Contractors management functions: an integrated approach for planning, estimating and control

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by

José Manuel Cardoso Teixeira (Civ. Eng., MSc.)

A doctoral thesis submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of the Loughborough University of Technology.

1993.

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Dedication.

To my wife Ana,
my parents,
and my daughter Xana, whose persistent
difficulties in falling asleep provided long time
everyday for profitable reflection upon this
work.
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Abstract.

Planning, estimating and control management functions as performed by Portuguese construction companies were studied. For this purpose, inquiries were made into the way a set of Portuguese contractors carried out these tasks, with special reference to planning, estimating and the preparation of data for control during the pre-contract stage. There is a lack of integration among those functions in the current practice of companies surveyed. This is a problem that companies would like to see solved. Data systems analysis was used to tackle the problem. It was concluded that there is no functional dependency between planning and estimating in most construction projects. This is especially due to the form in which data is structured in the basic documents currently used for those functions (the bill of quantities for estimating and the construction programme for planning). A possible integrated approach to planning and estimating is suggested by considering construction works assigned both to the items of the bill of quantities and to the activities of the construction programme. This facilitates the preparation of data for control on site because costs and time are closely related in this approach. A model for the integration of planning and estimating management functions during the pre-contract stage of construction projects is presented. The model also enables one to achieve efficient preparation of data for control on site. Computer support for the model is also presented. This is based on a Database Management System which provides for an adequate environment for the model. The model was tested in some Portuguese construction companies, and led to satisfactory results. Those companies highlighted the advantage of building up the model upon a relational database which makes data manipulation and retrieval easier and allows for integration among management functions.

Keywords: construction, contractors, management, estimating, planning, control.
Declaration.

No portion of the research referred in this thesis has been submitted in support of an application for another degree or qualification at this or any other University or other institution of learning.
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AI Artificial Intelligence.
AICCPN Associação dos Industriais da Construção Civil e Obras Públicas do Norte (Northern Association of Portuguese Contractors).
AR Average Revenue.
ASCE American Society of Civil Engineers.

BBI Banco Borges & Irmão (Borges & Irmão Bank).
BP Banco de Portugal (Bank of Portugal).
BPF British Property Federation.
BQ Bill of Quantities.
BRE Building Research Station.

CENFIC Centro de Formação Profissional da Indústria da Construção Civil e Obras Públicas do Sul (Centre for Professional Training of the Construction and Civil Engineering Industry of the South).
CESM Civil Engineering Standard Method of Measurement.
CPM Critical Path Method.

DBMS Database Management System.
DCP Departamento Central de Planeamento (Central Planning Department).
DIY Do It Yourself.

ES Expert System.

GBP Great Britain Pound.
GDP Gross Domestic Product.
GDFCP Gross Domestic Fixed Capital Formation.
GERT Graphical Evaluation and Review Technique.
HW Hourly Wages.

INE Instituto Nacional de Estatística (National Statistics Institute).
INIC Instituto Nacional de Investigação Científica. (National Research Institute of Science).

LNEC Laboratório Nacional de Engenharia Civil (National Laboratory of Civil Engineering).
LUT Loughborough University of Technology.

MC Marginal Cost.
MR Marginal Revenue.
MR Bill Method-Related Bill of Quantities.
MW Monthly Wages.

PERT Project Evaluation and Review Technique.
PPP Purchasing Power Parity.
PTE Portuguese Escudos.

RJEFOP Regime Jurídico de Empreitadas e Fornecimentos de Obras Públicas
(Legal Regulation for Contracts and Supplies for Public Works).

SMM Standard Method of Measurement.

TC Total Cost.
TP Total Profit.
TR Total Revenue.

WNWP Weekly Normal Working Period.
CHAPTER ONE

Introduction.

1.1 Background to the problem.

This thesis describes research into construction management functions as performed by Portuguese construction companies. In this first section the background leading to the formulation of the research hypothesis is explained.

The need for integration of the activities related to the management of construction projects appears to be widely recognised. Lack of integration among management functions usually performed by the contractors' organisations during the construction phase has been widely reported. With the aim of achieving integration, some solutions have been proposed, but a definite approach to the problem has not yet been agreed. This topic is discussed in sub-section 1.1.1.

A survey of Portuguese construction companies undertaken as part of this research also indicates that integration among management functions is seldom achieved in their common practice. This has been confirmed by the results of two inquiries reported in chapters 3 and 4 and referred to in the second part of this section.

Integration during the design phase is less well recorded, but a set of unstructured observations of Portuguese project promoters (made by the present author), shows that problems also exits in the clients' approach. This is briefly reported in sub-section 1.1.3.

1.1.1 Historical background.

Lack of integration among contractors' management functions has been often reported in the literature. Pasquire and McCaffer [1] observe that much of the data used is reworked by each function group in order to perform their tasks. Kodikara [2] refers to repetition and regeneration of data and Bowman [3] finds
duplication of both data and task in the common practice of construction contractors. Ndekugri [4] states that the effort required to carry out the manipulations and transfers of data necessary for integration is great. Ndekugri and McCaffer [5] find that the construction industry has always been bedevilled with great difficulties in sharing information among its participants. Lewis, Duff and Emsley [6] stated that estimating, planning and control of construction activity suffer from a lack of comprehensive, consistent and accurate data for the building-up of labour and plant schedules and costs. The form in which data is structured has been generally recognised as a considerable obstacle for integration. Betts [7] refers that project data within current formats prevents the smooth transfer of information among management functions. Estimating is usually the function responsible for the generation [8] and assembling [9] of initial data within the contractors' organisations. It is often mentioned that the flow of this data to other functions is limited by its format [9] and it has been suggested that it should be compiled in a way to be more easily used by other management functions [8]. Moreover the form of the contract documents has been mentioned as the main barrier to achieve integration [9] and to the design of integrated computer systems [10]. Particularly Bills of Quantities have long been highlighted as the major impediment for integration.

Indeed, criticism of Bills of Quantities is an ancient topic in the literature. In 1949 Fitzmaurice [11] considered them unsuitable for costing because the schedule is summarised by trades and not by operations. Traditional Bills of Quantities are viewed by some authors as mainly serving contractual purposes and thus not completely satisfactory [12]. Others refer to their inadequacy for financial control [13], [14] and to the tendency to use them inconsistently with reason [15]. More recently, Blyth and Skoyles [16] stated that the Bills of Quantities do not explicitly show the working form of operations and referred to the incompatibility of estimating with the production process. Singh and Banjoko [17] concluded that traditional bills of quantities are inadequate conceptually and functionally.

Some alternative arrangements to Bills of Quantities which have been suggested in the last years may also be understood as a clear effort towards integration. One of the most relevant works in this field was initiated by the Building Research Station (BRE) some 25 years ago. Operational Bills have
been proposed as a rational attempt to provide the builder with a document better suited than the conventional bill to the pricing, planning and control of building work [18] and to relate estimating methods to the way in which money is spent on site [19]. The basis of Operational Bills were the site operations involved in construction [20]. Operations were defined as the work done by a man or gang of men in some definite stage in the building process [19]. They were the units for estimating and pricing labour [21]. Their sequence was shown on a precedence diagram evidencing their inter-relations. Some practical examples of the use of Operational Bills have been reported [21]. In some cases design has also been integrated in the process [22].

Operational Bills are not only an alternative document to the traditional Bills of Quantities but also represent a significantly different approach to estimating (especially for the case of buildings) from the traditional unit rates. Nevertheless, practical applications of Operational Bills showed that a mixed solution would be of more immediate advantage ie a bill incorporating the production bias of the operational breakdown but retaining familiar methods of measurement and pricing using unit rates [23]. Bills of this intermediate type were initially given the name of Activity Bills [24] to distinguish them from the earlier Operational Bills, but it was later proposed that they should be called Bills of Quantities (Operational Format) [23]. Conventional methods of measurement are used in this new approach but operations remained the units under which the labour involved can be identified and recorded [25], [26]. This solution led to a compromise format for Bills of Quantities which utilised the British Civil Engineering Standard Method of Measurement (CESMM) [27] rules although work was represented in an erection sequence order [28]. Nevertheless, operational format of bills appeared over-complex to many and some problems arose in replacing the traditional unit rate estimating system by one geared to operational and production sequences [28]. For some authors, the construction industry was not ready for such innovatory changes [29]. Baldwin [9], states that operational formatted bills failed to make the impact they had hoped and are not in common use.

Following this work of BRE, further developments of the operational approach have been suggested in the literature. These mainly resulted from practical experience of the users, especially the Scottish National Building Agency.
Quantity Surveyors [30], [31]. Also, other similar approaches normally supported by SMM have been suggested in the literature thereafter. Elemental Bills of Quantities [32], and Communicative Bills of Quantities [20] for example, are two of these enhancements. An interesting extension of the latter allows for the separate analysis of labour, plant material and overheads within each activity. Smith [29] reports the results of an inquiry among the users of Communicative Bills showing that the majority found them useful in some ways but the proposal to convert the bill to an elemental format was not favourably received.

Other alternatives to the traditional bill of quantities specially aiming a better suited document for control have been suggested in the literature. Barnes [33], [34] developed the Method-Related Bill of Quantities (MR Bill) but although its principles have been incorporated into the CESMM yet it is not widely used [17]. Banjoko, [35] suggested six rational forms of bills which were evaluated for the satisfactory financial control of civil engineering projects [17] and eventually one of those forms was recommended. However, no practical use of this work has been reported so far.

Integration seems to meet the clients interests too. The British Property Federation (BPF) proposed that the traditional Bill of Quantities and the tender programme would be advantageously replaced by a Schedule of Activities Document consisting of a list of priced activities [2]. Therefore financial information would be directly linked to the programme for the works [2] and payments would be made on the basis of completed activities [36]. In order to support this approach, BPF produced its Manual for the BPF System for Building Design and Construction [37]. Although some projects have been contracted under the BPF system, lack of general utilisation has been reported [38]. Also it was found that under BPF contracts estimators usually produced their own bill of quantities from which a schedule of activities was subsequently prepared just to deal with the client and its consultants [39]. Moreover, schedules became progressively more complex as the number of activities included was successively augmented by the construction companies with the obvious intention of making the schedule resemble the traditional bill.
Computers have long been recognised as an important tool to improve integration among construction management functions. In the early 1960's the Committee for Application of Computers understood that construction industry applications should be so constructed that data once input to the computer is subsequently available in an appropriate form for use not only by the user but by all other users that require the information at any stage of design and construction [40]. Taking this statement as a general objective, further work on the subject aimed at assessing a framework that could serve to co-ordinate an information based information system with large scale integration on the horizon [40]. It was expected that computer applications in the construction industry would contribute greatly to achieve integration of industry-wide processes [40] but those that have been subsequently developed mainly work as "stand-alone" systems. Lack of integration among those programs has been recognised as involving substantial duplication of work but full integration would be difficult and costly [41]. However, several disadvantages of "stand alone" systems have been reported such as [4]: costly data capture, poor management of computer resources, inconsistency, inflexibility, etc.. Ndekugry [5] refers to the lack of software to meet the established need for more effective integrated computer systems.

Earlier approaches to the problem of integration attempted to use the part of the project documentation which reflects the contractor's price of the project (eg Bills of Quantities, Operational Bills, etc.) as the basis for management of the resources and costs. However, it is the resources required which generate costs and schedules [42]. Due to the fact that none of those documents facilitate the identification of the resources needed nor their specific costs, and they also do not successfully reflect how construction costs are incurred on site, they cannot be used as a reliable data base for the implementation of the intended solution [42]. Therefore the management effort should be supported by other documents that explicitly take resources into consideration, because neither the traditional Bills of Quantities nor any of the alternative documents discussed above are suitable for use alone as a reliable tool for that purpose. They must be complemented by other documents in order to fulfill the requirements of project management both in the client's perspective and in the contractor's perspective. Indeed, they are just a particular view of the project's data, suitable as a vehicle for the contractor to offer a price [42].
Moreover, integration of time and cost has also a great importance during the project execution on site for both clients and contractors. Actually, for the successful completion of any project, both time and cost have to be carefully planned, monitored and controlled [43]. These parameters are obviously interdependent [43] and should be closely related in order to assess the true position of the project at any time [44]. According to Bennet [45], beyond cost, clients are becoming very interested in the time parameter because they are increasingly concerned to get their buildings quickly [45]. Frame [46] adds the human and material resources to the above two parameters and discusses the three dimensional characteristic construction plans must have. Therefore, the relationship between estimating and planning appears to be of paramount importance for the preparation of data to be used during the project execution on site [47].

1.1.2 Planning estimating and control on the behalf of Portuguese construction companies.

Because this thesis is about Portuguese industry, it seemed of great importance to review the way Portuguese contractors undertake and interrelate the planning and estimating management functions. Unfortunately, it was not possible to find any previous relevant work on this topic. Therefore it was decided to collect data directly from the industry. This was achieved by means of a set of four inquiries to construction companies, construction clients and software vendors.

Inquiring is a powerful method of system analysis aiming at obtaining information on a particular subject form a selected set of individuals. Other methods (eg literature survey, record inspection etc.), were also considered but the lack of published reports on the subject made them unsuitable.

Inquiries often make use of questionnaires. In this context, questionnaires cannot be viewed as just a set of questions but as a complete document comprising questions and texts which supports data collection [48]. Moreover, it avoids forgetting to ask relevant questions to the participants in the inquiry,
helps to structure information according to a pre-established scheme and provides for important time savings [49]. The questionnaire may be administered by interview, by mail, by telephone, etc. [50]. Interviews provide for extensive discussions with the participants in the inquiry and allow for obtaining information from knowledgeable people [49]. Structured interviews [51], (ie supported by a questionnaire), were used in the inquiries reported in chapters 3 to 5 and briefly referred to hereafter. Inquiries to contractors' and to clients' organisations were supported by questionnaires administered in the course of interviews to the staff involved in management functions. The trading departments of software vendors were contacted directly about the products they could offer.

Initially, a thorough study of the activities related to construction project management on the contractor's behalf was foreseen. This was attained by means of an inquiry to a small sample of construction companies. This work is reported in chapter 3. The inquiry was supported by a questionnaire which was administered directly to each selected company during a set of interviews with their staffs. Answers from companies are listed in Appendix 1.1 - Detailed Inquiry to 5 Portuguese Construction Companies.

