installations.

Exceptional cases are the two very old sportshalls of the sample, Byron and Arta, where 10 and 15 days respectively are spent annually on maintenance. It was not possible to retrieve data old enough to certify whether this was the case since the construction of the halls, therefore, the figures used in the analysis could be misleading. However, these two halls are in a league of their own; even with more optimistic (favourable) values in annual maintenance duration, they would still be the worst performers of the sample.

Periodic Costs

As explained in the previous chapter, these affect tent based constructions more than the other systems examined. The analysis carried out, led to the identification of two "periodic refurbishment" (at year ten and twenty) for each building plus one substantial for the tents' fabric replacement at the middle of their predicted life. This decision was supported by the fact that no other expenses great enough to interfere with the overall costs analyses were identified in the field work.

6.2.2. Human User Satisfaction

HVAC

The heating, ventilation and air–conditioning performance of the building sample showed two main approaches, the conservative one (oil burning heating using radiators, mechanical ventilation and no air–conditioning or summer cooling) and the more up to date (again oil burning heating but using hot air via ducts, mechanical ventilation and air–conditioning). Peristeri, a fully air-conditioned example, though cumbersome to operate (a specialised engineer is needed for its operation) and expensive to run showed a great advantage over the mechanically ventilated halls. The summer cooling received "full marks" from the users and personnel. Natural ventilation proved insufficient in most other buildings except the high tech Hios double skin tent and, to a lesser extent, in Rethymno.

On the other hand, Hios double skin tent installations are much easier to use; pumping hot air in the tent created ducts during the winter and folding up during the summer to improve natural ventilation. Hence, the very good comments and the excellent HVAC rating in the research. Hios is an example of the improved ventilation possible on the tent covered halls where modifications in the envelope are enhanced by the loadbearing material. That is especially true when a highly reflective and low absorption exterior fabric (minimising heat gain) is combined with a low reflective and highly absorption inner layer fabric that maximises solar gain (Taleb, 1988). It clearly demonstrates the consequences of the design faults apparent in the Patra and Posidonio tents that prevent the proper use of the building.

The above average HUS performance of the two Glulam halls agrees with Touliatos' (Scientific Seminar on Long Span Structures, Greece 1990) and Loizos' (1948) statements that, generally, wood is a material closer to human mentality. Especially in the case of Galatsi, heating is carried out by three small (compared to the other buildings of the sample) heaters on the west side of the hall and is still very successful. However, the small size of the hall should be considered also. Additionally, the two Glu-lam buildings were the ones that faced no problem at all with condensation in the changing rooms and toilets. A possible reason is the natural properties of the material and the lack of condensation-prone materials.

Loutraki and Byron halls use floor mounted heating radiators leading to serious problems with blocking them (using protective mats) and litter falling through the grilles. The latter being more of a hygiene issue when the heating is turned on and the accumulated litter starts disintegrating. The whole issue in Byron was serious enough for a complete redesign of the radiators into wall mounted ones. The latter addressed a new problem in terms of athletes' safety as the radiators protrude from the walls—no provision for special "pockets" in the walls found in other buildings of the sample. In Loutraki's case, the actual heating devices are not under–floor leading to easier cleaning and reduced hygiene problems. Arta employs a similar system where there is no parquet floor to protect and, consequently, block the floor mounted heating ducts. However, bearing in mind that the system is used in official games only, no problems and complaints were reported.

Summarising, natural ventilation should be designed very carefully in order to be effective in the high temperatures prevalent during the summer. Many of the halls analysed used three to five fans for the ventilation which, as the questionnaire replies show, are not sufficient. An intermediate solution should be found so that the great capital cost of a fully air-conditioned building would not be prerequisite. Similarly, heating was implemented successfully in most buildings, the issues that should be considered in future designs are the environmental, passive energy design since the climatic conditions are appropriate (Stoll et al, 1987).

Lighting

The buildings of the research sample featured three different types of lighting; natural, artificial and translucent tent–based lighting. The **naturally lit** buildings (Mets, Arta, Rethymno, Galatsi and Byron), with windows mainly on north and south and no rooflighting, are rated very low from the athletes (and slightly better from the spectators). The only exception is Byron, where high trees surround the hall preventing direct light entering—athletes rated it better than the spectators.

Although the questions set in the questionnaire explicitly focused on the natural lighting of the halls, in certain cases the replies were more likely affected substantially by the artificial lighting. This was clearly demonstrated in Peristeri sportshall, whose commanding lead was due to an almost exclusively **artificial** lighting system with minute rooflights and no side windows. However, this extreme solution bears a negative impact on electricity running costs. (An overall weighting of its pros and cons needs further investigation.)

Loutraki hall cannot be included in the same category, since it relies heavily on north facing rooflights together with the more conventional north windows. However, performance wise it is much closer to Peristeri than to the rest of the naturally lit buildings. This shows the advantage of the indirect lighting of such spaces as stated by Faulkner-Brown (1973).

Tents, are average performers with Posidonio, according to the users, in the third place and the other two in fifth and sixth places. The HUS analysis that included all users' replies showed a considerable deviation from the athletes only. A possible explanation is that spectators, being on a higher level and looking downwards, are not affected by glare from the tent, whereas athletes, being at the lowest level and looking upwards, are highly disturbed. Thus, it is more appropriate to consider the athletes' opinions in the analysis. Similar opinions were expressed by Perrin (1981) regarding translucent domes which present the same annoying effects of glare when the athletes are looking upwards especially to a white ball such as in water polo.

A reason that, in the researcher's opinion, explains tents' variation in lighting performance is the transparency of the fabric. Hios is the newest and most transparent tent, causing more problems to the athletes (especially due to the low reflective high absorption inner layer), whereas Patra, due to bad ageing of the fabric, is not letting enough light through. Posidonio, which is identical to Patra but in far better condition, has the most favourable light transmission rate, getting the best score of the three.

Table 6.1 compares the lighting performance of the buildings to the size and orientation of the windows and investigates whether a relationship between them exists. This analysis demonstrates that direct sunlight is a definite disadvantage since light intensity is high and glare occurs. North facing rooflights and the elimination of side windows (with the possible exception of north facing ones) is a well performing solution. As Walter (1971) argues:

> '*This whole attitude towards glazing is a subject urgently in need of scientific review. There may be a modicum of truth in the belief that some architects seek some visual link in their designs with the external environment beyond the four walls; but in the context of sportshalls this is highly undesirable, and even more so in the case of swimming pools...*'

Buildings	*North*	*East*	*South*	*West*	*Roof*	*Usg*	*Artif.*	*Users*	*Athlt.*
Peristeri	n/a	n/a	n/a	n/a	2.25	10	allday	2.60	2.74
Mets	2.33	4.76	8.98	4.44	n/a	15	17:00	-0.24	-0.67
Hios	0.82	n/a	0.82	n/a	tent	15	17:30	0.08	-0.41
Patra	n/a	6.66	n/a	n/a	tent	18	17:00	-0.46	-0.34
Rethymno	3.60	n/a	5.62	n/a	n/a	15	17:00	0.04	-0.25
Loutraki	~9.00	n/a	n/a	n/a	~3.50	12	17:00	0.24	0.08
Posidonio	n/a	6.57	n/a	n/a	tent	18	17:15	0.08	0.05
Galatsi	10.06	11.48	10.06	19.68	n/a	16	17:00	-0.57	-0.54
Byron	n/a	6.17	n/a	6.17	n/a	14	17:00	-0.80	-0.44
Arta	8.31	n/a	2.25	n/a	n/a	16	partly	-0.96	-0.82

(*) All Values are m^2 of window area as percentages over the Usable Floor Area except for:

Usage, measured in daily average use of the buildings

Artificial lighting (Art.), time lights are turned on in the first week of February.

Users' and Athletes' scores, measured in Standard scores.

Table 6.1. Lighting Performance of the Building Sample

Acoustics

In analysing the acoustics performance of the research sample no clear pattern emerges, suggesting no particular constructional system as exceptionally good. The fact that six buildings are rated as poor (Hios, Rethymno, Posidonio, Galatsi, Byron and Arta) could imply that the questions set were not fully understood by the users and so the responses were affected by the overall performance of each building (Smith 1975, Christie et al 1970). These six buildings include almost all constructional systems used (except for the prestressed reinforced concrete) as well as all flooring systems, finishes etc.

As Konya (1986) argues, the following parameters should be considered in the design of sportshalls and swimming pools:

- layout of building minimising nuisance from noisy areas
- 45dB reduction between noisy and other spaces
- short reverbation time in each space
- sound absorbent materials impervious to moisture
- installation of machinery likely to create problems on floating or resilient mountings.

Examining the sample of this particular research, no explicit provision was found for most of the above mentioned issues. This was especially true in the ceilings which are, as Perrin (1980) explains, the main area for acoustic control of such buildings.

Bearing in mind the above, the poor performance of tents and simple steel structures is demonstrated, providing an explanation for the better rating of the space framed Peristeri roof and the deep Glu-lam beamed Loutraki hall.

Function

An issue discussed a lot with the managing committees in the researcher's observations is the condition of the users' related ancillary rooms. Condensation in the changing rooms, showers and toilets seems to be the main cause of problems in such buildings following the—almost inevitable—main roof leaks (most of the buildings feature a main roof spanning across the main hall and on a different elevation a short spanning one over the changing rooms, toilets, offices and in general secondary rooms).

Other problems observed sporadically were incompatibility of materials used and non standard sizes (i.e. corridor and door heights, shower doors width, etc.). It should be noted that these were not at a worrying level and few, if any, complains were made by the users (Peristeri hall on corridor heights). Surface's specifications and various other minor details are set explicitly by the GSS making the overall performance of the halls satisfactory. This is expressed in the overall performance of the halls where no pattern seems to exist on the rating of the various buildings; the first five places include all different constructional systems.

Aesthetics

As far as aesthetics is concerned, Black (1973) argues that users up to the age of 22 are not conscious of the surrounding or functional deficiencies; older users become increasingly aware. He also stresses that although the colour and other patterns used are designed to create a pleasing and relaxing environment, many times during the action these patterns and colours can become obstructive, tiring and even annoying to the users. This partly explains the relatively poor performance of Rethymno hall with its striking colour schemes compared to the rest of the sample.

Galatsi is the opposite example where a simple and low-toned building fails to justify itself although it performs all its functions remarkably well; the darken "*isobelek*" and the lack of colours have a negative effect. This was, together with the two swimming pools and Arta, the non-colourful buildings of the research. These are the ones on the negative scale of the rating.

Passive Energy Systems

An issue disregarded in most of the buildings of the sample is passive energy. Solar collectors for water heating are used only in Loutraki. Discussing the issue further with the GSS members it was found that in the, admittedly few, previous examples, serious problems occurred. These were mainly waterproofing-related ones that led to even the discarding of the whole system in one case (Illisia pool). However, this is not a reason to avoid such systems in the future as the electricity and oil consumption performance of Loutraki demonstrated.

As demonstrated in the previous sections, the sportshalls and swimming pools in Greece are lacking in the implementation of passive energy systems as well as lighting design. A first general suggestion should be on the use of roof mounted solar collectors (Wright 1987, Anderson et al 1982) that, as Loutraki demonstrated, lead to a substantial reduction in the consumption of heating oil. Additionally, north facing rooflights could be incorporated easily in the same roof structure in the gaps created between the south facing solar collectors.

More advanced systems such as the "trombe wall" (Andreadaki et al 1985, Gillet et al 1985) could be implemented also. This is a passive heating-ventilating system based on the principle of hot air circulation. A south facing wall is built with no windows, painted in a dark colour and covered with a glass cladding leaving a 10-20 cm space in between. Utilising flaps on the top and bottom of the solid wall, this system can provide heating during the winter and cooling during the summer. At the same time it solves the problem of glare caused by south facing windows. Finally "solar chimneys" (Dimoudi 1989) could be used on west facing walls of the halls further improving summer cooling with minimal cost as well as justifying the lack of west facing windows that have proved problematic.

6.2.3. Technical

Following the analysis, it should be noted that the two best performing buildings are the ones designed by the GSS design department. This shows that the implementation of their principles, ideas, as well as the design criteria set on the evaluation, is quite successful.

According to Korbas (1990) the 716 systems (described earlier in Chapter Three) provide the best suited buildings due to the judging committees being more technical and less political, monitoring the construction as well as the design's being in greater depth. On the contrary, in the case of architectural contents and Design & Build, the plans are approved at an earlier stage and the contractor is more free to make modifications. However, this argument conflicts with the research analysis results where DDGSS buildings proved more successful than privately designed ones.

6.3. Constructional Systems and their Performance

6.3.1. Steel

The foundations, perimeter beams and columns usually are constructed of reinforced concrete. Effectively, the clear span is the only steel part of the roof. This reduces the cost of the structures and simplifies the construction itself since labour availability for concrete construction is greater and cheaper than for steel. Not to say that concrete construction is simple but since it is used so extensively, all the Greek labour force is familiar with it and, therefore, is, in a way, specialised.

The steel based constructional systems used in Sportshalls in Greece (represented in this research) can be broadly classified in two groups; the trussed and the high-tech space framed structures. High-tech is Peristeri whose cost–performance ratio was not competitive to the rest (sixth place) and Arta (the worst performer of the whole sample). However, the trusses have another parameter separating them; age. The new one (Rethymno) is an excellent performer, which suggests that steel has an important role in Greek long span construction. On the contrary, the old one is exactly the opposite, setting questions and doubts on the long run performance of steel constructional systems in general.

Overall, steel framed buildings do not present a completely different view, in terms of the visual impression and aesthetics, compared to the buildings and structural norms of contemporary Greece. This is due to the extensive use of reinforced concrete and plaster in the same way and style as found in houses, office blocks, high rise buildings, Mets sportshall and even Hios tent.

6.3.2. Tents

The overall fourth place of Hios pool, shows the potential of the system. Bearing in mind the "hostile" environment of the research model (cost biased—unable to compensate for tents' particularities) the results are promising. However, it is difficult to draw conclusions on the performance of tents against the other constructional systems examined since the main use of the subsequent buildings varied—sportshalls against pools. Further research on this aspect would facilitate better / more extensive comparisons.

Until the construction of Hios swimming pool, tents were considered a cheap and temporary alternative to more "solid" structures like timber and steel. Therefore, examples of older tents 1980-1985 are not in existence since the managing committees and municipal authorities managed to obtain the capital needed for the construction of steel or timber buildings. People's perception of tents is many times negative as shown when the managing committee members of Posidonio pool were informed by the researcher of the possibility of building a Hios–like tent in replacement of their existing, ageing one. Their comments and general opinion was very discouraging—strongly opposed to the idea of having another "*non-solid*", "*fake*", "*temporary*" (to use their comments) building. Having suffered with the existing tent, they were not willing to have anything similar, no matter the researcher's attempts to explain the advantages of this new constructional system and the enthusiastic comments of the Hios managing committee. Surprisingly, the members of the committee that have visited Hios pool agreed with the researcher's comments but still opposed the idea of having one for themselves.

Another incident reported by the GSS engineers was the removing of 'balloon' shaped polyester fabric PVC coated tents over two swimming pools in Athens and Larisa. This was initiated by the users themselves who argued that the environment felt "heavy", "cold" and "dark" and, therefore, preferred to swim in open air during winter to having an un-inspiring tent cover. Later, both buildings were covered by Glu-Lam timber roofs. This incident should be considered as an important disadvantage of tents on users' having experienced the first, and admittedly, poor examples built in Greece.

6.3.3. Glue Laminated Timber

The use of timber in long span structures was fully justified in this research. The two buildings of the sample were quite consistent in performance terms, their strongest points being the resources and technical. Users rated them as very good for Loutraki and average for Galatsi. The effect of the age of the latter plus the lack of stimulating environment (colours, finishes, etc.) were, as explained earlier, key factors on this ranking.

Fixed portal frames used in the older example were dropped in favour of the three-pinned portal frames, whose structural stability properties are superior as well as enabling smaller beams in section and, thus, reducing costs.

Bearing in mind the age difference between the two timber framed halls of the sample, the question discussed on steel Rethymno and Byron hall is applicable also. Nevertheless, the performance variation is much smaller than in the steel examples and, bearing in mind the structure change and evolution carried on during these years, it is quite unlikely to cause problems. However the ageing of Loutraki in particular can be problematic, since rain and corrosion protection of the external envelope panels is poor. This is due to an overall construction cost reduction attempt by the contractor and not intrinsic design or constructional system related problems.

6.3.4. Reinforced Concrete

Regarding Mets, GSS engineers explained that this was an experiment, following the—by that time—well performing Alexandrio Melathro in Thessaloniki. The latter was built in the mid 70's and features a reinforced concrete dome spanning over 50 metres (the thickness of the dome at the apex is approximately five centimetres). Recently, serious problems with the waterproofing of the roof have been experienced and an extensive restoration project is currently planned.

The overall result is not promising and is hardly justified for spans up to 30-35 metres. Even so, reinforced concrete is unable to reach such spans with the widely available techniques and the high-tech ones needed (prestressed) are imported, complex and, therefore, expensive. Unless Greece develops its own know-how and research and development sectors (dealing with concrete which is readily available and cheap) there is no advantage in using this constructional method. Domes are also problematic and, bearing in mind the earthquake history of the country, do not seem to be a feasible alternative. Moreover, the possibility of reinforced concrete competing, in terms of span, with tent and steel successfully is minimal as the subsequent capital costs will be too high to justify the decision. This is independent of the construction method used (shells or prestressed).

However, as the research results demonstrate, reinforced concrete will remain the structural material for the sub-structure and, in many cases, the super-structure up to the roof level. This proved to be true on all steel framed buildings as well as Hios tent.

Chapter 7 Conclusions

7.1. Overall Conclusions

Appraising Building Performance

The review of the previous research on this topic, revealed two main categories of aims; the appraisal of buildings at the design stage and the appraisal of buildings in use. Subsequently, three main approaches were identified in terms of their objectives; cost dependant, quality dependant and cost-time dependant.

The objectives of the research proscribe the use of any partial model reviewed in the literature. An inclusive approach towards the concept of building appraisal is needed and hence applied since this research focuses on the human and user needs, the functional requirements and criteria and the performance requirements, as well as the capital and running costs and technical issues. *Consequently, a systems concept is employed in the holistic evaluation of buildings in use carried out.*

Development of a Research Model

The main issues that an inclusive appraising model should address are cost, time, users' satisfaction and technical. The research model developed, uses data obtained from the methodologies presented and discussed in the literature as well as from the GSS model. The cost and time, grouped together as resources, have become parameters of major importance in the last decade and, therefore, are more appropriately examined in a holistic manner. The life cycle cost approach provides depth whereas capital costs or running costs analyses alone do not produce comprehensive financial modelling of the buildings under evaluation. Users' satisfaction is the second most important issue according to both GSS model and the engineers survey. Therefore, it must be considered with great care, collecting information not only from the building users but from the building owners, neighbours and designers as well. The questionnaire developed and the interviews carried out facilitate the monitoring of the diverse views of such a sample and enhance the validity of the data analyses and of the appraisal itself. Finally, technical issues, being to a greater extend quantitative, facilitate the development of objective measures addressing HVAC, constructional details, materials used, acoustics, electromechanical installations, passive energy systems etc.

Most of the building appraisal methodologies presented and criticised in the literature, end at the level of data analysis and draw conclusions on the individual aspects they investigate, focusing on a fraction of the general problem of building appraisal. *Therefore, the mathematical model of quantification developed is of paramount importance since it led to the drawing of overall conclusions.*

This mathematical model facilitated the construction of an overall index of performance by measuring the performance of each building as a whole through its components' performances and comparing this performance to the others in the sample.

Application of the Research Model

The application of the research model in the Greek sample of buildings, identified the issue of availability of running cost data which was particularly apparent in maintenance costs. The success of such an invasive and time consuming operation–research is based upon the overall organising and the links with the decision makers and sources of data (ministries, local authorities, engineering practices, contractors, etc.). *Consequently, the pilot (preliminary) study is crucial in certifying the availability and accessibility of the information needed and facilitate the overall planning of the work. The particular research evaluation method succeeded (accomplished the objective set) in drawing overall conclusions on the performance of long spanning sportshalls and swimming pools in Greece.*

Timber

A timber Glu-lam framed sportshall (Loutraki) was the overall 'winner' in the research carried out, due to its excellent overall performance and very good predicted long term performance (reflected by the running and maintenance costs as well as HUS performance of the similar structured and much older Galatsi sportshall). Glu-lam proved to be better than the alternative constructional systems examined in terms of overall performance.

Key issues for the success of Glu-lam are the very good HUS performance and the combination of very low running costs in terms of electricity (solar collectors, and roof-lighting), small number of employees, lower than average maintenance costs, structural simplicity and lack of imported, and, therefore, expensive, structural assemblies (materials).

Steel

Steel space framed buildings (as featured in Peristeri and Arta) are not strong contestants due to their high capital costs and technical complexity leading to expensive servicing. The flat roofs that such constructions employ usually are another cause of problems.

On the contrary, *steel trussed frames—as in the form employed in Rethymno—are very close to timber in overall performance. This particular example, compared to its very poor performing predecessors, showed no problems related to running costs and HUS performance. This is due to the improved structural details implemented in terms of roof cladding, steel frame, wall panels insulation and windows.*

Tents and Sportshalls

The tents examined in this research are subdivided into two categories; the old (over 7 years) tents supported by a steel structural frame and the tensioned fabric tents. The quality and HUS performance of the older examples analysed (Patra and Posidonio), approximately eight years after their construction, is very poor. Their only advantage is the extensive prefabrication leading to fast erection and the low capital cost; such factors alone are not sufficient to make a building successful.

The analysis of the HUS performance figures of the latest tent–structured example (Hios double skin tent), demonstrates that this constructional system is highly competitive, rated third in both HUS performance and overall. However, capital cost scores are poor compared to the older tents, Glu-lam and steel trussed structures, due to the double skin fabric and the tension related technology and costs, restraining them from better overall classification. *Tents' overall performance and, consequently, applicability in Greece, is related to the constructional system used (tension structure versus supported on trusses) and the structural details implemented (polyester fibre fabric PVC coated versus glass fibre fabric with Teflon or rubber coating, double skin with hot air channels versus single layer fabric).* DDGSS, and Greek engineers in general, avoid the use of tents in sportshalls, considering them as 'temporary solutions'. However, as the research analysis results show, constructional systems employing double skin tents similar to Hios swimming pool lead to very successful permanent buildings.