During the development of the inquiry it was concluded that planning and estimating largely depend on the requirements of production control. This led to the enlargement of the initial objectives of the inquiry in order to take control into consideration.

The conclusions of the inquiry show that its objectives have been reached. The most important for the moment are summarised below:

1 Estimates are normally based on traditional bills of quantities (bq) either purchased by the client or specifically generated by the contractor. Beyond their importance as a tender document, priced bqs are extensively used for work valuations on site and are often used for discussion of unit prices for un-predicted works.

2 Unit rate estimating is generally adopted for direct cost evaluation of building projects. Computer based estimating using unit rates is now current.
3 The accuracy of planning is variable throughout the project development. Planning efforts are usually greater after commitment than during the pre-tender stage. Computer based planning is normally restricted to network scheduling.

4 Re-analysing the project after commitment (including new measurements, a new assessment of the project costs and a bigger effort in planning) is recognisably advantageous for production. This takes place during the pre-contract stage which is often called the production preparation stage.

5 Production control is generally supported by the information contained in the bill of quantities. Companies are mostly concerned with cost control although the control of the other resources involved in production has also been found.

Lack of integration among planning, estimating and control management functions could be understood from the common practice of the surveyed construction companies. Main reasons for this are listed below:

1 Planning and estimating are done separately, in different time instances, and often carried by different people throughout the project life.

2 Information seems to flow typically in one direction, ie from estimating to planning and not the other way. Still, it has to be re-arranged in order to be used.

3 Control is mainly supported by the outputs of estimating and so information generated by planning has little interest for production management purposes.

4 No integrated computer approach dealing with estimating, planning and control could be found in use.

After considering these results and some informal discussion with construction professionals it was concluded that a model for the integration of the surveyed management functions would be useful. A two-phases development for the model seemed advisable:
1 in the first place, it should include planning, estimating and the preparation of data for control;

2 other aspects of the project control on site would be attached later.

Once the idea for the integrated approach has been roughly established, it was decided to survey some construction companies specifically about it. This was achieved by means of an inquiry directed to a large number of construction companies. This work is reported in chapter 4. The inquiry was supported by a questionnaire which was administered directly to each selected company during an interview with their staffs. Answers from companies are organised in table A1.2.1 of Appendix 1.2 - Specific Inquiry to 21 Portuguese Construction Companies.

The inquiry aimed to survey the companies' receptiveness of the idea and to check the most important findings of the previous inquiry. Main results of the inquiry may be extracted from inspection of table A1.2.1 and are summarised below:

1 Main findings of the first inquiry have been confirmed. Additionally, it is of interest to note:

1.1 no alternative arrangement to the traditional bill of quantities could be found in use by the surveyed companies;

1.2 unit rate estimating is typically used for building projects whereas operational estimating is often used for civil engineering projects.

2 Lack of integration among the contractor's management functions has been widely recognised.

3 The idea of integrating the planning, estimating and control management functions has been generally approved.
4 Companies understand that the development of specific construction computer software is still needed. Accordingly, the suggested model should be supported by a computer programme but existent partial solutions could be used as a starting point for the integrated approach.

The results of this inquiry led to the enlargement of the fundamentals for the idea for the integrated model suggested above. Moreover it has been decided to restrict the scope of this thesis to the first sub-phase mentioned above. Firstly, because of the relevance of the pre-contract stage in achieving integration among management functions. Secondly, because the full integration of control is only attainable after the first sub-phase has been implemented in the companies. Thirdly, because of the limitations of time that would possibly prevent the carrying out of the whole task.

The perspective of the construction companies has been the focus of the two inquiries mentioned above. However, the perspective of the clients during the construction phase is also relevant because they use data generated by the contractors. Therefore, it seemed of interest to survey how clients regard the quality of time and cost data delivered by contractors.

It was decided to collect some opinions from a restricted number of Portuguese clients by means of a small inquiry. This work is reported in chapter 5.

The conclusions of this inquiry confirm the importance of the bill of quantities in construction contracts both as a tender document and to support tender valuations on site. The clients surveyed understand that estimating techniques used by contractors are sufficiently accurate but planning should be improved. Actually, construction programmes are seldom sufficiently detailed for the project execution to be efficiently monitored and they often bear little relationship to the project costs.

Therefore it seems that integration between planning and estimating would help contractors to produce more reliable data which could match the interests of both clients and contractors.
Following the main conclusions of the second inquiry, the suggested model should be supported by a computer programme. Moreover, existing partial solutions could be used. Therefore, it was decided to survey the existing software to support estimating, planning and the preparation of data for control of construction projects and to search for possible integrated approaches. This was carried out by means of an inquiry directed to the Portuguese software dealers. This work is reported in chapter 5.

Main findings are listed below:

1 Satisfactory software packages for unit rate estimating and for scheduling could be found. However, integration between estimating and planning is not acceptably achieved by any of them.

2 Some estimating packages include the preparation of data for control, but this is based on the tender bill of quantities and not on the construction programme for the works.

3 Planning packages require the user to enter all data for resource allocation to activities.

Therefore, it seems that computer software currently available in Portugal does not support an integrated approach for planning, estimating and control management functions. Moreover, during the inquiries to the Portuguese construction companies, no software tool fulfilling these requirements was found.

1.2 Research hypothesis.

Against this background, the following research hypotheses were formulated:

1 A model for the integration of contractors' management functions which provided for extensive interchange of elementary data, would overcome the difficulties due to the different structures of data traditionally used by those functions.
2. If a computer system could be developed to support the practical use of such an integrated model, then better efficiency would be reached by contractors' organisations in achieving integration between estimating, planning and the preparation of data for control. The efficiency of the computer system could be assessed by comparison to current procedures through the following criteria:

- the amount of data duplication and regeneration which is limited or avoided;
- the adequacy of the output data for the requirements of estimating, planning and the preparation of data for control;
- the improvement in data interchange between management functions;
- the suitability of the intermediate data used by the program for estimating, planning and the preparation of data for control;
- the generation of data for subsequent management functions not supported by the program;
- the data structures to be adequate for construction management functions as performed by Portuguese contractors;

Moreover, the above set of criteria could be taken as a measure of integration performance of the computer program.

1.3 Aims and objectives.

The general aim of this study may be summarised as follows:

To investigate the integration of planning, estimating and control management functions in Portuguese construction projects.

The sub-aims of the study are as follows:
to establish the methodology followed by Portuguese construction companies in performing estimating, planning and control management functions;

to generate a model for the integration of estimating planning and the preparation of data for control in Portuguese construction companies;

to develop a computer system to support the integrated model.

According to the survey of the Portuguese industry as referred to in section 1.1.2, the need for integration is especially felt during the construction stage of project development. Accordingly, suggested solutions will be chiefly designed for this stage and the contractor's perspective will be particularly relevant. The scope of the study is discussed in section 1.5.

1.4 Research methodology.

The need for the integration of construction management activities is widely recognised. However, lack of integration among management functions usually performed by the contractors' organisations during the construction phase has been reported in the literature. Therefore, the first step in this research was to review relevant literature on the subject with the following aims:

- to identify the extent of the problem;
- to survey previously suggested solutions;
- to appreciate the effectiveness and the usefulness of those solutions.

Despite the importance of construction project management, Portuguese literature on this topic is hard to find [52]. Therefore, other sources of data have been used, especially from a survey of the British and American literature on the subject. The American approach to construction project management was found to be different in many ways from the European one. From the experience of the author, the British approach seemed to be closer to the Portuguese, although some relevant differences could be found. This will be further mentioned throughout the thesis. Furthermore, the lack of support from
Portuguese bibliography has been partially covered by direct inquiries to various parties as mentioned below.

The second step was to survey the current practice in Portuguese construction industry. This was achieved by means of a set of four inquiries aiming at:

- studying the way contractors perform the activities related to the management of their projects;
- surveying a set of contractors on the development of an integrated approach for management functions;
- understanding the receptiveness of construction clients to the idea;
- searching for the adequacy of existing computer programs to support contractors' management functions.

The inquiries were organised following a comprehensive frame presented by Javeau [50]. Other readings (e.g., Santos [53], Boudon [48], Stephenson et al. [54], etc.) helped the author through the world of Sociological Research Methods. Inquiries are fully described in chapters 3 to 5. The methodology used to carry them out is also explained therein.

The next step was the development of an integrated model supporting estimating, planning and the preparation of data for control.

Firstly, the way Portuguese construction companies perform planning and estimating management functions during the pre-tender stage was examined. The results of the inquiries mentioned in the previous step were used.

Secondly, an identical study was undertaken for the pre-contract stage. The results of the inquiries mentioned in step 2 above were used.

The structures of the data used to perform these management functions
were investigated and data flow charts during the pre-tender stage and during the pre-contract stage were established. The results achieved previously were used in this process.

Finally, the integrated model was formulated using a data systems analysis procedure. The methodology used is explained in chapter eight.

The seventh step was devoted to the development of a computer software package supporting the integrated model. This involved the selection of a database management system, a methodology to build up the data files and the generation of the software necessary to perform operations with data. This process is fully described in chapter nine.

The validation of the model was undertaken continuously throughout the development of the study. However, the final validation with real data in construction companies was only possible after computer support for it had been provided. Therefore, it took place after all the preceding steps were accomplished and the computer prototype was available. The methodology followed for the validation process is fully described in chapter ten.

Finally, conclusions of the work undertaken are described in chapter eleven.
1.5 Scope.

Construction is mainly a project oriented activity. A project is an organised endeavour to accomplish a specified non-routine or low volume task [55], [56]. Portuguese construction projects generally involve a great number of participants such as [57]:

- **the owner** (the client) - the promoting organisation;

- **the design team** - the entity that undertakes the design for the facility
the constructor - the entity which contracts with the owner the construction of the facility or some part of it;

the user - the entity that uses the facility;

the local, national or international authorities involved in the project.

Some of these may possibly be the same (eg the owner and the user in a D.I.Y. job, the owner and the constructor for in-house construction, etc.). However, the general case of distinct participants will be assumed.

A construction project, like any other project has a specific time and place location. Thus, it may be compared to a living thing. It is generally assumed that the project begins when the idea of building a facility comes to the mind of the client. Darnell et al. [58] state that the projects end when it is decided that one of the conditions exists, viz:

the objectives have been attained;
the operational objectives have not been attained and further resources must be committed to do so;
the objectives will never be attained.

The life of a construction project may be divided into several phases from inception to completion. Typically, the project will pass through the following phases:

conceptual design;
preliminary design;
detailed design;
construction;
start and commissioning;
utilisation.

A simplified three-phase division may also be envisaged [59]:

the concept/design phase;
the construction phase;
the utilisation phase.

Many authors have suggested a closer division of these phases, particularly for the construction phase (McCaffer and Baldwin [60], Oxley and Poskit [61], Pilcher [62] etc.). Specifically, a distinction between the pre-tender stage and the contract stage within the construction phase is often considered. Sometimes, this latter stage is divided into the pre-contract stage and the contract stage of work on site [62]. This will be further returned to throughout the thesis.

The main participants in the concept/design phase are the client and the design team. The client usually contracts the design of the project with the design team. Despite the possible advantages of the participation of construction companies in this phase [63], this is normally restricted to turnkey projects.

The main participants in the construction phase are the client, the construction companies and the suppliers of materials and construction parts. The client usually contracts the project execution with the construction companies and sometimes with some suppliers too. However, generally clients only contract construction companies and these make their arrangements with suppliers thereafter.

Users are the main participants in the utilisation phase although these may also be clients and/or construction companies.

Management of a construction project is undertaken by the participants involved in it according to their attributions, competencies, and responsibilities. Because the skills and tasks differ, both the participants and their duties may vary throughout the project life.

Only the concept/design phase and the construction phase will be object of this study. The flow of resources required to carry out the project is much higher during these two phases than during the utilisation phase. Also, the design/build concept is more common in the construction management
literature and it is closer to the project management approach. Furthermore, Management of Utilisation is currently regarded as an important independent subject [64].

For the aims of this study, it is assumed that the concept design phase starts when the client decides to construct a facility; similarly, it is assumed that the construction phase starts when an offer is requested to build the facility. Therefore, the involvement of a construction company in the project begins with the tendering process; its further participation in the contract depends on whether it is selected to carry out the works.

Nevertheless, the increasing tendency [65] of overlapping design and construction makes this division somehow artificial. Beyond the possible need for some overlap, inherent time gains may lead to cost savings to the client. However, excessive overlap may be counter-productive [52] and result in losses [66].

This thesis refers to Portuguese construction projects. Its subject may be included in Construction Project Management topics. This is a field which uses the concepts of Project Management in the environment of construction projects. Project Management is distinct from Business Management [67], [68]. It can be viewed as a particular topic within Operations Management in a project-type production process [69] as is normally the case in construction. Therefore, it is also understood as an important issue in the Construction Management discipline, because this deals with all the topics which pertain to the process of constructing buildings and other facilities [70].

The American Project Management Institute identifies six basic functions that project management must address [55]:

scope of the project;
human resources involved;
communications;
time;
costs;
quality.
Other authors (O'Neil (1989) [72], Ahuja (1984) [73], etc.) have been suggesting other areas of concern, but time, costs and quality seem to deserve a general consensus [74] as they are the classic design and construction objectives [75]. Moreover, these are inter-related and inter-dependent [76]. Accordingly, only these three areas will be discussed:

- **time** - completion is required within a certain time;
- **costs** - expected costs versus benefits will enable rewards to be gained or profits to be made;
- **quality** - completion is required within criteria which measure standards achieved against standards required or specified.

The achievement of the project requirements may eventually be measured through performance criteria [72].

Quality compliance will be included in the price and schedule of the project if the participants operate under a quality programme. Quality is currently regarded as a complete process from inception to conclusion of the project and management of quality is recognised as an important independent discipline. A discussion on this topic may be found elsewhere (1). For the aims of this study, it will be assumed that estimating and planning techniques take the quality requirements into consideration.