Reinforced Concrete

Spans in the region of 40 metres cannot be covered using simple reinforced concrete structures. Therefore, imported prestressed concrete technology is needed which has a serious drawback in terms of roofing capital costs. The research showed that such spans make the capital cost involved non-competitive—up to 30% higher than Glu-lam timber, steel trusses and tents (in drx/m^2). Consequently, concrete based structures, including prestressed ones, are not financially efficient solutions for Greece. However, all constructional systems reviewed use reinforced concrete in the substructure and, in many buildings, up to the roof level and perimetric beam (all steel framed examples). *Reinforced concrete's constructions are not financially competitive except when used in foundations and vertical loadbearing structural elements only where concrete performs well–in both technical and economic terms.*

Passive Energy Systems

Passive energy systems were applied in only two out of the ten buildings of the sample. *Substantial reduction in energy expenses (up to 40% of the annual heating oil consumption) was measured in both Loutraki and Hios buildings due to implementation of solar collectors and use of hot water from a neighbouring power station respectively.* The serious problems that occurred (roofs' waterproofing failures, pipes' insulation, protection against frost, etc.) in a few earlier examples, where solar collectors were used (Hatzakou, interview 1991), has made DDGSS reluctant on their use. This is reflected on the low relative importance of this issue in the GSS model for evaluation of proposals.

The calculated reduction in energy expenses demonstrates the importance of the extensive employment of systems such as 'trombe' walls, energy chimneys as well as (roof mounted) solar collectors. The actual design cost of implementing such solutions is small and, furthermore, justifies the effort (relevant references in the GSS briefs should help also).

Natural Lighting

North lighting and rooflights scored high in users' and athletes' opinions due to lack of reflections, glare and constancy in the light intensity. The field work revealed that, in terms of natural lighting, most buildings featured windows oriented to the east, south and west; these proved distracting and annoying to users, both athletes and spectators. This is caused by the GSS briefs specifying the total windows area being at least 25% of the hall's floor area, whilst not focusing on the orientation of these windows explicitly. In order to avoid disqualification by the judging committee, designers include windows even in inappropriate locations. *The research showed that designers prefer to specify windows than rooflights as the latter are more difficult to design and construct and impose extra waterproofing problems.*

Tents' lighting performance is dependant on the transparency of the fabric cover. Extreme conditions (very transparent and very dark fabrics) are criticised extensively by both users and athletes. Spectators' opinion on lighting in general and tents in particular is forgiving whereas athletes are very strict in their judgement. *The variation in results is due to users horizontal and upward directions of viewing, while spectators are watching mainly on the horizontal plane and downwards.*

Artificial lighting is another cause of problems in the 'budget' halls. *The incandescent bulbs and fluorescent tubes used result in higher running costs and extensive criticism from users.* Systems like the quartz–iodine tungsten filament lamps (suggested by Traister, 1982) used in Peristeri (notably the only source of lighting) and Loutraki led to top HUS lighting performance sampled.

Roofing Failures

Another problem identified in the study is waterproofing failures, leading to dampness, corrosion and deterioration of the insulation and finishes. Contractors' attempts to minimise construction costs lead to the use of cheaper materials and/or employment of non specialised personnel for the construction. *The main causes of roofing failures are the construction materials and the inadequate design of expansion joints, to accommodate temperature variations, due to engineers' inexperience with such long spans.*

Decoration–Colouring

Decoration and the colour schemes used in sportshalls and swimming pools influence the behaviour of, and in certain cases tire and distract, the users (both athletes and spectators). *The research analysis agreed with the GSS brief in that the designs should not be excessively complicated with many striking colours.* On the other hand, they shouldn't produce an un-inspiring environment by having a single coloured scheme, e.g. everything painted white. The latter imposes additional lighting and glare problems. Use of 'toning' colour schemes, as shown in the research analysis, is beneficial.

Impact of Constructional Systems on Building Performance

Performance comparisons between constructional systems applied in swimming pools and sportshalls should be made with much care as both capital and running costs are affected by the function of the buildings leading to higher figures for the pools. *Similarly,* *great care must be taken in interpreting and generalising conclusions drawn on particular constructional systems since performance is related to non–structural together with structural issues.*

The only constructional systems restricting the implementation of the passive energy systems (heating, ventilating, air–conditioning and lighting) suggested in the previous chapter are the fabric tents structures based ones. However, their intrinsic lighting properties (transparency of the fabric), that the other constructional systems examined lack, compensate this restriction in lighting terms as the analysis results show. Consequently, tents' problems of passive energy systems' implementation focuses on HVAC and, particularly, the solar collectors' positioning, trombe wall utilisation and energy chimneys' usage. *The solid walls and the structure supporting the heavy solar collectors needed are problematic considering the lightweight frame of tents, demanding redesign of the whole constructional system.*

Analysis of aesthetics and acoustics performance of the buildings showed that constructions featuring reinforced concrete are preferred by both users and spectators. The properties and similarity of concrete structures to the everyday architecture which users in Greece encounter, causes this preference.

The constructional systems implemented in the last five years show a great improvement over older systems in terms of overall performance rating. The main reasons are the design improvement, the constructional details used, lower running costs, improved heating, aesthetics and lighting. *All three constructional systems (based on timber glue laminated, steel trusses and tents) have similar performance and, therefore, are appropriate in Greece. However, the particularities of their implementation (such as cladding, lighting, heating, energy conservation, colours etc.) are key issues in constructing well performing buildings.*

Research Hypothesis

As the overall conclusion of the research, the hypothesis that *'the GSS system is effective for the appraisal of 25 to 60 metres (long) spanning sportshall and swimming pool buildings in Greece'* is not supported.

The very good performance of recent GSS designs (Rethymno) demonstrates that GSS design criteria in technical, costs and HUS are, to a great extent, successful. *However, GSS failed to communicate design criteria with the competing practices (through the briefs) as shown by the performance of the majority of the building examples.* Furthermore, in terms of heating, passive energy and lighting, the GSS expectations, and consequently briefs, are not fully justified in the research which also reflects on the performance of the building sample.

The conclusions demonstrate the limitations of the GSS evaluation methodology. Problematic natural lighting specifications (window area), lack of passive energy systems specifications, low priority (relative importance) of the roof's waterproofing and heating systems design, justify the need for revised GSS briefs and fine tuning the GSS model of evaluation.

7.2. Limitations and Recommendations for Further Research

This research was limited in various ways during the course of the study. A main restriction was the availability and suitability of running cost data for the buildings of the sample; in most cases it was extremely difficult to obtain data for more than the past two to three years. This was particularly restrictive in the maintenance data, the only part of running costs fluctuating significantly throughout the life of a building. However, the recent re–organising of the GSS (archives filing, microfilming plans and invoices, etc.) should improve conditions for future research.

Another problem faced in the research was the difficulties and, consequently, time spent, in collecting information from the managing committees and certain buildings' training staff. The bureaucratic structure of the public sector was the main cause of considerable delays together with the lack of co-operation of a few sportshalls' employees. Consequently, the data collection process was extended from the programmed two, to almost five months.

The distances to be travelled, since the buildings are spread throughout Greece (and in a few islands), was another drawback. It should be noted that further problems were avoided by prior phone contact by GSS members—in many cases the researcher was introduced as a GSS engineer as this was the only way to obtain the relevant information.

Given the problems, the following suggestions for further research are put forward:

Carry out similar research on a larger sample and a longer spanning cost in–use database. The former could be possible when the new generation of halls under construction in 1992-1995 are completed. The latter should become more practical following the recent attempts to computerise all the relevant invoices—as in Posidonio; this will take a few years before it is implemented fully and enough data are recorded. The present study could be used for further testing including more new technology buildings like Peristeri and Hios. Pool examples featuring the alternative constructional systems should be included—this was not possible in this study since the available, mainly Glu-lam, examples where only months old or under reconstruction and data availability was poor. Additionally, buildings like Rethymno and Hios as well as Peristeri that were rated high in this study will be reaching an age that potential problems would possibly appear.

Examine the Hi-Tech expensive versus conservative and cheaper solutions in terms of overall performance as demonstrated in Peristeri sportshall against Rethymno and Loutraki as well as the annual maintenance duration and cost versus the age of buildings ('bath-tub curve').

Create a data bank for the running and maintenance costs of long span buildings in Greece using this work as a pilot and starting point. This will benefit future appraisals and lead to an easily applicable, minimal resources tool for the evaluation of existing sportshalls and swimming pools. Consequently, designers and contractors can be more aware of the performance provided by various alternative constructional systems and, therefore, modify their designs and bids accordingly.

Test applicability and feasibility of this evaluation model on other long spanning building types in Greece. This would enable further comparisons and drawing of overall conclusions. Application of the model to other countries would require modifications to the mathematical model since the relative importance of the research variables would need adjustment.

Develop a model for the evaluation of proposals of sportshalls and swimming pools in Greece based on the research evaluation model of complete buildings. Preliminary discussions have been made with the director of the DDGSS and further action will be taken following the translation of the methodology and conclusions. The aim set is to modify the existing GSS model (improving briefs, revising judging criteria and supervision objectives) and in certain parameters discard it and develop new design criteria based on the research conclusions.

The need for imported technology, constructional systems or contractors is an important drawback in some of the buildings examined. Structures such as tents, steel space frames and timber could be more competitive if Greek engineers were taught such subjects to a larger extent. There are many instances where architects are facing problems in finding structural engineers willing, as well as able, to calculate timber framed structures—that is even for small houses. This is due to the existing Higher Education curriculum developed around reinforced concrete—based on the argument that it is used in approximately 90% of the buildings constructed in Greece. Therefore investigation on alternative curriculum focus should be attempted based on the conclusions of this research.

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Appendix A Construction in Greece

	1976	*1977*	*1978*	*1979*	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*
France	29.7	29.8	29.1	28.8	29.1	28.2	26.1	24.5	22.7	22.2	21.6
G.F.R.	33.5	32.2	34.3	35.7	34.6	31.5	30.1	30.5	28.9	25.8	25.8
Greece	7.9	10.6	11.5	12.0	12.3	13.4	13.3	14.2	13.5	12.7	12.8
Italy	34.2	38.2	38.2	39.3	41.9	42.1	40.2	39.8	38.3	37.2	36.4
Spain	24.1	28.0	29.3	28.1	28.0	28.8	29.6	31.2	25.5	21.9	22.0
U.K.	16.9	15.5	15.9	16.1	14.8	12.7	13.0	13.4	13.5	13.3	13.4
Canada	9.7	9.9	10.5	11.5	10.3	10.2	8.1	7.1	8.6	9.6	n/a
Japan	65.5	73.1	84.9	87.8	88.0	84.8	80.7	80.9	78.9	72.8	71.3
U.S.A.	62.1	72.6	77.5	76.6	68.2	65.1	57.5	63.9	70.5	70.3	71.1

(*) All figures in million metric tons. 1985.86 Statistical Yearbook, U. N. (pp. 524–526).

Table A.1: Cement Production, 1976-86

	1970	*1971*	*1972*	*1973*	*1974*	*1975*
France	791.7	790.3	731.4	947.0	956.0	1003.0
G.F.R.	1145.4	1038.0	1074.1	1453.9	1753.1	1265.0
Greece	342.3	675.4	763.2	367.0	2015.2	3059.2
Italy	128.5	182.7	700.8	596.0	370.5	348.0
Spain	146.6	610.8	722.1	876.4	1511.3	3140.0
U.K.	313.9	168.3	226.9	298.4	372.7	267.0
Canada	513.8	888.0	1140.0	1200.0	1148.7	996.6
Japan	1596.9	1680.1	919.8	234.7	1401.9	4098.4
U.S.A.	144.5	113.0	91.6	294.6	262.9	448.2

(*) All figures in thousand metric tons. Cement Industry, (Dec. 1976) OECD (pp. 22–23).

Table A.2: Cement Exports, 1970–75

	Pig-iron & Ferro-alloys					*Crude Steel*				
	1975	*1980*	*1983*	*1984*	*1985*	*1975*	*1980*	*1983*	*1984*	*1985*
France	18.4	19.6	14.1	15.4	15.7	21.5	23.2	17.6	19.0	19.1
G.F.R.	30.3	34.1	26.6	30.4	31.6	40.4	43.8	35.7	39.4	39.2
Greece	.5	.3	.1	.1	.1	1.0	1.1	.8	.8	1.0
Italy	11.6	12.4	10.5	11.9	12.3	21.8	26.5	21.8	24.1	23.9
Spain	7.1	6.8	5.6	5.6	5.8	11.1	12.6	13.3	13.4	14.7
U.K.	12.3	6.4	9.6	9.6	10.5	20.1	11.3	15.0	15.1	15.7
Canada	9.3	11.2	9.4	10.5	7.4	13.0	15.9	12.8	14.7	13.5
Japan	89.3	89.1	74.3	82.0	82.1	102.3	11.4	97.2	105.6	105.3
U.S.A.	74.3	63.7	44.9	48.1	46.6	105.8	101.5	76.8	83.9	80.1

(*) All figures in million metric tons. 1985/86 Statistical Yearbook, U.N. (pp. 527–528).

Table A.3: Pig–Iron and Crude Steel Production, 1975–1985

		Imports					*Exports*				
		1980	*1981*	*1982*	*1983*	*1984*	*1980*	*1981*	*1982*	*1983*	*1984*
France	*raw*	24.0	20.7	17.2	13.2	19.4	13.6	11.3	10.3	9.4	10.7
	stl.	7.6	7.0	7.1	6.5	6.9	10.7	9.3	7.5	7.8	9.1
	str.	4.6	4.6	4.5	3.9	3.9	4.5	4.3	3.3	3.6	4.3
G.F.R.	*raw*	54.7	48.7	42.9	39.0	46.8	12.1	11.1	8.0	7.8	10.8
	stl.	11.5	11.3	10.2	11.5	11.1	19.1	19.2	17.0	15.8	18.4
	str.	6.7	6.7	6.3	6.9	6.4	9.0	8.5	7.2	6.8	7.4
Greece	*raw*	.6	.4	.5	.6	.3	.07	.07	.03	.05	0
	stl.	1.2	.8	.8	1.5	1.1	.5	.4	.4	.5	.5
	str.	.3	.2	.3	.3	.05	.3	.2	.2	.2	.1
Italy	*raw*	25.9	21.9	22.8	19.2	25.8	.8	.8	.6	.3	.7
	stl.	7.1	4.9	5.0	4.9	6.0	6.8	8.3	7.3	7.2	7.7
	str.	2.4	1.7	1.6	1.6	2.1	4.1	4.4	3.8	3.8	3.7
Spain	*raw*	10.2	9.4	10.0	9.6	n/a	2.6	1.6	2.3	1.7	n/a
	stl.	1.8	1.1	1.5	n/a	n/a	4.7	5.3	5.1	n/a	n/a
	str.	.4	.4	.4	.3	n/a	3.3	3.8	3.4	1.3	n/a
U.K.	*raw*	9.3	15.6	11.9	14.9	17.1	4.1	5.0	4.6	4.8	4.6
	stl.	4.7	3.4	3.9	3.4	3.7	2.8	4.0	3.6	4.1	4.2
	str.	2.5	1.7	2.0	1.8	1.8	1.5	2.4	1.8	2.0	2.1
Canada	*raw*	7.5	7.4	4.4	5.2	n/a	n/a	42.8	28.4	26.8	n/a
	stl.	.9	2.5	1.0	1.0	n/a	3.3	3.6	3.3	2.7	n/a
	str.	.3	1.9	.7	.7	n/a	1.6	1.6	2.2	1.4	n/a
Japan	*raw*	139.8	128.3	127.3	115.8	132.5	.2	.3	.3	.5	.5
	stl.	1.1	1.6	2.0	2.7	4.0	29.7	28.5	28.7	30.9	31.9
	str.	.5	.7	1.0	1.4	1.8	15.2	14.7	16.7	18.8	18.2
U.S.A.	*raw*	28.6	32.2	16.8	15.7	20.8	18.0	12.7	10.0	11.4	15.0
	stl.	13.8	17.9	15.0	15.2	23.4	4.0	2.9	1.9	1.3	1.1
	str.	8.3	9.2	7.6	9.8	13.9	1.4	1.1	.6	.5	.4

(*) Figures in million metric tons. Annual Bulletin of Steel Statistics for Europe, 1984 U.N.

Table A.4: Foreign Trade of Raw Materials, Steel Products and Structural Steel

Appendix B Construction of Sportshalls and Swimming Pools

B.1. Procurement Systems Used by the GSS

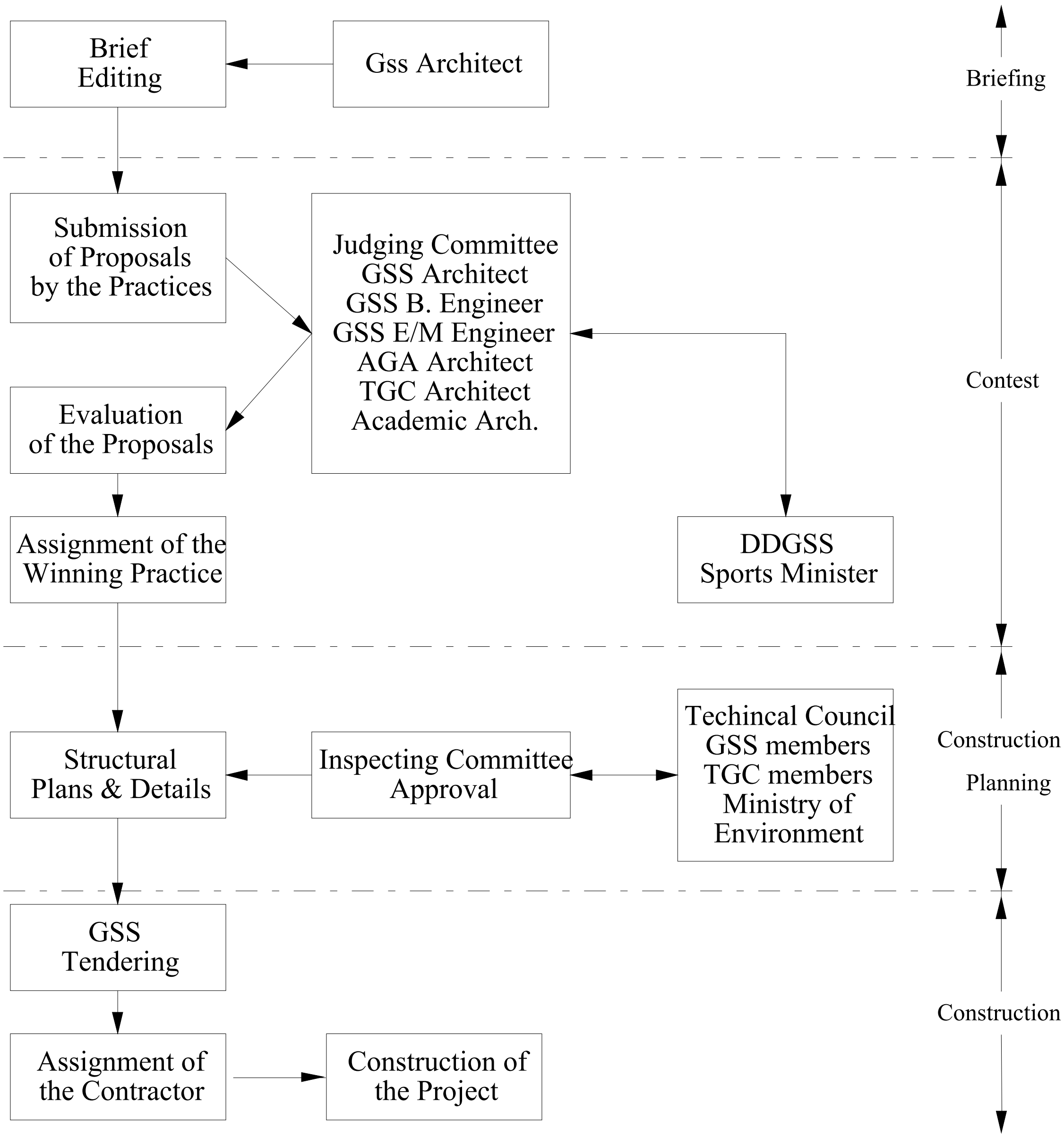
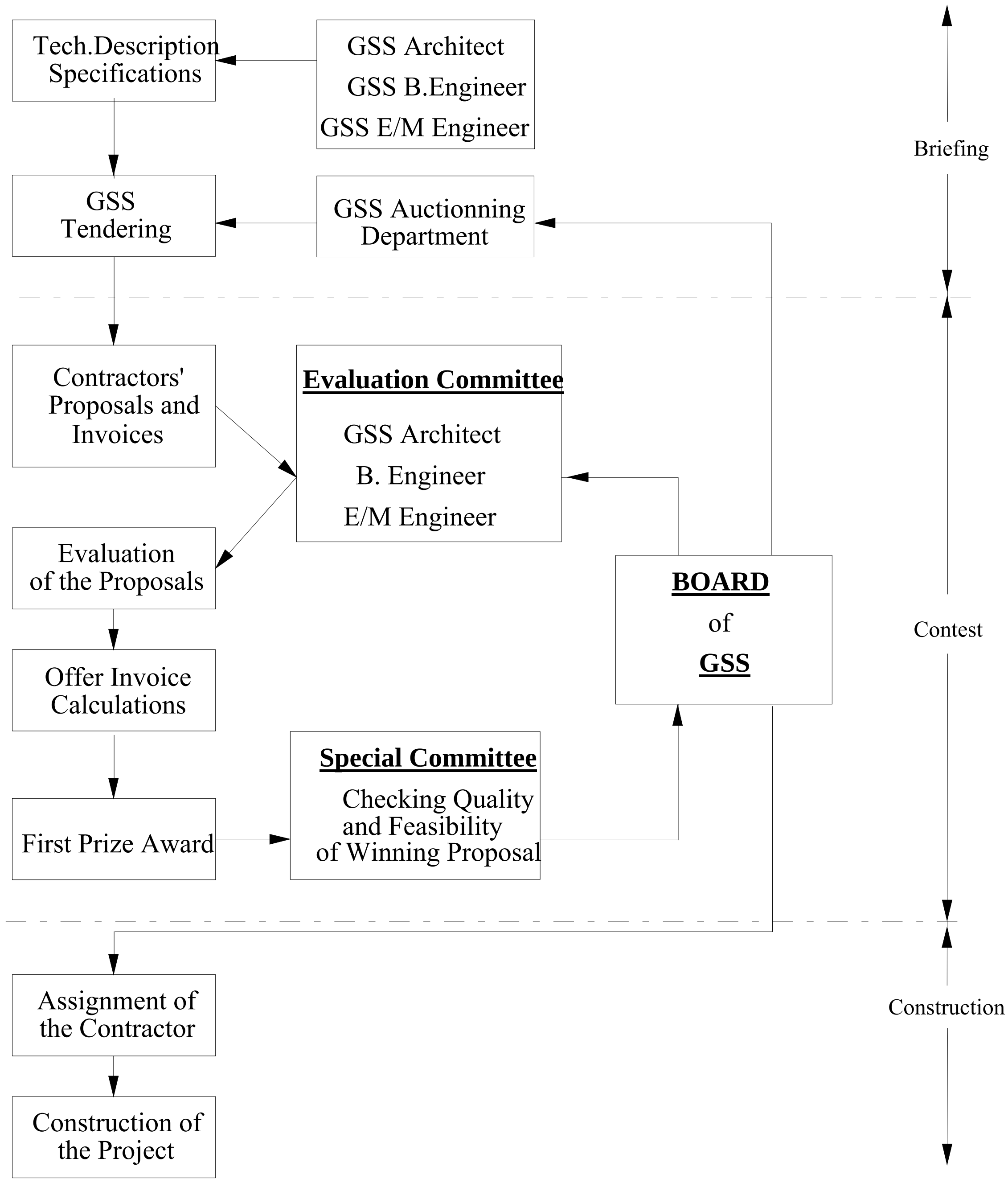