Project management topics typically address the owners' side or the contractors' side [74] and so it may be stated that two different perspectives are present in a construction project:

- **The client perspective**;
- **The contractor perspective**.

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(1) See for example Borges (1988) [56] or Ashford (1989) [77].
The participants involved in the project operate under one or the other perspective (although they are not necessarily antagonistic).

Management of the design contract (usually between the client and the design team) is not intended in this study. Furthermore, the design team often acts as a client agent during the construction phase because there is no tradition in Portugal for a construction manager acting on the client's behalf (2).

The way contractors manage their projects is largely dependent on the organisation structure of their staff [78]. In mainstream construction activity, some form of matrix management is likely to be adopted by construction firms [79], [80]. This seems to agree with a recent survey of a set of Portuguese construction companies (3). Accordingly, project management during the pre-tender stage is usually performed by head office personnel whereas it is mostly carried by site personnel after the contract has been awarded to the company. The site manager is normally regarded as the main agent from the contractor during the contract stage but his role is often restricted to the accomplishment of the contract, according to the conditions agreed with the client by other people and before his direct participation in the project [81].

Management of a construction project includes a great number of activities which may be organised in management functions. Project planning, project cost estimating and project control are three commonly accepted management functions. They have a crucial importance both from the client and from the contractor perspectives because they are about two cornerstone issues: time and costs.

Some authors tend to join them in just one or two. Ahuja [73] for example, understands estimating as an integral part of systematic planning. Stewart and Stewart [65] state that scheduling is an integral part of estimating. Drigani [82], includes planning in the scope of project control, while Laufer and Tucker [74]

(2) See Chapter 2.
(3) See Appendix 1.1.
recognise control as a function of planning. Other authors regard cost control as the main component of project control (e.g. Levi [83]) and tend to include in its scope the estimating of time and money [72]. Patrascu [84] states that both cost and schedule are integral parts of cost control and Neil [85] includes planning, estimating, scheduling and cost control in a cost engineering discipline. Estimating is sometimes considered superseded by cost planning techniques [86] thus suggesting different scopes for it. These apparent inconsistencies basically emerge from different meanings assigned to identical words.

Some additional and/or alternative management functions related to project time and cost objectives have been reported in the literature. Ndekugri [4], identifies seven different functions in the management of contracting organisations. A comprehensive description of their scope and activities included may be found in [5]. Following a survey to three construction companies, McCaffer and Pasquire [8] grouped a large set of tasks usually performed by those companies into five different function groups (management functions).

However, for the aims of this study, the previous set of three management functions will be adopted. For the sake of simplicity, they will be henceforth referred to as planning, estimating and control, the project environment being implicit.

Planning is a multi-stage multi-level process [68]. It is sometimes subdivided into specific stages throughout the project life. Each stage not only narrows down the options of the previous ones but it is often directed to different objectives. Therefore, distinct types of planning can be identified for each phase of the project development [73]. The following types of planning will be adopted:

- initial planning;
- preliminary planning;
- definitive planning;
- construction planning.
Although not always present, initial planning is sometimes necessary to identify the need and develop the concept; preliminary planning leads to the preliminary design; definitive planning leads to the detailed or definitive design; and construction planning leads to the project implementation.

The first three types of planning take place during the design phase of the project. Construction planning takes place during the construction phase and it is mainly carried out by contractors. It is expected to fully support the project implementation, and to lay the foundations for project monitoring and control [87]. However construction companies use varying degrees of detail [61] for planning depending on their involvement in the project. Actually, the contractor's planning process has been developed around the construction stages [78] mentioned above. Accordingly, a distinction between pre-tender planning and contract planning is often found in the literature (McCaffer and Baldwin [60], Oxley and Poskit [61]). Other more detailed plans showing resources in greater detail and dealing with small unit activities may be further derived [72]. In the case of in-house implementation, the construction plan would directly follow from the detailed design.

Construction planning aims to answer the following questions [84], [88]:

- **What** has to be done? (project activities).
- **How** should activities be carried out? (construction methods).
- **Who** should perform activities and with what means? (resources).
- **When** should activities be performed? (sequence and timing).

According to the aims of the research, construction planning (from the contractor's point of view), will be given special attention in this study. Moreover, planning during the pre-tender stage (tender planning), and during the pre-contract stage (contract planning) will be dealt with separately.

Similarly to planning, estimating is a continuous process progressing throughout the project development. Accordingly, distinct types of estimating normally related to each phase of the project have been reported in the literature (ACE [89], Patrascu [84], O'Neil [72], Bezelga [59], Peters [90] etc.). The following classification of estimating types will be used:
order of magnitude;  
preliminary estimate;  
definitive estimate;  
construction estimate.

The order of magnitude estimate is just a rough figure of the costs. The preliminary estimate and the definitive estimate take place during the design phase of the project. The construction estimate usually takes place during the construction phase and it is normally drawn up by the construction companies involved in the project.

A great number of estimating methods has been suggested and reported in the literature (eg Fu [91]). Their classification is generally in agreement with the type of estimating for which they are best suited. However, the following easier classification is sufficient for the aims of this section:

order of magnitude estimating methods;  
design-phase estimating methods;  
construction-phase estimating methods.

Cost estimates are predictions - the best approximation that can be made at a time - and are not expected to be accurate in the accounting sense. Their degree of accuracy is expected to improve as the project develops [92]. Acceptable degrees of accuracy for the different types of estimating have been suggested in the literature (Ostwald [93], O'Neil [72], Ahuja [73], etc.). Usual ranges are:

order of magnitude (30% - 50%);  
design-phase estimating methods (15% - 30%);  
construction-phase estimating methods (5% - 15%).

The main difference between order of magnitude or design-phase estimating methods and construction-phase estimating methods is that while the former rely on unit rates calculated from historical projects, the latter are analytical or resource based [94].
In accordance with the aims of this research, we will focus our attention on **construction estimating**. Estimating during the pre-tender stage (tender estimating) and during the pre-contract stage (contract estimating) will be dealt with separately.

**Construction-phase** estimating is normally carried by contractors. A considerable amount of data is required so that the expected degree of accuracy may be reached. This is only attainable after a thorough study of the **detailed design** and site conditions. In most cases however, these informations are not available at the pre-tender stage for the reasons to be discussed later. Therefore, a distinction between pre-tender estimating and pre-contract estimating will be made in later chapters.

Integration of construction phase estimating and planning is a corollary of the expected accuracy of these functions. Firstly because cost information is required in the construction programme and secondly because costs cannot be estimated independently from time.

**Control** aims at the achievement of the project objectives. Therefore, it is directly related to the implementation of the plans derived for the project [73]. Accordingly, the following different types of control may be identified:

- initial control;
- control of preliminary design;
- control of detailed design;
- control of contracting and construction.

**Initial control** is just a first checking of the economic feasibility of the project. **Control of design** takes place during the design phase. **Control of contracting and construction** takes place during the implementation of the project and involves both the client and the contractor.

The extend to which the client is involved in control during the project implementation largely depends on the type of construction contract. In short, it follows from the partition of the construction risks between the client and the
contractor [87]. From the contractor's point of view construction control involves measuring and evaluating performance and taking corrective action when performance diverges from plans [74]. Consequently, it is concerned with ensuring that [88]:

The participants in the project are properly briefed as to what has to be done, when and how and with which means.

Resources are available as planned and they are used effectively.

The resulting work output meets the forecast objectives (contractual requirements and benefits).

In accordance with the aims of this research, construction control will be the main objective of this study. Furthermore, the contractor's control usually appears to be more demanding than the client's control. So, the contractor's perspective of control will be pursued in order to cover the most general case.

Contractor's control involves comparing actual site performance with the plans and taking corrective action if necessary [87]. In order to achieve such control, data from construction planning should be used. Therefore, the requirements of data for control should be borne in mind during the generation of the construction programme. This aspect of integration of construction planning and the preparation of data for control will be specially studied. Project monitoring on site as well as other operational aspects of control are beyond the scope of this thesis.

Figure 1.2 shows a general chart of the project phases and the corresponding types of planning, estimating and control.

Figure 1.2 also shows the inter-related nature of planning estimating and control management functions in a construction project environment. They may be viewed as three distinct yet inter-related processes throughout the project life. It is obvious that these functions should be undertaken in the scope of a global management system because they are not expected to stand for
themselves but to jointly contribute to a larger action: the management of the project.

Figure 1.2: Project phases and the corresponding types of planning, estimating and control (adapted from [73]).

1.6 Main findings.

Integration among planning, estimating and control management functions on the construction companies' perspective has been studied.
Lack of integration among management functions has been widely discussed in the literature. Although several approaches to this problem have been suggested, none has been fully successful so far.

A set of inquiries to several parties involved in Portuguese construction projects, confirmed lack of integration among management functions in the current practice of Portuguese contractors. Fully satisfactory computer support for the management of construction projects has not been found.

A model for integration among management functions has been formulated. This has been built up by adapting current management procedures in Portuguese construction companies to the requirements of integration. Furthermore, a data systems approach has been used to tackle the problem of lack of integration.

Computer support for the model on the basis of a database management system (DBMS) has been developed leading to the generation of PECI. This is an efficient computer package which enables the practical utilisation of the model.

The presentation of the integrated model and the demonstration of PECI in construction companies revealed the adequacy of the model and the usefulness of PECI. Moreover, several suggestions aiming at further developments aiming their implementation have been collected.

1.7 A guide to the thesis.

This thesis is about Portuguese construction projects. Therefore, it seemed of interest to include an introduction to the Portuguese construction industry. This provides a better understanding of the environment in which those projects take place. This work is reported in chapter 2. Next chapters follow the research methodology according to the chart depicted below.
Figure 1.3: A guide to the thesis.
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CHAPTER TWO


2.1 Introduction.

This was written in the Spring 1990 and is based on published data on the subject and complemented with comments of the author. It provides for a general view of the Portuguese construction industry and its environment. Data was collected from a number of distinct sources as mentioned throughout the text and the author's opinions result from his perception and understanding of the construction industry in Portugal.

It is somewhat difficult to characterise the Portuguese construction industry, because the available data is neither up to date nor sufficiently reliable (1). In the next sections, reports from the following entities have been used:

* Instituto Nacional de Estatística-INE (National Statistics Institute);

* Banco de Portugal-BP (Bank of Portugal);

* Departamento Central de Planeamento-DCP (Central Planning Department);

* Banco Borges & Irmão-BBI (Borges & Irmão Bank);

* Associação dos Industriais da Construção Civil e Obras Públicas do Norte-AICCOPN (Northern Association of Portuguese Contractors).

---

(1) There is a general lack of statistical information about construction in Portugal. Data collection and analysis mainly depends on the Instituto Nacional de Estatística-INE (National Statistics Institute). However, information available is scarce and it is often released with some delay. For example, the most recent edition of the main report used to support these notes, was published in November 1989. This includes much data from 1988 but some still refers to 1987. Besides, it is sometimes inconsistent with information from other sources. In order to try to minimise these problems, a single data source has been used to support comparisons among figures from distinct years. Various remarks about the last data available and the sources used may be found throughout the text.
The most relevant reports from the INE are the *Estatísticas da Construção e da Habitação* (Statistics of Construction and Housing) [1] and the *Estatísticas Industriais* (Industry Statistics) [2], which are both published yearly.

The reports from BP are also published yearly. They are generally recognised as the most accurate source of macro-economic data.

DCP is basically concerned with forecasts. Data is usually published in the reports of the *Conselho Nacional do Plano* (Nacional Planning Board). Data from the DCP reports has been used instead of statistical data if necessary.

BBI as well as other commercial banks, usually make reports about some industrial sectors of the Portuguese economy.

AICCOPN mostly uses the above sources of data in their studies. An interesting summary is usually included in their annual directories [3]. Data collected from their associate members seems otherwise less reliable due to the poor response AICCOPN usually achieves to mailed inquiries (relevant answers are generally not more than 10%).

Additionally, some selected papers and other occasional reports have also been surveyed. Unfortunately, there is some lack of specific construction journals in Portugal, so it is rather difficult to find relevant material.

In the next section, a macro-economic approach for the construction industry is drawn. Section 2.3 is devoted to the productive point of view. In the first place, the aggregate production data is handled and the dominant activities are identified; then, the most important production sub-sectors are analysed separately; finally, some comments about each of the main production factors are added. Section 2.4 refers to the most common construction contract arrangements. In section 2.5 some basic conclusions and other remarks are briefly listed.

Portuguese money units will be used in next the sections. In May 1990, one "conto" (ie 1000 Portuguese escudos - PTE) = £ 4.0 sterling - GBP (@ about 250 escudos to the pound).
2.2 The relation of the construction industry to the national economy.

The economic and social relevance of Construction in the context of the Portuguese economy may be evaluated from some macro-economic rates. In the following analyses, the reports of BP were used to get the figures of years 1985/1988. The forecasts and the predictions of DEP were used for 1989 because INE has not published them so far.

(1) It has a significant impact in the Gross Domestic Product (GDP). In table 2.1, a comparison is made between the net output of construction and the Portuguese GDP in the last five years.

\[
\begin{array}{|c|c|c|c|c|}
\hline
\hline
\text{Construction} & 193.8 & 245.7 & 303.2 & 374.3 & \\
\text{G.D.P.} & 3 536.3 & 4 418.8 & 5 169.9 & 6 000.4 & \\
\text{Rel. Weight \%} & 5.5 & 5.6 & 5.9 & 6.2 & 6.7 \\
\hline
\end{array}
\]

(Figures in current million contos.)

The relative importance of Construction has increased in the last five years.

(2) It is the industrial sector that contributes most for the Gross Domestic Fixed Capital Formation (GDFCF). Actually, over 95% of the Construction outputs are fixed investments [4]. In table 2.2, a comparison is made between the value of construction outputs and the Portuguese GDFCF in the last five years.
Table 2.2

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>432.1</td>
<td>535.9</td>
<td>665.0</td>
<td>842.7</td>
<td></td>
</tr>
<tr>
<td>G.D.F.C.F.</td>
<td>766.7</td>
<td>986.4</td>
<td>1 037.3</td>
<td>1 680.4</td>
<td></td>
</tr>
<tr>
<td>Rel. Weight %</td>
<td>56.4</td>
<td>54.3</td>
<td>50.9</td>
<td>50.1</td>
<td>50.1</td>
</tr>
</tbody>
</table>

(Figures in current million contos.)