Figure B.1: Architectural Contest



When project's budget is more than half a billion ECU, the Evaluation committee is extended; a municipal representative, a TCG and an Academic member are added. There are three variations in the design and built contest. In the first one contractor is employing Architect, B and E/M Engineers, in the second architect is by the GSS and the contractor is only employing the B. and E/M Engineers. In the last variation, three to five contractors are preselected and the contest takes place among them.

Figure B.2: Design and Build Contest

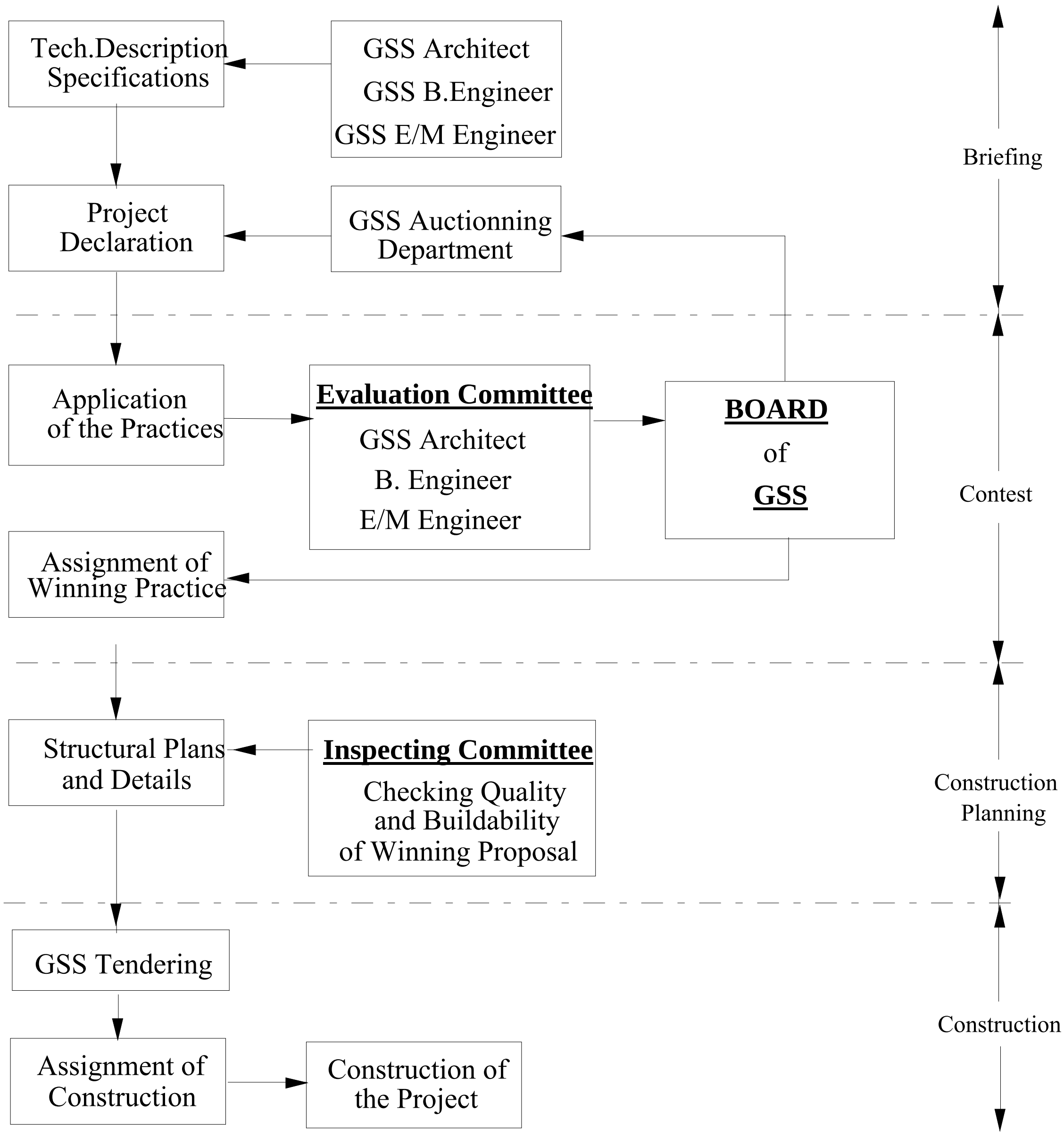


Figure B.3: 716 Legislative Act

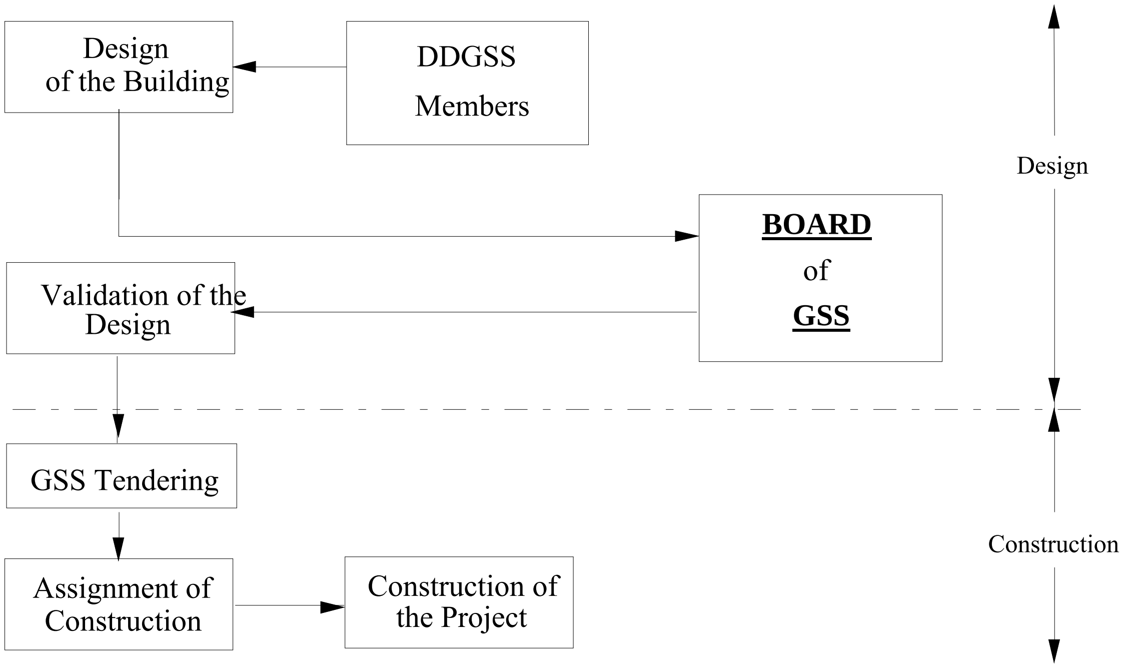


Figure B.4: GSS Design

B.2. Requirements Set by the GSS

B.2[redacted] General Functional Remarks

Multi–function of the buildings; used for conferences, lectures, music perf[redacted]mances, exhibitions etc.

- Separation between athletes and spectators in their movement.

Safety of both spectators and athletes in the buildings in general and particularly in their movement at peaks and in case of panic. (i.e. emergency exits and light[redacted]g confirming to the safety standards in existence).

- Minimum width for athletes' corridors 1.25m.

General layout of the available site, enhancing future expansion of the buil[redacted]ngs.

Designs conforming to the existing urban legislation; G.S.S. facilitate small scale exceptions, following special urban legislative regulations available to them.

B.2[redacted] General Structural Remarks

- All sub–assemblies:
  - are selected and designed for constant and heavy use
  - withstand (as far as possible) vandalism
  - are simple and solid (the two virtues of buildings' members)

The servicing and maintenance of buildings should be easy and economic;

ease in maintenance and replacement of building parts and sub–assemblies, availability of spare parts.

economy in terms of maximum intervals between consecutive services and not highly spec[redacted]lised maintenance personnel needed

All materials protected against water penetration, rust, decay etc. according to the material's producer specifications and the specifications of the chosen prot[redacted]tive material or method.

All materials carrying a warranty by their producer must be also warranted by t[redacted] contractor for the specified period stated by the fabricator.

Materials used are: of proved (tested) resistance to natural wear, water penetration, deterioration and intensive use and applied following the rules of the science and craft and especially according to their fabricator's specifications

B.2.3. Functional Criteria

These are presented in the section of the brief named 'Structural Specifications'. Regardless what the name implies these are the functional criteria of the main hall of the buildings. They are further classified in five sections listed below:

Sid[redacted]alls

- Resisting ball hits—preferably slight elasticity

Safe–harmless for athletes falling or slipping on them (nothing protruding for [redacted] to 2.20m, walls' and doors' edges smoothed)

- Non–reflective for both natural and technical lighting

Safety of entrances and exits (panic mechanism security doors etc.)

Roo[redacted]ng

- Resisting ball hits (shock–proof resistant)
- Sound proofing and absorbing
- Protection and ease of replacing for the lighting units

Provision for suspension of athletic devices, design withstanding the addi[redacted]nal loads

Height restrictions according to the sports accommodated

Nat[redacted]al Lighting

Anti–glare and uniformity (North lighting preferred, no direct sunbeams in the t[redacted]rain)

No windows in the two short sides of the hall unless:

- the materials have excellent antiglare properties
- facilitates uniformity of the lighting of the hall
- Total window surface (not less than 25% of the plan size of the main hall)

Natural Ventilation

- openings on both side windows and maybe on roof as well that facilitate the ventilation and circulation of the air in the hall
- remote controlled mechanisms (in some projects manually operated...)

Acoustic

- Level of clarity (?) (minimum 80% in empty hall)
- No serious acoustic faults (?)(subjective)(no explanation on how measured)

Under the title of 'Aesthetic Remarks' some general functional criteria are stated. According to them the proposed buildings should:

- show–declare–present their character and use
- avoid bulky solutions
- enhance the feeling of lightness (at least for the main hall's roof)
- avoid monotonous flat elevations
- match the building and the surrounding to the landscape and neighbourhood

Some other points made were mainly on colours used that should be pleasant each one alone and their combinations and express the liveliness of the buildings and the people involved. Additionally, the structural subassemblies and fittings should be complying to the previous remarks (i.e. colour and type of floors, arrangement of the lighting units, etc.). Furthermore, installations that are visible should be also designed and constructed accordingly; air–conditioning installations, piping, wiring, fire extinguishing hoses and assemblies, heating, passive energy systems should all be considered.