The decrease in the relative importance of Construction in the last three years is especially due to the increase of the investment in equipment.

(3) Construction employment makes up a significant part of the Portuguese work force. Figures from the last five years are listed in table 2.3.

Table 2.3

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>331.5</td>
<td>332.1</td>
<td>354.2</td>
<td>362.1</td>
<td></td>
</tr>
<tr>
<td>Total employ.</td>
<td>4 075.7</td>
<td>4 084.2</td>
<td>4 191.1</td>
<td>4 299.2</td>
<td></td>
</tr>
<tr>
<td>Rel. Weight %</td>
<td>8.1</td>
<td>8.1</td>
<td>8.5</td>
<td>8.4</td>
<td>8.4</td>
</tr>
</tbody>
</table>

(Figures in 1000 individuals.)

According to the last figures available (1988), Construction employed about 8.4% of the labour force but only contributed to 6.2% of the GDP. This means that it is a labour intensive industry [4].

The Government forecasts for 1990/1992 show that Construction will increase its importance in the Portuguese economy in the near future. According to a recent study [5] based on these forecasts, Construction would stand for 7% of the GDP, 53% of the GDFCF and 10.6% of the total employment in 1992.

The macro-economic rates listed above, seem to agree with identical figures from other countries. Obviously, these are slightly distinct from country to
country according to the state of development of each country [6]. Generally speaking, however, it may be stated that the importance of the construction industry in Portugal is similar to other countries’.

2.3 Production.

2.3.1 A general view.

Data about production in the Portuguese construction industry is hard to find. The main sources used in this section are the statistics published by INE [1], [2]. For the aims of the statistic studies carried out by INE, construction companies have been classified into four classes according to the number of employees [7]:

Table 2.4

<table>
<thead>
<tr>
<th>Number of employees</th>
<th>class 1</th>
<th>class 2</th>
<th>class 3</th>
<th>class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 to 19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 to 49</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 or +</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.5

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>26 269</td>
<td>26 506</td>
<td>24 739</td>
<td>25 139</td>
</tr>
<tr>
<td>Class 2</td>
<td>2 208</td>
<td>2 196</td>
<td>2 092</td>
<td>1 979</td>
</tr>
<tr>
<td>Class 3</td>
<td>828</td>
<td>804</td>
<td>851</td>
<td>808</td>
</tr>
<tr>
<td>Class 4</td>
<td>680</td>
<td>691</td>
<td>677</td>
<td>668</td>
</tr>
<tr>
<td>Total</td>
<td>29 985</td>
<td>30 197</td>
<td>28 359</td>
<td>28 594</td>
</tr>
<tr>
<td>Number of employees</td>
<td>221 456</td>
<td>208 880</td>
<td>207 329</td>
<td>217 034</td>
</tr>
</tbody>
</table>
Table 2.5 shows the evolution of the number of companies according to their classification from 1984 to 1987 (last published report) [1]. The total number of employees in Construction is also mentioned.

Some comments should be made about the figures listed in table 2.5:

(1) The number of companies referred to has been computed by means of an inquiry to a set of selected companies listed in the INE data bases. However, not all the companies therein included are construction companies in the usual sense. The following ones should be excluded:

(a) almost all subcontractors the main activity of which is not construction;

(b) some companies and entities usually classified in other activity groups that occasionally go in for self construction with their own staff for their exclusive use [7].

Taking into account these exclusions, it can be stated that the figures of table 2.5 are most probably exaggerated.

(2) The number of employees, refers to those working in the last week of each year. This does not include the temporary workers that are not busy during the Winter time. It is thus reasonable to assume that the upper figures may be low. Incidentally, an easy comparison between data from tables 2.3 and 2.5 clearly justifies the comment of note 1.

Data about the distribution of the total number of employees by each class of companies has not been published in the last few years. Last figures available refer to 1984 [1]. These are listed in table 2.6:
Table 2.6

<table>
<thead>
<tr>
<th>Number of employees</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>71 001</td>
<td>25 297</td>
<td>19 928</td>
<td>105 228</td>
<td>221 456</td>
</tr>
<tr>
<td>Relative weight %</td>
<td>32.1</td>
<td>11.4</td>
<td>9.0</td>
<td>47.5</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The total production has increased from 1984 to 1987 (last published report) [1]. Data about the evolution of the Gross Production Value (GPV) in construction and its distribution by the main construction activities in the last five years is listed in table 2.7 (figures in current million contos).

Table 2.7

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Building Construction</td>
<td>176.0</td>
<td>194.9</td>
<td>219.6</td>
<td>287.8</td>
</tr>
<tr>
<td>1.1 Housing</td>
<td>122.2</td>
<td>134.4</td>
<td>146.8</td>
<td>189.3</td>
</tr>
<tr>
<td>1.2 Other</td>
<td>53.8</td>
<td>60.5</td>
<td>72.8</td>
<td>98.3</td>
</tr>
<tr>
<td>2 Civil Engineering</td>
<td>83.3</td>
<td>91.5</td>
<td>102.2</td>
<td>127.1</td>
</tr>
<tr>
<td>3 Refurbish.</td>
<td>20.7</td>
<td>24.6</td>
<td>34.5</td>
<td>41.2</td>
</tr>
</tbody>
</table>

According to table 2.7, the construction industry sector may be divided into two main sub-sectors: Building Construction and Civil Engineering Works. The Building Construction sub-sector has a greater importance in the GPV than the
Civil Engineering Works sub-sector (about 63% vs. 30%, with the figures of 1987) [1].

Data about the distribution of the total production by each class of company has not been published since 1982. Table 2.8, reports the production structure for that year in percent over the total for three sets of companies [4].

<table>
<thead>
<tr>
<th></th>
<th>Small Companies</th>
<th>Medium Companies</th>
<th>Large Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.P.V.</td>
<td>16.7</td>
<td>21.5</td>
<td>61.8</td>
</tr>
<tr>
<td>1 Building</td>
<td>20.7</td>
<td>24.4</td>
<td>54.8</td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Housing</td>
<td>28.7</td>
<td>28.5</td>
<td>42.8</td>
</tr>
<tr>
<td>1.2 Other</td>
<td>4.8</td>
<td>16.3</td>
<td>78.9</td>
</tr>
<tr>
<td>Civil</td>
<td>4.8</td>
<td>13.8</td>
<td>81.4</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Refurbish.</td>
<td>30.2</td>
<td>20.4</td>
<td>49.4</td>
</tr>
</tbody>
</table>

Accepting no relative evolution of data from tables 2.6 and 2.8, it can be stated that over 50% of the buildings and over 80% of the civil engineering projects are executed by the larger construction companies using almost half of the total labour force.

However, the market share cannot be studied using aggregate production figures alone. Beyond the type of project and its location, there are some additional parameters that must be taken into account. The following ones are among the most important: the technology required to carry out the project, the contract conditions, the budget, the dimension of the project etc. As a matter of
fact, it seems clear that the market for small housing projects for individual clients in Valença do Minho must be different from the market for 12 storey buildings for bank clients in Porto. Unfortunately, the available data is not sufficiently detailed to enable a thorough discussion of the subject.

Nevertheless, it is reasonable to assume that the larger the projects are, the more concentrated production should be and that larger companies are likely to tender for larger projects. This does not mean however, that larger companies do not submit tenders for small projects as well. Actually, some of the largest companies have created departments within their organisations in order to deal specifically with small projects.

2.3.2 The Building Construction sub-sector.

2.3.2.1 Building technology.

According to the last statistical data available [1], 27 597 buildings were concluded in 1988. About 78% of these were for housing, 11% for industrial activities, 2% for commercial activities and 9% for other purposes. These figures give an idea of the importance of housing buildings in the Portuguese construction activity. The clients of housing projects are typically private entities.

The evolution of the technology used in building construction is hard to evidence using the available statistic data. One of the parameters included in the INE statistics is the bearing structure. This may be used to get an idea of what that evolution has been like in the last few years. In table 2.9, the total number of buildings erected in five selected years from 1973 to 1988 is divided into the six types of bearing structures referred to therein.
Table 2.9

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of buildings</td>
<td>20,110</td>
<td>23,939</td>
<td>24,527</td>
<td>27,597</td>
</tr>
<tr>
<td>Brick block walls</td>
<td>11,122</td>
<td>9,337</td>
<td>3,626</td>
<td>4,051</td>
</tr>
<tr>
<td>Stone walls</td>
<td>1,742</td>
<td>1,360</td>
<td>300</td>
<td>155</td>
</tr>
<tr>
<td>Concrete structure</td>
<td>6,041</td>
<td>7,833</td>
<td>18,073</td>
<td>21,493</td>
</tr>
<tr>
<td>Concrete block walls</td>
<td>1,175</td>
<td>5,139</td>
<td>2,466</td>
<td>1,854</td>
</tr>
<tr>
<td>Metallic structure</td>
<td>19</td>
<td>60</td>
<td>84</td>
<td>40</td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
<td>195</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

Some comments may be made about the above figures:

(1) Concrete structures have been increasingly used in buildings. Only 33% of the buildings erected in 1973 had a concrete structure, but this figure has raised to 78% in 1988.

(2) Metallic structures were only used for at most 0.4% of the buildings ever erected in a single year.

(3) The other types of structures listed in table 2.9 generally correspond to lower levels of technology [8]. This includes the use of bricks and concrete masonry units in bearing walls, due to the lack of quality.
control during their manufacturing processes. Luckily, they were only used in 7% of the total buildings erected in 1988. Furthermore, their relative importance has been decreasing in the last 15 years.

2.3.2.2 Building quality.

The quality of buildings is hard to measure not only because of the lack of statistical data but also because there is no quality evaluation system in use for the moment in Portugal. Data available refers to the basic installations of housing buildings concluded each year. Table 2.10 shows which part of the buildings concluded in four selected years had characteristics listed therein.

Table 2.10

<table>
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<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Water supply</td>
<td>77.1 %</td>
<td>86.0 %</td>
<td>93.5 %</td>
<td>99.3 %</td>
</tr>
<tr>
<td>Public system</td>
<td>52.2 %</td>
<td>51.2 %</td>
<td>61.0 %</td>
<td>72.2 %</td>
</tr>
<tr>
<td>Dom. drainage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public system</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dom. drainage</td>
<td>89.4 %</td>
<td>95.6 %</td>
<td>99.9%</td>
<td></td>
</tr>
<tr>
<td>Public system</td>
<td>27.5 %</td>
<td>35.8 %</td>
<td>47.1%</td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>86.1 %</td>
<td>93.0 %</td>
<td>98.8%</td>
<td>99.8%</td>
</tr>
<tr>
<td>Central heating</td>
<td>7.2 %</td>
<td>5.0 %</td>
<td>4.1 %</td>
<td>5.9 %</td>
</tr>
</tbody>
</table>

The figures of table 2.10 allow us at least to state that the basic installations already exist in almost all the houses which are being constructed. Central heating is obviously not usually important in Portuguese climate.

2.3.3 The Civil Engineering sub-sector.
Civil engineering works are hard to characterise. According to the last statistical data available, the G.P.V. in civil engineering works was 127.1 million contos in 1988. This value was mainly distributed among road and airport projects (33%), development projects (27%), hydraulic projects (11%) and other projects (29%). However, these figures also include the values of some projects which are not traditionally performed by construction companies. Almost all the clients of civil engineering projects are public entities.

The evolution of the technology used in civil engineering works recent years is quite sensible, especially in the case of the mechanisation of the construction processes. In fact, there has been a considerable increase in the number, the diversity and the power of plant used by the larger construction companies. There is a general conviction that Portuguese contractors have sufficient capacity to carry the National civil engineering projects with their own resources. This may be evidenced by the importance that the foreign market has in the portfolio of some of them (especially African and South American projects). Furthermore, there is a tradition of large civil engineering works due to the Portuguese presence in Africa until 1974. Some of the larger contractors had a strong position in those markets and they aim to recover it. Finally, another hint at the capacity of Portuguese civil engineering contractors is the fact that very few projects in the Country have been undertaken by foreign companies. Unfortunately, there are no statistical data that may support the above statements.

2.3.4 The production factors.

2.3.4.1 Labour.

The importance of labour in the Portuguese construction industry has already been mentioned above. The figures of table 2.3 show that construction is a labour-intensive industry. Unfortunately, it is not possible to find out the importance of labour in each construction sub-sector because data available is not suitably organised for this purpose.
Taking into account the figures of table 2.5 above, it can be stated that 83% of the total number of employees in 1987 were labourers. This rate has been steady for the last few years. However, according to the results of a recent inquiry carried out by the CENFIC\(^{(2)}\) among 2 163 construction companies from 10 Portuguese districts \([9]\), there is a great demand for skilled workers. This covers 62 000 employees for the next five years, including labourers (78%) and other personnel (22%). The inquiry also led to the conclusion that construction workers require additional formation and that there is a greater concern for technical supporting staff.

The cost of labour in Portugal is low when compared to other European Countries. According to a EUROSTAT study where data from 1989 was used \([10]\), the costs of labour in Portuguese industry is 2.64 ECU per hour (8.99 in UK) with a corresponding PPP (Purchasing Power Parity) of 3.82 ECU (8.90 in UK).

The available statistical data for the construction sector refers to the gross hourly wages\(^{(3)}\) paid by the employer. Last figures (1987) quoted roughly 180.00 PTE per hour for tradesmen and 147.00 PTE per hour for labourers\(^{(4)}\).

Table 2.11, shows the costs of labour for tradesmen (scaffolding carpenters) in a set of selected years since 1973 to 1988. Figures are expressed in current PTE per hour\(^{(5)}\).

---

\(^{(2)}\) CENFIC stands for Centro de Formação Profissional da Indústria da Construção Civil e Obras Públicas do Sul (centre for professional training of the construction and civil engineering industry of the south).

\(^{(3)}\) The gross hourly wages (HW) have been computed using the following expression: \(HW = (MW \times 12)/(52 \times WNWP)\), with MW: monthly wages and WNWP: weekly non-mal working period.

\(^{(4)}\) Assuming a 30% increase in wages from 1987 to 1989, the hourly rate for tradesmen would be updated to 234.00 PTE (1.42 ECU) per hour. The costs of employing labour in 1989 were fixed by AICCPN as an overhead of 228% \([11]\), but this figure is usually considered high for most of the companies. Taking 80% of the suggested figure (say 182%), the figures of the EUROSTAT study are reached and so they seem acceptable for the construction sector.

\(^{(5)}\) Figures for 1973 to 1975 are expressed in the sources in current PTE per working day. However, they were changed to the hour time unit in order to make the comparisons easier.
Table 2.11

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</tr>
</thead>
<tbody>
<tr>
<td>Tradesmen</td>
<td>18.5</td>
<td>25.4</td>
<td>32.7</td>
<td>34.5</td>
<td>38.8</td>
<td>41.9</td>
<td>47.8</td>
<td>57.8</td>
</tr>
</tbody>
</table>

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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tradesmen</td>
<td>71.9</td>
<td>84.2</td>
<td>101.6</td>
<td>118.8</td>
<td>135.9</td>
<td>161.4</td>
<td>181.2</td>
<td>206.9</td>
</tr>
</tbody>
</table>

2.3.4.2 Materials.

The available statistical data is hard to manipulate because:

(1) Little data is available about the consumption of construction materials. Moreover, it tends to be aggregated into classes, which makes it difficult to handle.

(2) Data is mainly organised into typical accounting classes and it is expressed in money units. This is not convenient for some analyses.

The consumption of almost all materials inquired into by INE has increased in the last few years. This is not surprising because the volume of construction has also increased. Nevertheless, the following two comments are of interest although they have no statistical support:

(1) There is a great utilisation of slabs made by precast pre-stressed concrete beams;

(2) Hollow bricks are much more used for non-bearing walls in buildings than any other type of material.
Therefore, some more characteristics may be added to the typical building described in section 2.3.2.1: Floors are made by precast pre-stressed concrete beam slabs and the non-bearing walls are made of hollow bricks.

Finishing materials for walls and pavements are more variable. Some non-traditional solutions have been tried using new materials and new techniques. Ejected mortars used over smooth surfaces (specially for laminar concrete construction), are one of the best early examples. Other more recent products with additional properties, have been advertised \[12\], \[13\], \[14\] and recommended for renovation works \[15\].

The relationship between the Portuguese construction sector and other industrial sectors is very strong. From 85% to 87% of the "intermedium" inputs come from other important industries \[4\]. Almost all these inputs have a National origin. Currently, imports have a very small weight in the total consumption of materials. Similarly, the external trade in construction materials is not significant. However, in the period of 1986/88, a positive evolution can be found both in imports and in exports \[16\]. The flows are mainly to and from EEC countries (81% for exports and 96% for imports). A considerable rate of growth can also be found in the same period (44% for exports and 51% for imports). The balance is favourable to Portugal by 48.6 million ECU.

The relative importance of the several classes of materials during that period of time was not the same \[17\]:

Plywood for wall panelling, and architectural sections in aluminium for windows and doors, were the exported products with the highest rate of growth;

Floor ceramic mosaics and wall clay tiles were the imported products with the highest rate of growth.

Spain is increasing its importance as the Portugal's leading supplier (about 50% of the total figure in 1988) of construction materials. Portuguese clients are otherwise distributed among the EEC countries.
However, it must be stated that external trading in construction materials is insignificant in comparison with the totals for the country (0.77% for exports and 0.16% for imports in 1988).

Table 2.12, shows the costs of steel and bulk cement in a set of selected years from the period 1973 to 1988. Figures are expressed in current PTE.

Table 2.12

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</tr>
</thead>
<tbody>
<tr>
<td>Steel (6)</td>
<td>5.60</td>
<td>7.63</td>
<td>8.50</td>
<td>9.10</td>
<td>11.50</td>
<td>15.80</td>
<td>20.00</td>
<td>23.10</td>
</tr>
<tr>
<td>Cement (7)</td>
<td>616</td>
<td>666</td>
<td>721</td>
<td>967</td>
<td>1178</td>
<td>1659</td>
<td>1967</td>
<td>2519</td>
</tr>
</tbody>
</table>

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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel (6)</td>
<td>24.40</td>
<td>31.60</td>
<td>43.30</td>
<td>46.20</td>
<td>54.30</td>
<td>57.70</td>
<td>56.95</td>
<td>57.80</td>
</tr>
<tr>
<td>Cement (7)</td>
<td>3096</td>
<td>3869</td>
<td>5900</td>
<td>6428</td>
<td>7230</td>
<td>7642</td>
<td>7565</td>
<td>8057</td>
</tr>
</tbody>
</table>

2.3.4.3 Plant.

The development of industrial building construction processes definitely contributed to a higher rate of mechanisation. As a matter of fact, there has been a marked growth in the number of elevation mechanisms (especially tower cranes) and concrete mixers in the last 15 years.

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(6) Cost of 1 Kg of A235 12 mm diameter steel bar.
(7) Cost of 1 000 Kg of Portland cement.
The positive evolution which has been felt in the civil engineering projects has already been mentioned in section 3.3.

Almost all plant is imported.

2.3.4.4 Sub-contracts.

Portuguese construction sub-contractors may be included in at least one of the following classes:

(1) Companies with one or more specialisation (such as carpentry, electric installations, plumbing installations, etc.). When they work as subcontractors, they usually participate in projects committed by other construction companies which do not have own resources to carry out these tasks by themselves. They are not usually construction companies in the sense discussed in section 2.3.1 above.

(2) Ordinary construction companies that usually participate in projects undertaken by other (most frequently) larger companies, which decide to subcontract part of their projects.

(3) Companies with expertise in some construction tasks (such as pile foundations, concrete injections, tunnelling, etc.). They usually participate in special projects when their expertise are required.

(4) Manpower or plant suppliers.

The importance of sub-contracts in the Portuguese construction industry is hard to measure. According to the available statistic data, the rate of sub-contracts over the total expenditures in construction materials has not changed very much in the last 15 years. It would also be interesting to see the relative importance of each category of sub-contractor and its evolution throughout that time. Unfortunately, the available data does not give much help.
However, it is generally recognised that there are few projects ever executed without the participation of sub-contractors in the sense of (1) above. This is especially true for the case of building projects. In fact, probably no Portuguese company has or ever had the necessary skills to execute all the different tasks required in a building project. Almost all of them are just concerned with the concrete structure, the walls and the traditional finishings. Some of them also sub-contract all the excavation works. Companies seldom have specific skills for other tasks and if they do, they are generally organised in separate departments (or even separate companies managed by a holding)\(^{(8)}\). In a sense, this is also a type of sub-contract organisation.

Sub-contractors of type (2) above have had a more recent development. They are especially common in building projects although they can be found in civil engineering projects too. In some projects, all the works become sub-contracted (sometimes more than once). This leaves for the main contractor just the task of sub-contractor manager. Unfortunately there are many complaints about this system, because of the apparent inability of the main contractor to manage its sub-contractors. Problems seem to arise from the difficulty of the main contractor in passing its responsibility to client to the sub-contractors. Consequently, time schedules or quality standards or both may not be acceptably adhered to. Private contracts between the owner and the main contractor are seldom sufficiently well designed to prevent intensive sub-contracting or at least the possible unpleasant consequences of it. Contracts with public clients are however more concise and in most cases sub-contractors need to be accepted by the client before they begin working on the project. Anyway, the Portuguese regulations do not seem to be completely adapted to this new approach to project execution.

\(^{(8)}\) The skills of any company to carry a given type of project, must be recognised by AICCOPN (for the Northern companies, of course). The decision depends on the technical staff of the company, its past experience, its resources, etc. A positive decision allows the company to tender for that type of project. Projects are divided into classes and each class is divided into several categories. The classes correspond to the type of project (for example, Parks and Gardens or Hydraulic Works); the categories correspond to its value. A company may thus be allowed to tender for projects of type A for a budget not exceeding $X$ contos, for instance. The document used for the certification of this, is called Alvarã (building permit).
In what concerns sub-contractors of type (3), there is an obvious growth as well. This is mainly due to the increase in the number of different expertise now required in construction projects, and also to the diffusion of non-traditional construction methods. Sub-contractors of type (4) are a relatively new phenomenon in Portugal. They are being used by the larger construction companies as a way to rapidly find workers without supporting their costs of employment. The numbers of subcontractor of this type is also growing fast.

2.4 Construction contract arrangements.

2.4.1 Private contract arrangements.

Private construction contracts are regulated by 21 articles of the Código Civil Português [18][9] (Portuguese Civil Code). However, this Code refers to all types of contract arrangements by which "one party promises to undertake some work to another party for some price" (article 1297 of [18].) This is a very general definition but a more precise one covering all types of contracts would probably be difficult to achieve. Furthermore, the Code is hard to use in the construction environment because some of its concepts do not fit construction reality [19].

2.4.2 Public contract arrangements.

Beyond the general law referred to in the previous section, a specific regulation for the public construction works is applicable: Regime Jurídico das Empreitadas e Fornecimentos de Obras Públicas - RJEFOP (legal regulation for contracts and supplies for public works) [20]. This is to be used for the construction contracts running for the Portuguese State, Public Associations and Public Institutions. Moreover, the field of application of the RJEFOP is often extended to the public companies and to other public entities. The RJEFOP defines two

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(9) The path for the section of the Código Civil devoted to contracts is as follows: Código Civil, livro II: Direito das Obrigações, Título II, Capítulo II, Empreitadas.
parties in a construction contract: The owner and the constructor(10) (art. 2 of [20]). Then, it lists the following types of contracts according to the way the contractor gets paid (art. 6 of [20]):

a) *por preço global* (by global price);
b) *por série de preços* (by series of prices);
c) *por percentagem* (by percentage).

These types of contract arrangements are identical to British lump sum contract, bill of quantities contract and cost reimbursement contract respectively.

The above contract types also correspond to distinct distribution of the construction risks between the client and the contractor. The risk for the contractor is higher for the first type. Therefore, this may only be used "for the projects the design of which enables full understanding of the nature and the quantities of the works to be undertaken and the assessment with a small probability of failure of the costs of materials and labour to be used" (art. 8 of [20]. Under a "series of prices" contract, risks are shared by the client and the contractor. This type of contract is extensively used for non-repetitive projects. Under a "percentage contract" the contractor refunds all the costs incurred in carrying out the work on site plus a percentage over costs covering indirect costs and profit (art. 42 of [20]). Therefore, risks are on the client side under this contract arrangement.

### 2.4.3 Typical private contract arrangements.

Most of the Portuguese private clients use some of the concepts of the RJEFOP in their contract with construction companies. This is commonly well accepted by both parties because the approach of the *Código Civil* does not fit the requirements of typical construction contracts. However, a wide range of

(10) The entities "owner" and "constructor" are currently replaced in Anglo-Saxon literature by "client" and "contractor" and so they will be referred to as such hereafter.
variations to RJEFOP may be found in use. A survey of the most common types of Portuguese construction contracts could not be found in the literature, but it is the author's conviction that lump sum contracts are mostly used. A bill of quantities is frequently used for work valuations each month, but for small projects, fixed payments may otherwise be agreed between the client and the contractor.

Unfortunately, most projects are not sufficiently detailed at the tender stage and so, according to RJEFOP, lump sum contracts should not in fact be used. In agreement with the articles of RJEFOP, the contractor may claim for errors and omissions in the tender documents (delivered by the client) after undertaking the job. However, this is not fully satisfactory, so, contractors tend to include safety clauses in their offers in order to cut down risks.

2.4.4 Relationship among parties during construction.

Portuguese construction contracts are typically a two-parties bargain between the client and the construction company (art. of [20]). Instead of a general contractor, the client may decide on a set of subcontractors to undertake the project. This is most common for large projects or if highly specialised contractors are required.

For large projects, the client may wish to appoint a third party acting on his/her behalf to ensure supervision of the job. The client or the supervisor coordinate the execution of the project and deal with the contractors. They try to follow up the project execution on site in order to ensure that cost and time targets are achieved in agreement with the quality standards defined during the design stage. Due to the increasing complexity of construction projects, expert knowledge about a variety of fields is becoming more and more required in order to carry out supervision. Therefore, the design team is often asked by the client to perform the supervision of the project on site. This is an interesting arrangement because during the design stage, the team acts as a contractor to the client but it is expected to act as the client agent afterwards [21]. However, this ambivalent position of the design team is sometimes hard to bear because some claims of the contractor may possibly refer to design faults. Besides, the
design team must work with the contractor and not against it [22], as may happen in possible disputes.

Therefore, the need for project supervision independent from the design team has been progressively felt by clients. Nowadays, project supervision performed by a third party independent of the design team is becoming usual on Portuguese construction sites. On the other hand, project managers acting on the behalf of the client from project inception to conclusion are less common.

Project management on the behalf of the contractor is usually ensured by different people throughout the project development. During the tender stage and the pre-contract stage, the staff of the Estimating department or the Commercial department is usually on charge of the relations with the client. Thereafter, the site director is usually committed to that function.

2.4.5 Tender documents.

According to RJEFOP, tender documents delivered by the client include the design, the specifications and the conditions of contract. The composition of these documents is also described in RJEFOP and it can be seen that a substantial degree of precision is aimed at in the text.

Although the spirit of RJEFOP is frequently adopted for private contracts, clients may not deliver to contractors some of the documents therein stipulated for tendering. For example, the bill of quantities must be delivered by public clients, but private clients often fail to include it in tender documents.

RJEFOP also indicates which documents should be included in the contractors' offers. Similarly, most of these documents are not required by private clients.

2.5 Conclusions and remarks.

Although the available data is scarce, it was possible to draw the following conclusions:
(1) There has been a marked evolution in the Portuguese construction industry in the last few years. Macroeconomic data and production data have been used in order as evidence for.

(2) The Building Construction sub-sector is by far the most important sub-sector of the Portuguese construction industry.

(3) The production structure is characterised by a small number of large companies and a large number of small companies. The larger have a significant share in the Portuguese market of construction projects.