Appendix C Building Sample and Questionnaires

C.1. Building Sample

	Building	Frame	Type	Year	Span
1	Peristeri hall	st. pseydo-space	716	1986-88	50m
2	Mets hall	prestressed r.concrete	DDGSS	1982-86	34m
3	Hios pool	double skin tent	D&B	1984-87	60m
4	Patra pool	tent on steel trusses	D&B	1985-86	40m
5	Rethymno hall	steel trusses	DDGSS	1989-91	35m
6	Loutraki hall	glu-lam beams	D&B	1985-86	39m
7	Posidonio pool	tent on steel trusses	D&B	1985-86	40m
8	Galatsi hall	glu-lam beams	716	1983-85	24m
9	Byron hall	steel trusses	DDGSS	1978-81	30m
10	Arta hall	steel space frame	716	1977-78	42m

Table C.1: Research's Building Sample

C.2. Greek Building professionals Questionnaire

Following the analysis of the GSS model of evaluation, three main variables were identified: **Resources**, **Human–User satisfaction** and **Technical.** The relative importance of these three variables was established as follows:

RESOURCES 59%, HUS 26% and TECHNICAL 15%.

What do you think about this ranking?

Would you rank them differently?

Could you assign your own percentages on these three factors?

C.3. Construction Superintendants' Questionnaire

1. Actual construction period.
2. Contractor's offer (nbcoi).
3. Total building cost (tbc).
4. Cost of the building envelope.
5. Cost of prefabricated parts for the envelope.
6. Cost of native parts for the envelope.
7. Technical expertise of construction personnel (Very Low, Mediocre, Average, High, Very High).
8. Availability of materials and spares (Very Poor, Mediocre, Average, Good, Excellent).
9. Technical expertise of maintenance staff (Very Low, Mediocre, Average, High, Very High).

C.4. Building Managers' Questionnaire

1. Hours of daily use (in average)
2. Time of day the artificial lights are turned on for a specified week of the year.
3. Annual running costs incorporating electricity, fuel staff salaries, consumables and other expenses.
4. Annual costs of regular maintenance.
5. Annual regular maintenance duration.
6. Days lost repairing failures annually.

C.5. Users' Questionnaire

1. Sex and age group (under 15, 16–18, 19–25, 26–35, over 35).
2. What sport are you usually doing (major and minor use)?
3. When did you start using this building?
4. How often are you using this building?
5. You believe that the temperature inside the building is: very poor, mediocre, average, good, excellent.

6. The air–quality inside the building, in terms of dust, dampness, etc. is: very poor, mediocre, average, good, excellent.

7. The ventilation of the hall is: very poor, mediocre, average, good, excellent.

8. The natural lighting of the hall is: very poor, mediocre, average, good, excellent.

9. Is there any glare problem (from windows, roof, flooring etc.)? If yes specify.

10. The acoustics of the hall (echo, clarity of sound, etc.) is in your opinion: very poor, mediocre, average, good, excellent.

11. The noise level of the hall is: very poor, mediocre, average, good, excellent.

12. Have you been interrupted by repair and maintenance work carried out in the building? If yes, how often?

13. Safety of the building (problems with injuries caused by protrusions coarseness of the surfaces, slippery floors, insufficient heights, etc): very poor, mediocre, average, good, excellent.

14. Visibility in the sports terrain from the seating area is: very poor, mediocre, average, good, excellent.

15. Do you believe that the aesthetic appeal of the interior of the building is: very poor, mediocre, average, good, excellent.

16. Please rate the external appearance—attractiveness of the building: very poor, mediocre, average, good, excellent.

Appendix D Data Analysis

Years	*1974*	*1975*	*1976*	*1977*	*1978*	*1979*	*1980*	*1981*		
Resid. (1)	16.8	17.8	20.8	25.1	30.9	39.9	48.4	56.6		
Non_Res(2)	**14.4**	**15.2**	**18.0**	**21.5**	**25.8**	**32.8**	**39.5**	**48.0**		
Years	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*
Resid. (1)	63.7	74.1	85.8	**100**	122.9	137.4	152.8	178.6		
Resid. (3)	58.8	71.4	84.6	**100**	124.2	136.4	149.5	174.2	203.9	245.6
Non_Res(2)	**56.8**	**68.3**	**83.7**	**100**	**125.3**	**143.8**	**164.1**	**191.4**	*223.5*	*272.0*

(1985=100)

(1) OECD (1991), Historical Statistics 1960-1989, Residential Construction: implicit price index

(2) OECD (1991) Historical Statistics 1960-1989, Non-Residential Construction: implicit price index

(3) OECD, Main Economic Indicators, Feb.1992 (pp.134-5), March 1989 (pp.132-3) and March 1986 (pp.124)

Table D.1: Construction Cost Index Used in the Research.

Name	*Minimum*		*Average*		*Maximum*	
	P.Value	*S.Scores*	*P.Value*	*S.Scores*	*P.Value*	*S.Scores*
Peristeri	248.7	-0.08	248.7	-0.05	248.7	0.00
Mets	225.6	0.13	225.6	0.16	225.6	0.23
Hios	191.9	0.43	191.9	0.48	191.9	0.56
Patra	292.5	-0.47	292.5	-0.46	292.5	-0.43
Rethymno	101.5	1.24	135.5	1.01	189.9	0.57
Loutraki	90.8	1.34	90.8	1.42	90.8	1.54
Posidonio	234.2	0.05	234.2	0.08	234.2	0.14
Galatsi	184.3	0.50	184.3	0.55	184.3	0.63
Byron	395.0	-1.39	395.0	-1.42	395.0	-1.43
Arta	433.5	-1.74	433.5	-1.78	433.5	-1.81

Table D.2: Cost Variable Sensitivity Tests on Operational Costs of Rethymno Sportshall

Se Low	*BestFit*	*Se High*	*discount*	*PV-low*	*PV-B.F.*	*PV-high*	*year*
101.07	180.19	282.022	0.9762	98.6673	175.902	275.31	*1*
302.16	430.68	581.906	0.95297	287.948	410.419	554.537	*2*
367.78	508.4	671.726	0.93029	342.144	472.955	624.897	*3*
356.58	495.22	656.561	0.90815	323.831	449.728	596.253	*4*
311	441.22	594.157	0.88653	275.716	391.159	526.738	*5*
255.49	374.57	516.376	0.86543	221.105	324.168	446.888	*6*
203.37	310.84	441.029	0.84483	171.811	262.609	372.596	*7*
161.19	258.12	377.765	0.82473	132.94	212.88	311.553	*8*
131.51	220.16	331.526	0.8051	105.88	177.252	266.911	*9*
114.97	198.6	304.941	0.78594	90.3618	156.087	239.665	*10*
112.11	194.83	300.268	0.76723	86.0153	149.482	230.376	*11*
124.37	210.9	320.131	0.74897	93.1509	157.954	239.769	*12*
136.77	227.0	339.851	0.73115	100.002	165.938	248.481	*13*
149.3	243.0	359.445	0.71375	106.565	173.453	256.552	*14*
161.95	259.1	378.923	0.69676	112.84	180.516	264.017	*15*
174.7	275.1	398.297	0.68018	118.826	187.144	270.911	*16*
187.54	291.2	417.575	0.66399	124.526	193.355	277.264	*17*
200.48	307.3	436.766	0.64818	129.945	199.164	283.105	*18*
213.49	323.3	455.876	0.63276	135.087	204.587	288.459	*19*
226.58	339.4	474.911	0.6177	139.956	209.639	293.352	*20*
239.73	355.4	493.877	0.603	144.559	214.334	297.806	*21*
252.96	371.5	512.778	0.58865	148.902	218.688	301.844	*22*
266.24	387.6	531.618	0.57464	152.991	222.713	305.487	*23*
279.58	403.6	550.401	0.56096	156.833	226.422	308.753	*24*
292.97	419.7	569.131	0.54761	160.435	229.828	311.661	*25*
306.42	435.8	587.81	0.53458	163.803	232.945	314.228	*26*
319.91	451.8	606.441	0.52185	166.946	235.782	316.472	*27*
333.45	467.9	625.026	0.50943	169.869	238.353	318.409	*28*
347.03	483.9	643.569	0.49731	172.579	240.668	320.052	*29*
360.65	500.0	662.071	0.48547	175.085	242.737	321.417	*30*
TOTAL:				**4809.3**	**7156.9**	**9983.8**	

(1) discounting is calculated as in the periodic costs $1/(1+r)^n$ as in equation 5.3.

Table D.3: Calculation of Present Values per m^2 for the Annual Maintenance Costs over the 30 years of the Building Life

Name	Capital(1)		Maint.(1)		Operation(1)		Energy(1)		Various	
	Envel.	Servic.	Ann.	Per.	Salar.	Cons.	Electr	Oil	Use(2)	MD(3)
Peristeri	42.2	15.0	7.16	1.7	55.7	4.0	8.7	3.5	10	0
Mets	34.4	3.4	9.98	1.7	41.3	5.5	7.9	51.6	15	0
Hios	42.6	18.3	4.81	7.9	41.1	4.6	11.7	11.9	15	40
Patra	24.5	0.0	7.16	8.7	103.5	21.1	25.9	28.2	18	50
Rethymno	31.6	1.9	7.16	1.7	33.6	8.8	5.6	20.0	18	0
Loutraki	30.6	5.0	7.16	1.7	10.7	5.0	3.1	0.9	12	0
Posidonio	23.8	0.0	7.16	8.5	68.2	3.8	20.8	49.5	18	10
Galatsi	23.9	6.0	4.81	1.7	61.6	6.9	25.3	3.2	16	0
Byron	43.7	10.4	7.16	1.7	168.2	15.8	5.8	7.6	15	10
Arta	40.0	11.7	7.16	1.7	213.3	23.3	7.9	1.4	16	15

(1) Present Values in thousand drachmas per m^2 in constant 1985 prices

(2) Daily use of the buildings in hours

(3) Annual Duration of Maintenance in days

Table D.4: Analysis of the Present Value of the Building Sample

Peristeri Sportshall

Capital Costs. Envelope: 224200 Servicing: 79500 Total Building: 303700
UBA: 5310m^2 Roof Prefab.: 52700 Roof Import.: 74700 Total Roofing: 98000

Annual Running Costs Salaries: 14000 Consum.: 1000
Electricity: 2190 Oil: 890
2nd year of operation Maintenance: 2190

User Questionnaires Replies: 28 replied 74% .

Mets Sportshall

Capital Costs. Envelope: 77700 Servicing: 7600 Total Building: 85300
UBA: 2256m^2 Roof Prefab.: N/A Roof Import.: 14000 Total Roofing: 30700

Running Costs Salaries: 4410 Consum.: 590
Electricity: 840 Oil: 5510
6th year of operation Maintenance: 1400

User Questionnaires Replies: 26 replied 81% .