(4) The relevance of the low costs of labour in the Portuguese construction industry has already been mentioned. Construction is by no means an exception. A comparison of materials costs and labour costs between Portugal and other European Countries clearly shows that the differences are much higher for labour costs than for the materials costs. This is probably one of the reasons why some industrialised construction solutions now current in those Countries are not yet successful in Portugal. There are of course other factors that may influence the adoption of these solutions but the final production costs are obviously important.
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CHAPTER THREE

Detailed Inquiry to 5 Portuguese Construction Companies.

3.1 Introduction.

3.1.1 General characteristics of the inquiry.

The objective of this inquiry is the study of the activities related to the management of construction projects in Portuguese construction companies. This follows one of the sub-aims of this thesis as stated in section 1.3. This also corresponds to the second step of the research methodology as presented in section 1.4. In order to achieve this a questionnaire has been produced as listed in section 3.3. Answers were collected during interviews with the staff of a set of selected construction companies. The author was directly involved in all the necessary interviews.

Activities to be surveyed by means of this inquiry were only those directly related to production. It has been assumed that they can be clearly identified by construction companies. For the sake of simplicity, they were grouped into estimating, planning and control management functions. Moreover, it has been assumed that this terminology is adequately understood by the companies.

Initially, data to be collected was only about estimating and planning management functions. However, during the work preparatory to the composition of the questionnaire, it became clear that control should also be included.

3.1.2 Objectives of the inquiry.

The direct objectives of the inquiry may be summarised as follows:

(1) to survey how companies perform estimating and planning management functions;
(2) to study the flow of information among those activities;

(3) to analyse the degree of integration between estimating and planning management functions and their relations to control;

Following the definition of the direct objectives of the inquiry, a preliminary inquiry involving three companies was conducted, with the aim of validating those objectives.

The pre-inquiry was composed of:

(1) a bibliographic survey of the subject to be studied;

(2) meetings with professionals of the construction industry;

(3) appointments with people involved in management functions in companies.

The results of this work were very useful for the composition of the questionnaire. Conclusions of the pre-inquiry are summarised in section 3.2.

Indirect objectives were also envisaged. They were mainly related to future contacts with the companies, with the purpose of discussing data collected during the inquiry and the possibility of testing solutions. They may be summarised as follows:

(1) to identify the companies' staff more directly involved in the coordination of the management functions;

(2) to find out if companies use computer support to perform management functions;

(3) to discover whether if the companies would accept alternative management procedures aimed at increasing their efficiency.

Finally, it was also an objective of the inquiry to draw conclusions from the
answers of the companies. These conclusions were expected to include valuable data for the study and produce basic data for other specific inquiries involving a larger number of construction companies.

3.1.3 The way the inquiry was conducted.

The inquiry was carried out by means of a questionnaire administered to a set of selected construction companies. The way the questionnaire was constructed, the selection of the companies and the problems of finding the right people to speak to are described in section 3.2. The questionnaire is listed in section 3.3. Answers to the questionnaire were organised separately for each company and are listed in Appendix 1.1. Final conclusions are described in section 3.5.

3.2 The Organisation of the inquiry.

3.2.1 Introduction.

This section describes the methodology used for the organisation of the inquiry. It includes the following stages [1].

The first stage of the study was the definition of its objectives. These have already been listed above.

The second stage was the pre-inquiry. This comprised the review of the literature on the subject, contacts with construction industry professionals and a preliminary inquiry into three construction companies.

The third stage dealt with the selection of the companies to survey and establishing reliable sources of information within the companies. Section 3.2.3 describes this work.

The composition of the questionnaire was the fourth stage. This is referred to in section 3.2.4. The questionnaire is listed in section 3.3
Finally, the questionnaire was administered to selected companies and answers were collected as described in section 3.2.5. The report of the answers to the questionnaire in each companies may be found in Appendix 1.1.

It must be noted that despite the above division into sequential stages, extensive overlapping among stages took place. For example: the results of the pre-inquiry contributed to the definition of the objectives of the main inquiry; some companies which were selected during the third stage were used in the preliminary inquiry included in the second stage above; the decision on the reports of the answers was only taken after the questionnaire had been administered to the companies; etc. Moreover, each stage consists of a set of other smaller stages involving decisions which are not fully described here.

3.2.2 Results of the pre-inquiry.

One of the components of the pre-inquiry was the review of the literature on the subject. The following are the main conclusions of that work:

(1) few texts on the topic of construction management functions as performed by Portuguese construction companies could be found;

(2) a lot of British and American texts on construction management functions on the behalf of construction companies could be found, but each function is normally analysed independently of others:

(3) integrated approaches for estimating planning and control were hard to find.

Another component of the pre-inquiry were informal contacts with professionals from Portuguese construction companies which meant that the results of the review of the literature could be confirmed and useful opinions for the composition of the questionnaire could be collected.
Finally, a preliminary inquiry was conducted into three construction companies using a preliminary questionnaire which was built up according to the initial setting of objectives. The conclusions of the preliminary inquiry are listed below:

(1) The relationships between estimating and planning follow not only from the requirements of data of these two functions, but control also plays an important role in it.

(2) Despite the lack of literature on the relationship between estimating and planning the study of this topic appears to be of a great importance for construction companies. Moreover, the implication of production control in those functions has to be considered.

(3) The flow of information within the companies organisations is easier to understand if it is supported by a chart. Nevertheless, charts built up for the companies surveyed during the preliminary inquiry were probably too complex. In fact, companies did not pay a great attention to them when they were presented.

(4) Integration of estimating and planning is more sensitive in building projects than in civil engineering projects. In practice, bqs for the former projects tend to be more dissociated from construction activities than for the latter. Moreover, bqs for building projects usually comprise a large number and variety of items. This makes the estimating of building projects more independent of planning than civil engineering projects.

These topics will be further returned to in the conclusions of the inquiry.

About the receptiveness the companies to the inquiry and the selection of the people to talk to in each company, the following conclusion could be drawn:

(1) companies were very receptive to the preliminary inquiry;

(2) the selection of the people to talk to in each company was dependent on the organisation structure of the company, so no rules could be laid down;
(3) the companies' staffs are normally busy people so some difficulties in arranging meetings with them have to be expected.

The preliminary inquiry also gave some ideas of what the questionnaire should look like:

(1) questions should be broad in order to allow companies to answer irrespective of their organisation and their management styles;

(2) questions should be open (ie, not of a yes-no type) so that profitable discussions may arise;

(3) subjects to be discussed during the interviews should be introduced by short presentation texts so that answers should be kept within the expected scope;

(4) the questionnaire should not be too large so as not to increase the number and duration of interviews;

(5) the terminology used was adequate.

Finally, the preliminary inquiry showed that the questionnaire has to be administered directly because the complexity of the subjects to be discussed is not compatible with a mailed inquiry. Besides, according to chapter 2, contractors often fail to answer written forms.

3.2.3 Selection of companies and methods of approach.

3.2.3.1 Company selection.

Companies to select should pertain to the universe of Portuguese construction companies. Specifically, general contractors were envisaged.
The size of Portuguese contractors is variable: from the small family-type contractor with a few employees to the largest companies with more than a thousand. It was decided not to survey the very small ones, because of their centralised practice which make it difficult to evaluate the flow of information among management functions. Therefore, having specific staff concerned with estimating planning and control was elected as a selection criterion. The number of companies encompassing this requirement is very large, so it was decided to select companies of different sizes so that distinct cases could be looked at.

Moreover, it was decided to survey companies working in the north of the country, in order to make contacts easier.

Finally, it was decided to study building construction in detail because this is the main activity of Portuguese contractors.

Initially, ten companies fulfilling the above requirements were selected. The author's direct knowledge of their staff also contributed for the selection criteria. From those ten, three were studied during the preliminary inquiry.

3.2.3.2 Approach to the companies.

Who should answer the questionnaire within the companies was the first problem to be encountered. However, selecting the right people to do so was not straightforward because the companies' organisations were not known beforehand. Therefore, it was decided to postpone making that decision to a later time when companies would be known a little better.

The first contact with companies was made at the highest possible level in their hierarchical organisation. It aimed at:

(1) introducing the objectives of the inquiry and clarifying the goals of the study;

(2) arranging the first appointment.
Generally, companies were receptive to participating in the inquiry and the first appointment could be arranged in a reasonable time. The first appointment was intended:

1. to clarify the objectives of the inquiry;
2. to present the questionnaire;
3. to get acquainted with the information flow in the companies;
4. to decide upon who should answer each part of the questionnaire.

It was desirable that main staff from the companies' departments concerned with each management function under study should be involved in the inquiry. Accordingly, appointments with one to four people in each company have been achieved. Moreover, according to the results of the preliminary inquiry, the questionnaire should be administered in the course of several sessions with the companies' staffs. The above features made the study of each company take a long time (sometimes several weeks) because of the lack of available time of people involved.

Afterwards a final meeting with the first person contacted in the company took place for discussions on the results of the inquiry.

3.2.4 Composition of the questionnaire.

The questionnaire comprises a set of questions, a set of subjects to be discussed and a set of presentation and connection texts between questions and subjects. It was administered in each selected company, in the course of a set of appointments with its staff.

The general frame of the questionnaire is as follows:

a) First contact with the company.
b) Production management.
   b.1) General characteristics of the company.
   b.2) Company organisation.
   b.3) Field of activity.
   b.4) Management of construction projects.

c) Estimating.
   c.1) General characteristics.
   c.2) How it is done.
   c.3) Comments.

d) Planning.
   d.1) General characteristics.
   d.2) How it is done.
   d.3) Comments.

e) Control.
   e.1) General characteristics.
   e.2) How it is done.
   e.3) Comments.

Letters assigned correspond to the sections of the questionnaire listed in section 3.3 below.

The questionnaire is composed of five parts. The first part refers to the first contact with the company. The second part includes a set of general subjects to be discussed during the first appointment. Each of the following three parts is devoted to a specific management function.

3.2.5 Answers to the questionnaire.

Answers were mostly descriptive and in some cases very different among companies. Moreover, as several people had been interviewed in each
company, distinct slants to a given subject could be found within the same company. Therefore, it seemed that a rigid pattern for collecting answers would not be the best choice.

Accordingly, it was decided to collect answers freely and use those answers to compose a report on each company. Afterwards, the report also works as a summary of the work undertaken. Moreover, information flow in the companies has been depicted graphically in a chart.

An effort has been made to make reports as similar as possible among companies. This has facilitated the establishment of comparisons among reports and to drawing conclusions.

Each report has been discussed with the company concerned in the course of the final meeting as described in section 3.2.4.2. The chart showing the flow of information within the company helped to illustrate the results of the survey. Both reports and flow-charts have been improved afterwards according to that discussion. Final versions are listed in Appendix 1.1.

3.3 Questionnaire.

3.3.1 Contents.

a) Contact with the company.
   a.1) Information during the first contact.
      a.1.1) Objectives of the survey.
      a.2) Clarifications required.
      a.3) Settlement of the first appointment.
   b) Production management.
      b.1) General characteristics of the company.
      b.2) The organisation of the company.
      b.3) Field of activity.
      b.4) Management of construction projects.
   c) Estimating.
c.1) General characteristics.
c.2) How estimates are made.
c.3) Comments.
d) Planning.
d.1) General characteristics.
d.2) How planning is done.
d.3) Comments.
e) Production control.
e.1) General characteristics.
e.2) How control is performed.
e.3) Comments.

3.3.2 Questionnaire.

a) Contact with the company.

a.1) Information during the first contact.

A survey of how the activities related to management of construction projects (management functions) are carried out by the company. Data collected will be used in a research programme in the Universidade do Minho. There is also a collaboration with Loughborough University (UK) and with the Instituto Superior Técnico (Lisboa) and the support from the Instituto Nacional de Investigação Científica (INIC).

Is the company willing to participate in the study? One or more interviews with the staff of some departments of the company will be needed.

a.1.1) Objectives of the survey.

(1) inquire into the production activity of the company:

   general characteristics
   organisation
   field of activity
(2) to inquire into management of construction projects:

- general evaluation about the system used

(3) to inquire into estimating planning and production control procedures:

- data used
- methodologies used
- information flow.

Data collected will be analysed and the company will be informed about the evolution of the work. The results from identical surveys carried out in other companies will be handled together so that general conclusions may be drawn.

a.1.2) Clarifications required.

a.1.3) Settlement of the first appointment.

b) Production management.

b.2.1) General characteristics of the company:

- turnover;
- number of employees;
- geographical area of activity.

b.2.2) The organisation of the company.

Definition of the organisation structure - functional and hierarchical relationships among departments and identification of the activities carried out by each department.
b.2.3) Field of activity.

This aims at understanding the type of activity of the company.

what types of construction projects does the company tender for undertake?

which is the relative importance of each of those in the company's portfolio?

what are the reasons that influence the decision to submit a tender for a project?

b.2.4) Management of construction projects.

Management of a construction project includes a set of activities that take place from the decision to submit an offer till the final settlement of the project accounts. The following three management functions are the focus of this survey: estimating, planning and control.

Who performs the estimating and planning tasks?

What information generated by those two activities is used in control?

Who carries out the control activity on site?

Is available time for submitting an offer normally enough?

Does the company normally achieve costs and schedules as they were forecast? Which are the reasons for possible failures?
c) Estimating.

c.1) General characteristics.

General references about departments involved in the estimating process;

Stages of the project in which they play their parts.

c.2) How estimates are made.

Estimating implies knowing how work quantities are set by measurements and how they are organised.

If no bill of quantities (bq) is included in the tender documents, which measurements of the project are made and how are they structured?

Does the type of tender or the requirements of the client influence the structure adopted for the bq?

Are there relevant differences between the bqs normally included in the tender documents and those generated by the company?

The next step in estimating is deciding upon the prices of each item of the bill of quantities.

How are prices of each bq item evaluated?

if works therein included are to be executed with the company’s resources;

if works are to be subcontracted.

Which set of data is used for computing the prices of the bq items?

Which information is generated at this stage?
After commitment, there is usually a stage of “production preparation” before starting the project on site.

Are there any measurements, cost estimating or price analyses during this stage?

Which information is generated and how is it used?

c.3) Comments.

Difficulties in estimating.

Availability of computer-based procedures and tasks in which they are used.

Efficiency of estimating and accuracy of data generated.

Other comments and suggestions.

d) Planning.

d.1) General characteristics.

General references about departments involved in the planning process;

Stages of the project in which they play their parts.

d.2) How planning is done.

Planning a construction project implies selecting the activities, finding their durations and establishing precedence relationships among those. Finally, a scheduling method is used and information generated is reported.
Planning may possibly have different degrees of detail in distinct stages of the construction process. For each stage:

What criteria are used to perform the above tasks?

What data is used?

What scheduling methods are used?

What is the information generated and how is it reported?

Data generated by planning may include resource forecasting for the project execution on site.

What data on resource forecasting is used in planning?

How are resources required by several projects taking place at the same time managed together?

d.3) Comments.

Difficulties in planning.

Availability of computer-based procedures and tasks in which they are used.

Efficiency of planning and accuracy of data generated.

Other comments and suggestions.

e) Production control.

e.1) General characteristics.

General references about the departments involved in production control;
Stages of the project in which they play their parts.

e.2) How control is performed.

Production control implies comparing what happens on site with forecasts.

What data about resource utilisation on site does the company normally collect? How is it structured?

What data available from estimating and planning activities enables those comparisons to be made?

How are the production costs evaluated? How are they compared with the costs forecast?

Who checks to see if the project is on schedule?

e.3) Comments.

Difficulties in control.

Availability of computer-based procedures and tasks in which they are used.

Other comments and suggestions.

3.4 Summary of the answers to the questionnaire.

Answers form companies involved in this inquiry are summarised on table 3.1. Company names were replaced by aliases (companies A to E at their request).
Table 3.1.

<table>
<thead>
<tr>
<th>COMPANIES</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>comments &amp; remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnover</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>/figures of 88 in 1000 contos/</td>
</tr>
<tr>
<td>Number of employees.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>/all the employees/</td>
</tr>
<tr>
<td>Geographical area.</td>
<td>P</td>
<td>P(N)</td>
<td>P(N)</td>
<td>P</td>
<td>P+A</td>
<td>P: Portugal only; P(N): Portugal North; A: Abroad;</td>
</tr>
<tr>
<td>Types of projects.</td>
<td>bc</td>
<td>bc</td>
<td>bc</td>
<td>bc</td>
<td>bc</td>
<td>bc: building construction; pw: public works.</td>
</tr>
<tr>
<td>Information used in control.</td>
<td>cd</td>
<td>cd</td>
<td>cd</td>
<td>cd</td>
<td>cd</td>
<td>cd: cost data; sd: schedule data.</td>
</tr>
<tr>
<td>Time for tendering?</td>
<td>e</td>
<td>e</td>
<td>e</td>
<td>e</td>
<td>ne</td>
<td>e: enough; ne: not enough.</td>
</tr>
<tr>
<td>Measurements.</td>
<td>dm</td>
<td>dm</td>
<td>dm</td>
<td>sm</td>
<td>dm</td>
<td>dm: detailed meas.; sm: simplified meas.</td>
</tr>
<tr>
<td>Estimating method.</td>
<td>up</td>
<td>up</td>
<td>ur</td>
<td>up</td>
<td>up</td>
<td>up: unit prices; ur: unit rates; op: operational estimating.</td>
</tr>
<tr>
<td>Data used.</td>
<td>ru</td>
<td>ru</td>
<td>ru</td>
<td>mp</td>
<td>ru</td>
<td>ru: rates and unit costs; uc: unit costs; mp: market prices.</td>
</tr>
<tr>
<td>Information generated.</td>
<td>gci</td>
<td>gci</td>
<td>gci</td>
<td>gci</td>
<td>gci</td>
<td>gci: general contract info.; tpbq: tender priced bq.</td>
</tr>
<tr>
<td>Further estimating.</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m: measurements; ce: cost estimating; pa: price analysis.</td>
</tr>
<tr>
<td>Further info. generated?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y: Yes; N: No.</td>
</tr>
<tr>
<td>Computers?</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y: Yes; N: No.</td>
</tr>
</tbody>
</table>
Table 3.1 (continued).

<table>
<thead>
<tr>
<th>COMPANIES</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>comments &amp; remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria for plan. activities.</td>
<td>bqi+</td>
<td>bqi+</td>
<td>bqi+</td>
<td>bqi+</td>
<td>bqi+</td>
<td>bqi: items of the bq; +: further detail.</td>
</tr>
<tr>
<td>Data used.</td>
<td>oe</td>
<td>oe</td>
<td>oe</td>
<td>oe</td>
<td>oe</td>
<td>oe: output of estimating;</td>
</tr>
<tr>
<td></td>
<td>ds</td>
<td>ds</td>
<td>ds</td>
<td>ds</td>
<td>ds</td>
<td>ds: duration of subcontracts.</td>
</tr>
<tr>
<td>Scheduling methods.</td>
<td>bc</td>
<td>bc</td>
<td>bc</td>
<td>bc</td>
<td>bc</td>
<td>bc: bar charts; cpm: critical path method.</td>
</tr>
<tr>
<td>Information generated.</td>
<td>tp</td>
<td>tp</td>
<td>tp</td>
<td>tp</td>
<td>tp</td>
<td>tp: tender programme;</td>
</tr>
<tr>
<td></td>
<td>lc</td>
<td>lc</td>
<td>lc</td>
<td>lc</td>
<td>lc</td>
<td>lc: labour charts; ar: allocation of resources.</td>
</tr>
<tr>
<td>Criteria for plan. activities.</td>
<td>atp+</td>
<td>atp+</td>
<td>atp+</td>
<td>atp+</td>
<td>atp+</td>
<td>atp: activities of the tp; +: further detail.</td>
</tr>
<tr>
<td>Data used.</td>
<td>ds</td>
<td>oe</td>
<td>oe</td>
<td>ds</td>
<td>oe</td>
<td>oe: output of estimating;</td>
</tr>
<tr>
<td></td>
<td>oep</td>
<td>ds</td>
<td>ds</td>
<td>oep</td>
<td>ds</td>
<td>ds: duration of subcontracts;</td>
</tr>
<tr>
<td></td>
<td>oep</td>
<td>oep</td>
<td>oep</td>
<td>oep</td>
<td>oep</td>
<td>oep: output of earlier planning.</td>
</tr>
<tr>
<td>Scheduling methods.</td>
<td>bc</td>
<td>bc</td>
<td>cpm</td>
<td>bc</td>
<td>bc</td>
<td>bc: bar charts; cpm: critical path method.</td>
</tr>
<tr>
<td>Information generated.</td>
<td>cp</td>
<td>cp</td>
<td>cp</td>
<td>cp</td>
<td>cp</td>
<td>cp: construction programme;</td>
</tr>
<tr>
<td></td>
<td>lc</td>
<td>lc</td>
<td>lc</td>
<td>lc</td>
<td>lc</td>
<td>lc: labour charts; ar: allocation of resources.</td>
</tr>
<tr>
<td>Resource forecasting?</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y: Yes; N: No.</td>
</tr>
<tr>
<td>Management of resources among several projects?</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y: Yes; N: No.</td>
</tr>
<tr>
<td>Computers?</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y: Yes; N: No.</td>
</tr>
<tr>
<td>Control of labour?</td>
<td>mi</td>
<td>mi</td>
<td>mi</td>
<td>mi</td>
<td>mi</td>
<td>mi: all items; si: selected items; mi: main items.</td>
</tr>
<tr>
<td>Control of plant?</td>
<td>mi</td>
<td>si</td>
<td>ai</td>
<td>si</td>
<td>si</td>
<td>si: all items; si: selected items; mi: main items.</td>
</tr>
<tr>
<td>Control of materials?</td>
<td>ai</td>
<td>ai</td>
<td>ai</td>
<td>ai</td>
<td>ai</td>
<td>ai: all items; si: selected items; mi: main items.</td>
</tr>
<tr>
<td>Control of subcontracts?</td>
<td>ai</td>
<td>ai</td>
<td>ai</td>
<td>ai</td>
<td>ai</td>
<td>ai: all items; si: selected items; mi: main items.</td>
</tr>
<tr>
<td>Data from previous manag. functions.</td>
<td>bq</td>
<td>bq</td>
<td>bq</td>
<td>bq</td>
<td>bq</td>
<td>bq: bill of quantities;</td>
</tr>
<tr>
<td>Evaluation of costs.</td>
<td>cp</td>
<td>cp</td>
<td>cp</td>
<td>cp</td>
<td>cp</td>
<td>cp: construction programme.</td>
</tr>
<tr>
<td></td>
<td>end</td>
<td>per</td>
<td>per</td>
<td>end</td>
<td>per</td>
<td>per: periodically; end: at the end of the project.</td>
</tr>
<tr>
<td>Computers?</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y: Yes; N: No.</td>
</tr>
</tbody>
</table>
Table 3.1 shows that the five companies included in this study have very different turnovers and number of employees. All of them work in Portugal but two are restricted to the North of the country and one also works abroad. All the companies undertake building projects and three companies also undertake public works. Information used in control is mainly cost data but one company also uses schedule data. Time for tendering was considered to be enough by three companies and not adequate by one company.

If no bill of quantities is included in the tender documents supplied by the client, four companies make detailed measurements of the project but one company may use simplified measurements in some cases. The measurement document used by all the companies is the traditional bill of quantities. All the companies use unit rates to study construction costs but only one does not use market unit prices in specific cases. Tender estimating basically generates general contract information and the priced bill of quantities.

All the companies make additional measurements of the projects they contract for but only three out of five also perform cost estimating and price analysis. However, all companies agreed that further information is generated during the production preparation stage.

Three out of five companies use computers in their estimating procedures.

All the companies stated that construction activities in tender planning are in agreement with the items of the bill of quantities but further detail may be required in some cases. Data used by all companies in tender planning is the output of estimating and the expected duration of subcontracts. All companies use bar charts for their tender scheduling method and one contractor additionally uses the critical path method. Tender planning basically generates the tender construction programme, labour charts and information about the allocation of some resources on site in three companies.

All the companies perform further planning for the contracts they win. Construction activities are based on the tender programme with some more detail if necessary (in three companies), and on the items of the bill of quantities also with some more detail if necessary (in three companies as well). The output of earlier planning and the duration of subcontracts are used by all companies. Furthermore, the output of estimating is additionally used by three companies. The scheduling method used for detailed planning is the bar charts in four companies and the critical path method in one. Moreover, one contractor uses both methods. Detailed planning basically generates the detailed construction programme, labour charts and information about the allocation of some resources on site in all companies.
Resource forecasting is catered for by all the five companies, but only two of them manage resources among several projects.

Two out of five contractors surveyed use computers in planning.

All companies restrict site control of labour to the main items but extend control of materials and subcontracts to all items. Control of plant is restricted to the main items in one company, to selected items in three companies and includes all items in one company. The bill of quantities is clearly the main document used from previous management functions but it is complemented by the construction program in three companies. Costs control is performed periodically in three companies and at the end of the project in two.

Only one company out of five uses computers in site control.

3.5 Conclusions of the inquiry.

3.5.1 Introduction.

The inquiry contributed to a better understanding of how construction companies manage their projects.

From the seven companies selected for the definitive inquiry, it was not possible to get relevant answers from two of them.

In one of them a single large project fully absorbs the production from the last three years. This resulted in directing all the efforts of the company to that project thus distorting typical management procedures. Therefore, it would not be advisable to consider their answers.

In another, the staff has changed quite recently, and this probably explains some of the lack of consistency in the answers to the questionnaire. Therefore, it was decided to exclude this also.

Contacts with the companies were made through personal contacts with their staff in six cases, and after an inquiry from one of the companies (in the seventh case). All the companies were receptive to the research and participated willingly in the interviews. Everybody appeared to be interested in the evolution
of the study and encouraged further contacts. One of the companies also offered
the possibility of testing possible solutions. The originality of this kind of study in
Portugal was remarked on by all the participants in the inquiry.

The objectives of the inquiry were easily understood in the course of the first
contact. Companies just asked for some confidentiality. In one case, a written
invitation to participate in the inquiry was also required.

It was easy to find the right people to talk to for each subject in all the
companies. Generally, they were suggested during the first appointment in each
company.

Because of the type of questionnaire (open questions, separate sections for
each management function, etc.), answers reflected the degree of concern each
person had on each subject. Naturally, some people tended to give more
importance to their work than to others'. However, this problem has been
partially avoided in the reports presented in Appendix 1.1 because of the way
they have been built up as stated in section 3.2.6.

3.5.2 General conclusions.

The five companies included in this study have different characteristics. Both the
turnover and the number of employees are very different from each other. These
two figures do not seem directly relatable, probably because of the distinct
incidence of subcontracted work in each company.

Although the organisation of the companies is similar in many aspects, some
relevant differences could be found:

(1) Estimates are always made by specific departments independent of
production; only in one company do the Estimating and the Production
Departments belong to the same Division.
(2) Production planning does not belong to the same Direction as Production in one company, it does in two other companies and mixed solutions are adopted in the remaining two.

(3) Estimating and planning are done by the same department in one company.

(4) Control is dependent on the same management division as production management in four companies; in one company, however, a specific department independent of production takes care of control.

The type of building projects companies go in for does not apparently influence the way management functions are performed. The size of the projects is variable because of a large number of factors. This does not influence management functions either. However, the degree of detail may be different among projects according to their importance.

All the companies believe they are reasonably organised. Moreover, all the companies considered that they managed their projects efficiently.

The companies surveyed in this inquiry perform estimating, planning and control management functions following similar procedures to those described in Portuguese literature [2]. Moreover, they are also identical to those reported in several British sources (eg [3], [4], [5], [6] etc.). The flow charts depicted in Appendix 1.1 were recognised as a comprehensive representation of the flow of information within each company surveyed. The author could not find similar charts in Portuguese literature covering all the management functions surveyed. British literature has also been examined in order to validate those charts. Partial diagrams as the one presented by McCaffer and Baldwin [7] show that the flow charts of Appendix 1.1 represent typical information flows within construction companies.