Hios Swimming pool

Capital Costs. Envelope: 217400 Servicing: 93200 Total Building: 310600
UBA: 5100m^2 Roof Prefab.: 71700 Roof Import.: 71700 Total Roofing: 101600

Running Costs Salaries: 9920 Consum.: 1100
Electricity: 2820 Oil: 2870
2nd year of operation Maintenance: 1400 3rd year of operation Maintenance: 1460
4th year of operation Maintenance: 1500 5th year of operation Maintenance: 1470

User Questionnaires Replies: 26 replied 80% success.

Patra Swimming pool

Capital Costs. Envelope: 73400 Servicing: N/A Total Building: 73400

UBA: 3000m^2 Roof Prefab.: 60000 Roof Import.: 60000 Total Roofing: 60000

Running Costs Salaries: 14700 Consum.: 3000

Electricity: 3680 Oil: 4000

5nd year of operation Maintenance: 1450

User Questionnaires Replies: 30 replied 85% success.

Rethymno Sportshall

Capital Costs. Envelope: 87600 Servicing: 5400 Total Building: 93000

UBA: 2772m^2 Roof Prefab.: 5400 Roof Import.: N/A Total Roofing: 24400

Running Costs Salaries: 4410 Consum.: 1150

Electricity: 730 Oil: 2630

User Questionnaires Replies: 27 replied 80% success.

Loutraki Sportshall

Capital Costs. Envelope: 78200 Servicing: 12700 Total Building: 90900

UBA: 2556m^2 Roof Prefab.: 14000 Roof Import.: N/A Total Roofing: 21300

Running Costs Salaries: 1290 Consum.: 600

Electricity: 370 Oil: 110

1st year of operation Maintenance: 610 2nd year of operation Maintenance: 1570

3rd year of operation Maintenance: 1570 4th year of operation Maintenance: 1530

User Questionnaires Replies: 26 replied 80% success.

Posidonio Swimming pool

Capital Costs. Envelope: 73400 Servicing: N/A Total Building: 73400

UBA: 3084m^2 Roof Prefab.: 60000 Roof Import.: 60000 Total Roofing: 60000

Running Costs Salaries: 9950 Consum.: 560

Electricity: 3030 Oil: 7230

2nd year of operation Maintenance: 940 3rd year of operation Maintenance: 1920

4th year of operation Maintenance: 1750 5th year of operation Maintenance: 1620

6th year of operation Maintenance: 1210

User Questionnaires Replies: 28 replied 85% success.

Galatsi Sportshall

Capital Costs. Envelope: 32800 Servicing: 8200 Total Building: 41000
UBA: 1372m^2 Roof Prefab.: 7500 Roof Import.: N/A Total Roofing: 11900

Running Costs Salaries: 4000 Consum.: 450
Electricity: 1640 Oil: 210
8th year of operation Maintenance: 160

User Questionnaires Replies: 27 replied 85% success.

Byron Sportshall

Capital Costs. Envelope: 61900 Servicing: 14700 Total Building: 76600
UBA: 1418m^2 Roof Prefab.: N/A Roof Import.: N/A Total Roofing: 16600

Running Costs Salaries: 11290 Consum.: 1060
Electricity: 390 Oil: 510
6th year of operation Maintenance: 690 7th year of operation Maintenance: 500
8th year of operation Maintenance: 270 9th year of operation Maintenance: 300
10th year of operation Maintenance: 330

User Questionnaires Replies: 26 replied 80% success.

Arta Sportshall

Capital Costs. Envelope: 67600 Servicing: 19800 Total Building: 87400
UBA: 1692m^2 Roof Prefab.: 14400 Roof Import.: 14400 Total Roofing: 17200

Running Costs Salaries: 17080 Consum.: 1870
Electricity: 630 Oil: 110
11th year of operation Maintenance: 209 12th year of operation Maintenance: 313
13th year of operation Maintenance: 550

User Questionnaires Replies: 25 replied 80% success.

All prices in thousand drachmas in 1985 constant prices.

Parameters	Indic.	Individual All	Individual Athl.	Individual Oth.	Total All	Total Athl.	Total Oth.
HVAC	*Temp.*	.6	.7	.4	.4	.4	.3
	AirQ.	.4	.4	.4			
	Vent.	.1	.2	.1			
LIGHT	*Natur.*	.8	.8	.7	.8	.9	.7
	Glare	.9	.9	.8			
ACOUST	*Echo*	.5	.5	.7	.6	.6	.6
	Noise	.6	.7	.6			
FUNCT	*Maint*	.4	.4	.3	.6	.6	.4
	Safe.	.7	.8	.6			
	Visib.	.5	.7	.2			
AESTH	*Inter.*	.6	.5	.8	.6	.6	.4
	Exter.	.4	.4	.4			

(*) Means rounded to one decimal point may not agree strictly

Table D.5: Peristeri Sportshall

Parameters	Indic.	Individual All	Individual Athl.	Individual Oth.	Total All	Total Athl.	Total Oth.
HVAC	*Temp.*	0	.1	-.1	0	0	0
	AirQ.	.1	.1	.1			
	Vent.	-.1	-.1	-.1			
LIGHT	*Natur.*	.2	.1	.2	.2	.2	.1
	Glare	.2	.2	.1			
ACOUST	*Echo*	.1	.1	0	.1	.2	0
	Noise	.2	.3	.1			
FUNCT	*Maint*	.3	.2	.3	.5	.4	.6
	Safe.	.5	.4	.6			
	Visib.	.7	.6	.8			
AESTH	*Inter.*	.5	.4	.7	.5	.3	.6
	Exter.	.4	.3	.6			

(*) Means rounded to one decimal point may not agree strictly

Table D.6: Mets Sportshall

Parameters	*Indic.*	**Individual** *All*	*Athl.*	*Oth.*	**Total** *All*	*Athl.*	*Oth.*
HVAC	*Temp.*	.2	.1	.3	.2	.1	.4
	AirQ.	.3	.2	.5			
	Vent.	.3	.2	.4			
LIGHT	*Natur.*	.3	.1	.5	.2	.1	.5
	Glare	.2	0	.5			
ACOUST	*Echo*	0	0	0	0	0	.1
	Noise	0	0	.1			
FUNCT	*Maint*	.5	.5	.5	.5	.5	.6
	Safe.	.4	.3	.5			
	Visib.	.7	.7	.8			
AESTH	*Inter.*	.5	.3	.7	.5	.3	.8
	Exter.	.5	.3	.8			

(*) Means rounded to one decimal point may not agree strictly

Table D.7: Hios Swimming Pool

Parameters	*Indic.*	**Individual** *All*	*Athl.*	*Oth.*	**Total** *All*	*Athl.*	*Oth.*
HVAC	*Temp.*	-.2	-.2	-.1	-.2	-.2	-.1
	AirQ.	-.2	-.3	-.1			
	Vent.	-.1	-.2	-.1			
LIGHT	*Natur.*	.1	.1	.2	.1	.1	.1
	Glare	.1	.1	.1			
ACOUST	*Echo*	-.2	-.2	-.1	-.2	-.2	-.2
	Noise	-.2	-.1	-.2			
FUNCT	*Maint*	.2	.2	0	.2	.1	.3
	Safe.	0	-.1	.2			
	Visib.	.3	.2	.3			
AESTH	*Inter.*	0	-.1	0	-.1	-.1	0
	Exter.	-.1	-.1	0			

(*) Means rounded to one decimal point may not agree strictly

Table D.8: Patra Swimming Pool

Parameters	*Indic.*	**Individual** *All*	*Athl.*	*Oth.*	**Total** *All*	*Athl.*	*Oth.*
HVAC	*Temp.*	0	0	.1	.1	0	.2
	AirQ.	.3	.1	.4			
	Vent.	0	-.1	.2			
LIGHT	*Natur.*	.4	.2	.6	.2	.1	.3
	Glare	0	0	.1			
ACOUST	*Echo*	0	.1	0	0	0	0
	Noise	0	-.1	0			
FUNCT	*Maint*	.8	.8	.8	.7	.7	.6
	Safe.	.7	.8	.7			
	Visib.	.4	.4	.4			
AESTH	*Inter.*	.3	.4	.2	.4	.4	.3
	Exter.	.4	.4	.4			

(*) Means rounded to one decimal point may not agree strictly

Table D.9: Rethymno Sportshall

Parameters	*Indic.*	**Individual** *All*	*Athl.*	*Oth.*	**Total** *All*	*Athl.*	*Oth.*
HVAC	*Temp.*	0	.1	0	.1	.1	0
	AirQ.	.2	.2	.1			
	Vent.	0	0	0			
LIGHT	*Natur.*	0	0	.1	.3	.2	.4
	Glare	.5	.4	.7			
ACOUST	*Echo*	.3	.5	0	.5	.6	.3
	Noise	.7	.7	.6			
FUNCT	*Maint*	.7	.7	.7	.7	.6	.8
	Safe.	.7	.7	.9			
	Visib.	.6	.5	.7			
AESTH	*Inter.*	.7	.7	.6	.6	.6	.6
	Exter.	.6	.6	.6			

(*) Means rounded to one decimal point may not agree strictly

Table D.10: Loutraki Sportshall

Parameters	*Indic.*	**Individual** *All*	*Athl.*	*Oth.*	**Total** *All*	*Athl.*	*Oth.*
HVAC	*Temp.*	0	0	0	0	0	0
	AirQ.	0	0	0			
	Vent.	0	0	0			
LIGHT	*Natur.*	.1	.1	0	.2	.2	.3
	Glare	.4	.3	.6			
ACOUST	*Echo*	0	0	0	0	0	0
	Noise	0	0	0			
FUNCT	*Maint*	.1	.1	.2	.1	.1	.2
	Safe.	0	0	0			
	Visib.	.3	.2	.4			
AESTH	*Inter.*	0	0	-.1	0	0	-.1
	Exter.	0	0	-.1			

(*) Means rounded to one decimal point may not agree strictly

Table D.11: Posidonio Swimming Pool

Parameters	*Indic.*	**Individual** *All*	*Athl.*	*Oth.*	**Total** *All*	*Athl.*	*Oth.*
HVAC	*Temp.*	.1	.1	0	.1	.1	0
	AirQ.	.1	.2	.1			
	Vent.	0	-.1	0			
LIGHT	*Natur.*	.1	.1	.1	.1	0	.1
	Glare	0	-.1	.2			
ACOUST	*Echo*	0	0	0	0	0	0
	Noise	0	-.1	.1			
FUNCT	*Maint*	.5	.6	.5	.3	.4	.3
	Safe.	.2	.3	.1			
	Visib.	.3	.3	.3			
AESTH	*Inter.*	.1	0	.2	0	0	.1
	Exter.	0	-.1	.1			

(*) Means rounded to one decimal point may not agree strictly

Table D.12: Galatsi Sportshall

Parameters		Individual			Total		
	Indic.	*All*	*Athl.*	*Oth.*	*All*	*Athl.*	*Oth.*
HVAC	*Temp.*	-.4	-.5	-.3	-.3	-.3	-.2
	AirQ.	-.2	-.2	-.2			
	Vent.	-.2	-.2	-.1			
LIGHT	*Natur.*	.1	.1	0	0	.1	-.1
	Glare	0	0	-.1			
ACOUST	*Echo*	0	0	0	0	0	0
	Noise	0	.1	0			
FUNCT	*Maint*	-.1	-.1	-.2	0	.1	0
	Safe.	0	-.1	.1			
	Visib.	.2	.3	0			
AESTH	*Inter.*	.1	.1	.1	.1	0	.1
	Exter.	0	-.1	1			

(*) Means rounded to one decimal point may not agree strictly

Table D.13: Byron Sportshall

Parameters		Individual			Total		
	Indic.	*All*	*Athl.*	*Oth.*	*All*	*Athl.*	*Oth.*
HVAC	*Temp.*	-.2	-.3	-.1	-.2	-.3	-.2
	AirQ.	-.2	-.3	-.2			
	Vent.	-.3	-.3	-.2			
LIGHT	*Natur.*	0	0	0	0	0	0
	Glare	0	-.1	0			
ACOUST	*Echo*	0	0	0	0	0	0
	Noise	0	0	0			
FUNCT	*Maint*	.1	0	.2	.1	-.1	.2
	Safe.	-.1	-.3	.1			
	Visib.	.2	.2	.3			
AESTH	*Inter.*	.1	0	.2	0	0	.1
	Exter.	0	-.1	.1			

(*) Means rounded to one decimal point may not agree strictly

Table D.14: Arta Sportshall

Name	***GSS Model***				***Survey***			
	Res.	*HUS*	*Techn*	*Total*	*Res.*	*HUS*	*Techn*	*Total*
Co-effic.	*0.59*	*0.26*	*0.15*		*0.42*	*0.32*	*0.26*	
Peristeri	-0.03	0.39	-0.05	**0.31**	-0.02	0.49	-0.08	**0.39**
Mets	0.10	0.09	-0.09	**0.10**	0.07	0.10	-0.16	**0.01**
Hios	0.28	0.07	-0.03	**0.32**	0.20	0.08	-0.06	**0.22**
Patra	-0.27	-0.25	-0.03	**-0.55**	-0.19	-0.30	-0.06	**-0.55**
Rethymno	0.59	0.13	0.10	**0.82**	0.42	0.16	0.18	**0.76**
Loutraki	0.84	0.29	0.05	**1.18**	0.60	0.35	0.08	**1.03**
Posidonio	0.05	-0.14	-0.03	**-0.12**	0.04	-0.17	-0.06	**-0.19**
Galatsi	0.32	-0.08	0.04	**0.28**	0.23	-0.10	0.07	**0.20**
Byron	-0.84	-0.22	0.08	**-0.98**	-0.60	-0.27	0.13	**-0.74**
Arta	-1.05	-0.28	-0.03	**-1.36**	-0.75	-0.34	-0.05	**-1.14**

(*) Using athletes only replies in HUS and the average operating costs in Rethymno Sportshall

Table D.15: Standard Scores of the Overall Analysis

Appendix E Photographs of the Sample's Buildings

E.1 Peristeri Sportshall

Figure E.1 South View of Peristeri Sportshall

Figure E.2 Interior View of Peristeri Sportshall from Seating Area (artificial lighting on)

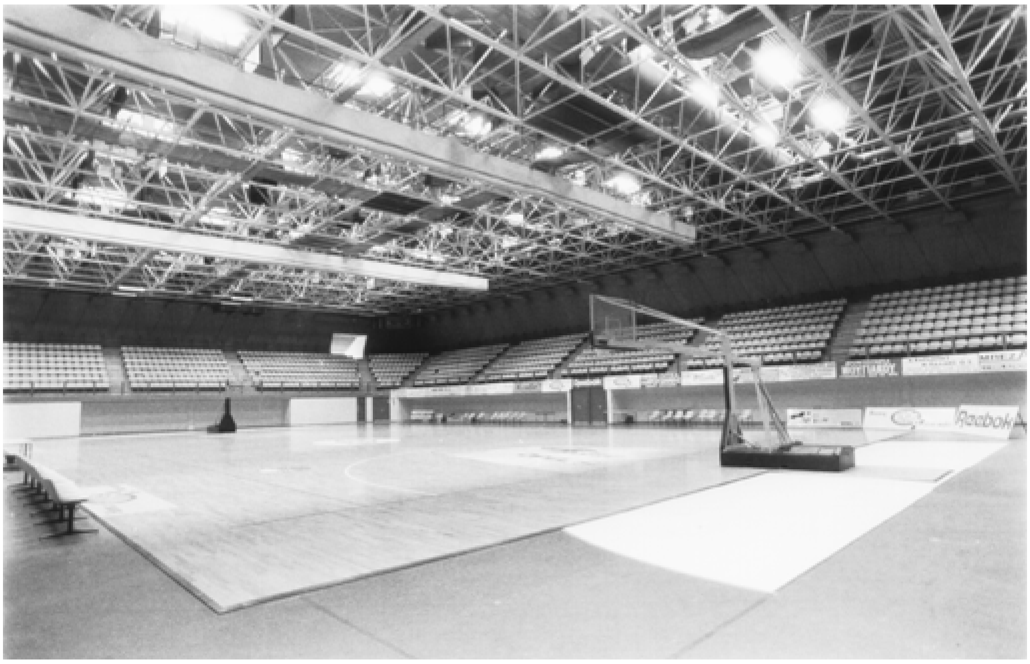


Figure E.3 Interior View of Peristeri Sportshall from the Playing Area (daytime all artificial lighting on)

E.2 Mets Sportshall

Figure E.4 North West Interior View of Mets Sportshall from the Playing Area

Figure E.5 South West Interior View of Mets Sportshall, Glare Effects from the South Facing Glazing

E.3 Hios Swimming Pool

Figure E.6 West Facing View of Hios Swimming Pool from the Seating Area

Figure E.7 Interior View of the Fabric Tent from the Athletes Perspective

E.4 Patra Swimming Pool

Figure E.8 South East View of Patra Swimming Pool

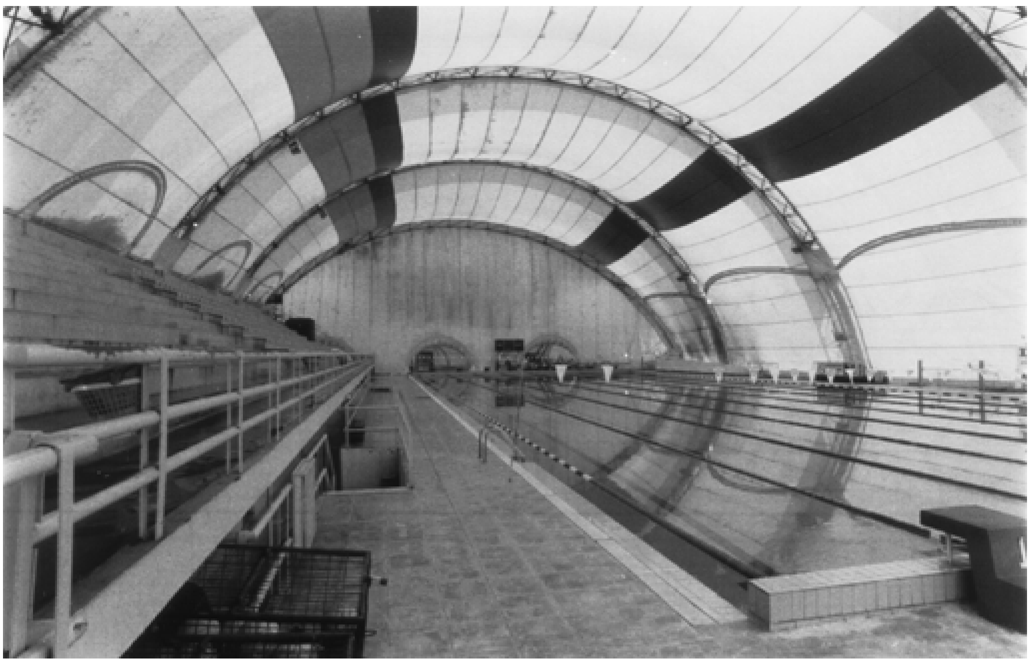


Figure E.9 Interior View of Patra Swimming Pool (daytime no artificial lighting)

E.5 Rethymno Sportshall

Figure E.10 Interior View of Rethymno Sportshall from the Searing Area (evening game, artificial lighting on)

E.6 Loutraki Sportshall

Figure E.11 South East View of Loutraki Sportshall

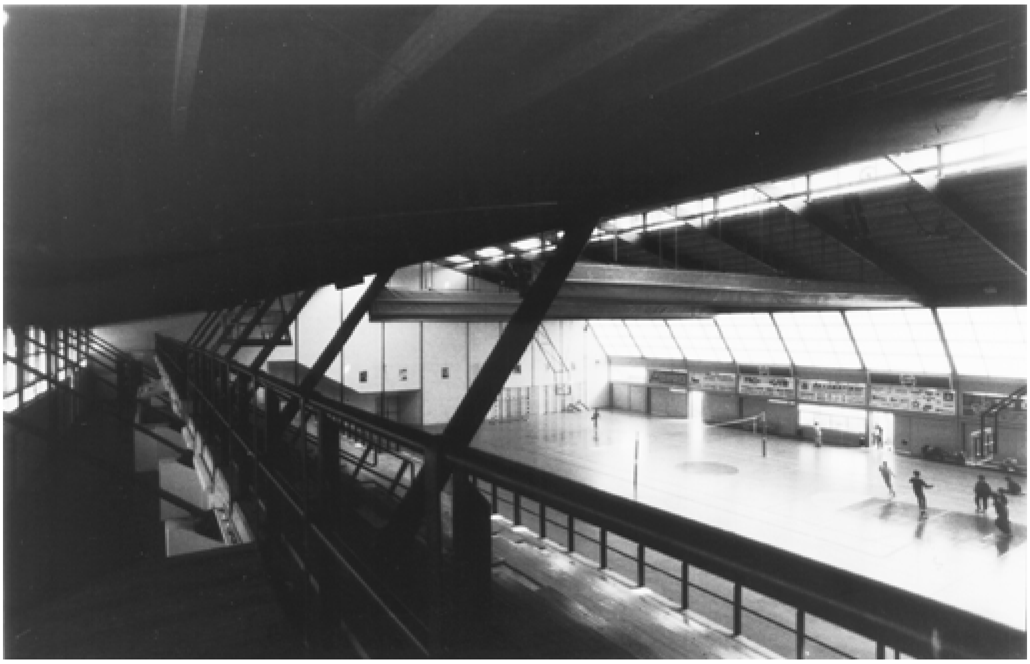


Figure E.12 Interior View of Loutraki Sportshall from the Seating Area (high contrast between natural lighting in seating versus playing area)

Figure E.13 Interior View of Loutraki Sportshall from the Seating Area (note two sources of natural lighting, north windows and north rooflight)

E.7 Posidonio Swimming Pool

Figure E.14 Daytime Interior View of Posidonio Swimming Pool

Figure E.15 Detail of Beam to Tent Connection in Posidonio Swimming Pool

Figure E.16 Interior Detail of Beam Mounting in Posidonio Swimming Pool

E.8 Galatsi Sportshall

Figure E.17 Interior View of Galatsi Sportshall (daytime natural lighting only)

Figure E.18 Interior View of the South Facing Windows of Galatsi Sportshall; note U.V. affected translucent window material ("isobelec")

E.9 Byron Sportshall

Figure E.19 East View of Byron Sportshall

Figure E.20 Interior from the Seating Area (daytime, natural lighting only)

Figure E.21 Interior of Byron Sportshall from the Playing Area (early afternoon view, glare from the southwest facing windows)

E.10 Arta Sportshall

Figure E.22 South West View of Arta Sportshall

Figure E.23 Interior View of Arta Sportshall from the Playing Area

Figure E.24 Interior View from the Seating Area (daylight view)