3.5.3 Specific conclusions.

From the answers to the sections c), d) and e) of the questionnaire, the following conclusions could be taken:
3.5.3.1 Estimating.

(1) Estimates are normally based on a bill of quantities produced by the client. In this case, all the companies stated that they do not make any measurements in the tender stage, unless significant errors or omissions are clearly detected in the bq.

If the bq is for any reason not available from the tender documents, it is generated by the contractors using a set of common criteria. Both the bqs supplied by the client and the ones generated by the companies are similar in contents and organisation. They usually follow a pattern normally well accepted among construction companies. Besides, companies consider them suited to estimating because available price and cost information is usually stored under a similar pattern. Furthermore, the bq items and the associated unit costs constitute a criterion for work valuation on site and a basis for discussion of prices of extra work if necessary.

An exception to this normal procedure could be found in one company. The company usually reduces the detail of the bill of quantities for current projects tendered on a lump sum basis for which no unit price list is required. Then a fast method of cost estimating can be used. However, the company recognised this was a risky procedure.

It may be concluded that an integrated model keeping usual estimating procedures should be prepared to deal with measurements organised in the format of traditional bills of quantities.

(2) Tender prices for bq items are studied in a different way depending on whether in-house or subcontracted resources are to be used. In the first case, prices usually follow from production cost studies, whereas in the second case, they come from the offers of subcontractors. Also, there may be cases where both approaches are used to calculate prices.
Tender prices are not established with cost criteria alone, but other parameters are also taken into account. In the limiting case, a study of costs is not actually performed for tender purposes but (possibly) done later. This is especially true for the most common items for which the companies have sufficient past experience and for which market unit prices are adopted. They are normally supported by recent offers by subcontractors for identical works. This method is frequently used by two companies and was considered to be safe enough for tender purposes.

(3) Unit rate estimating is generally well accepted for the study of direct costs of works involving in house resources. In practice, all companies recognised it as the best approach for cost estimating of building works. Costs are normally studied for labour, materials and plant. Unit rates are based on the companies' production data and/or published data. The costs of work to be subcontracted are added afterwards in order to build up the total direct unit costs for each bq item. Indirect costs have a more operational type of study if they refer to the site installations or to other resources difficult to allocate to individual items. Additionally, some allowances and management fees are included in order to get the final costs for the project. Final markups covering profit and risks are decided during the meeting before submitting the tender.

This means that any integrated model should support unit rate estimating for building projects if traditional estimating methods are to be maintained.

Two companies prefer to study the costs more accurately after commitment in order to generate more feasible data for production. This includes the re-measurement of the whole project so that quantities can be established more accurately. Both companies use specific documents to record all the relevant information generated at this stage. These documents are the basis for all subsequent management procedures and they are particularly useful for production control.

Most of the companies believe that costs should always be re-analysed after commitment because this is advantageous for the preparation of production. Moreover, re-measuring the project after commitment is a general procedure for
all the companies whenever it is possible to apply for errors and omissions in the tender bq.

Therefore, an integrated model should be developed taking this output into consideration.

(4) Computer-based unit rate cost estimating is already on use or at least envisaged by all companies. In house developed and commercial computer packages were found during the interviews.

Therefore, computer support for the integrated model is likely to be well accepted by the industry.

3.5.3.2 Planning.

(1) Tender Planning is done by all companies. The main output is the tender programme. This is a preliminary programme for the works but it is often required in the tender documents. In some cases a labour histogram is also demanded by the client. Construction activities of the tender programme are substantially aggregated, generally correspondence with the headings of the bq or with any relevant bq item.

One company could identify a pre-planning stage taking place before estimating.

(2) Activities durations and labour requirements of the tender programme are normally established on an empirical basis. Only one company tries to assess activity durations from the study of time-consuming resources (eg manpower, plant, etc.)

(3) In three companies, specific departments are involved in further planning after commitment. Site directors often become involved.

However, from the point of view of one of these companies, time based planning is not very important at this stage. Although they plan resources and corresponding costs, they do not actually schedule them.
In two other companies general production planning (General Planning) is done. The definition of the construction activities generally follows the bq items although those may be re-arranged in order to fit the production reality more closely. Tasks pertaining to each activity are established more carefully than in tender planning. Time-consuming resources required to perform tasks are allocated to corresponding activities using rates similar to estimating. The number of resources required to carry out each activity and the duration of it are balanced together in order to get an acceptable result. Other resources are also allocated to activities, enabling total resources required to carry out the project to be established. Detailed Planning is carried out later by site directors on the basis of General Planning.

It may be concluded that for the majority of the companies surveyed, planning efforts are greater after commitment that during the pre-tender stage. Moreover, from their point of view, this is advantageous for production preparation. Therefore, an integrated model should be developed taking this into consideration.

(4) In two companies, site directors are chiefly responsible for Production Planning. They do it according to their experience and based on the available Tender Planning. Activities definition follows the bq items closely. However, in some cases, they have to be aggregated or detailed so that they can fit the production reality more accurately. Activity durations are established on an empirical basis taking into account the tender schedule. Occasionally, the need for the most significant resources throughout the project life may be roughly estimated. The lack of time does not allow site directors to achieve better results.

(5) Computer-based planning is restricted to scheduling. In-house developments could be found in two companies. The scheduling method is CPM, but outputs are normally presented in a flow chart format that seems to be more suitable for site operations.

Therefore, computer support for the integrated model should take this aspect into consideration.
3.5.3.3 Production control.

(1) Production control mainly refers to cost control of the items of the bill of quantities. Moreover, resource control is also exercised by three companies but only one of these declared that it managed to achieve full control for all resources and for all items.

Cost control should therefore be a major element of any integrated model to be developed.

(2) Cost control aims at comparing production costs with forecast costs. Production costs result from data collection on site, and forecast costs result from work valuations using unit costs previously estimated. Obviously, this may only be achieved if resources have been allocated beforehand, otherwise actual production costs only become known much later, from the outputs of the Accounting Department.

(3) The control of time is performed by inspection of the programme for the works.

(4) Computer-based procedures in control are confined to some "worksheet" packages for data analysis.
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CHAPTER FOUR
SPECIFIC INQUIRY INTO 21 PORTUGUESE CONSTRUCTION COMPANIES.

4.1 Introduction.

4.1.1 General characteristics of the inquiry.

The objective of this survey is to ask Portuguese companies about the possible development of a methodology for the integration of estimating, planning and control management functions. This follows one of the sub-aims of this thesis as stated in section 1.3. Following the results of chapter 3, the second step of the research methodology as presented in section 1.4 is herein pursued. In order to achieve this, a questionnaire has been produced as listed in section 4.2.4. Answers were collected during interviews with the staff of the selected construction companies. The author was directly involved in all the necessary interviews.

4.1.2 Objectives of the inquiry.

According to chapter 1, the need to carry out this inquiry follows from the conclusions of the detailed inquiry as described in chapter 3. In a way, the latter served as a pre-inquiry to this one, thus the objectives listed here are mostly based on the conclusions of chapter 3.

The direct objectives of the inquiry may be summarised as follows:

(1) to find out if companies recognise the importance of integrating estimating, planning and production control management functions;

(2) to find out if the development of an integrated methodology for those management function would be useful;
(3) to discover how they are currently carried out in construction companies;

(4) to look at computer-based methods used to perform those functions, and
gauge possible receptiveness of construction companies to an integrated
computer-based approach.

Finally, it is obviously an objective of the inquiry to draw conclusions from the
survey. Moreover, it is expected that those conclusions may help to refine the
approach to the integration of planning, estimating and control management
functions.

4.1.3 The way the inquiry was conducted.

The inquiry was carried out by means of a questionnaire administered to a set
of selected construction companies. The way the questionnaire was drawn up,
the selection of the companies and the problems of finding the right people to
speak to are described in section 4.2. The questionnaire is listed in section
4.2.4. Answers to the questionnaire are summarised in table 4.1 and
commented in section 4.3. Final conclusions are described in section 4.4.

4.2 The organisation of the Inquiry.

4.2.1 Introduction.

This section describes the methodology used for the organisation of the
inquiry. The following stages were accomplished:

The first stage was the definition of its objectives. These have already been
listed above.

The second stage dealt with the selection of the companies to survey and
establishing reliable sources of information within the companies. Section 4.2.2
describes this work.
The composition of the questionnaire and the organisation of the answers to the inquiry was the third stage. This is described in sections 4.2.3 and 4.2.4. The questionnaire is listed in section 4.3.

It must be noted that just as in the previous inquiry, extensive overlapping took place among the stages mentioned above, thus the division into sequential stages is somewhat artificial.

4.2.2 Selecting and approaching companies.

4.2.2.1 The selection of companies.

As for the detailed inquiry, Portuguese general contractors were selected for this inquiry. Moreover, both building contractors and civil engineering contractors were surveyed this time.

During the selection process, it was concluded that very small companies should not be studied because their size does not normally allow them to perform management functions systematically. They are frequently family-type small firms with a very centralised structure highly dependent on the owner or on a few partners. They chiefly undertake for small private projects which are negotiated with a client on a "trust me" basis. Management functions are usually performed using "rule of thumb" techniques.

Accordingly, it was decided that companies to select should have a staff specially concerned with the management functions to be studied. However, this would be somewhat difficult to find out prior to knowing the companies from inside. The number of employees seemed to be the best indicator of management quality and this could be easy to discover. Therefore, it was assumed that companies with less than 50 employees would probably fail to satisfy that requirement. Moreover, this corresponds to a class of construction companies as defined in Portuguese official statistics. Latest figures available indicate 668 companies with more than 50 employees in 1987. However, this number is possibly excessive, because some companies included are not actually contractors but just have some department concerned with
construction for a variety of reasons (to construct the facilities they need for their own use, to support other main activities, etc.)\(^{(1)}\). Instead of using any random criterion to select companies in that universe, it was decided to use some knowledge the author might have in order to build up the sample. Moreover it was also decided that major Portuguese contractors should be included in the sample. Initially, thirty companies were selected. From these, five had already been approached during the detailed inquiry.

Finally, the questionnaire was administered to only 21 companies for reasons to be explained in the conclusions to this inquiry. However the significance of the sample appears to be good for the following reasons: Firstly, because of its size which is possibly more than 3\% of the total universe. Secondly, the value of construction projects carried out by all the companies pertaining to that universe is 80\% of the total national\(^{(1)}\) total. Therefore management techniques they use are surely very well known. Thirdly, larger companies sign contracts for larger projects, so the most efficient approaches to management functions can be expected to be found in their practice. Finally, the experience of larger companies tends to be followed by smaller ones, which can seldom afford to innovate. Therefore, most of the management techniques smaller companies might possibly aim to adopt for themselves can probably be found in use in large "school" companies.

4.2.2.2. Approach to the selected companies.

Who should answer the questionnaire was decided by the companies during the first contact. The questionnaire is shorter and more straightforward than the one used for the detailed inquiry, thus allowing for easier and more direct answers. Therefore the inquiry was designed for just one session per company. If more than one person was appointed to participate, a large meeting with everyone concerned would take place.

\(^{(1)}\) See chapter 2. The Portuguese Construction Industry. A few Comments.
4.2.3 Composition of the questionnaire.

The questionnaire comprises a set of questions, a set of subjects to be discussed and a set of presentation and connection texts between questions and subjects.

It was administered in each selected company, in the course of a single appointment with its staff.

The organisation of the questionnaire is as follows:

a) Contact with the company and activities of the company.

b) The integration of management functions.

c) The development of an integrated approach.

d) Computer-based procedures.

The questionnaire is composed of four parts. The first part refers to the contact with the company and to the identification of its main activities. The second part aims to clarify the importance of integration among management functions. The objective of the third part is to collect data about the way each company performs management functions. The fourth part is about computer based solutions companies may have in use.

4.2.4 Questionnaire.

a) Contact with the company and activities of the company.

   a.1) Contact with the company.

   a.1.1) General information.
A survey of management functions as performed by the company. Data collected will be used in a research programme in *Universidade do Minho*. There is also the collaboration with Loughborough University (UK) and with the *Instituto Superior Técnico* (Lisboa). This research has the support of the *Instituto Nacional de Investigação Científica* (INIC).

The basic idea is the development of a methodology for the integration of the management functions of estimating, planning and the preparation of control.

Is the company interested in participating in the study? An interview with someone qualified from the staff will be required.

Specifically, the objects of the survey are to find out:

1. If the company understands that integration of management functions is desirable and if it is fully achieved in the current practice of the company.

2. If the company believes that further developments in this area would be useful.

3. Which procedures currently used to perform those functions the integrated approach should support.

4. The importance of computer-based integrated approaches to management functions.

a.1.2) Clarifications required.

a.1.3) Settlement of the first interview.

a.2) General characteristics of the company.
b) The integration of forecasting and production control activities.

Management of a construction project includes a set of activities that take place from the decision to tender till the final settlement of the project accounts. There is a great number of activities related to the management of construction projects (management functions). The following will be surveyed: Estimating, planning and control. The preparation of data necessary to carry out control on site will be specially analysed.

Is it important to integrate estimating, planning and the preparation of data for control?

After integration among those functions is achieved, would it be of interest to proceed with other aspects of control?

c) The development of integrated methodology.

The basic idea of this research programme is to try to bring together in a general methodology estimating, planning and the preparation of data for control preparation. The integrated approached should support possible distinct estimating methods; planning should be done in accordance with estimating; and preparation of data for control should enable the company to perform control with the same degree of precision as estimating and planning functions.

What methods does the company use for estimating?

What are the criteria used for the definition of the construction activities of a project?
What resources are planned?

Does the company believe that the development of the integrated methodology would be useful? Suggestions.

d) Computer-based procedures

Does the company use any computer support for estimating and planning?

Does the company believe that the development of construction-specific computer software is still required, or are current solutions completely satisfactory?

Does the company believe that the development of a computer based support for the suggested methodology would be useful?

Which are the most suitable machines for the development of construction management software?

4.3 Answers to the questionnaire.

Answers form companies involved in this inquiry are summarised on table 4.1. Company names were omitted at their request and replaced by aliases (companies A to U). Companies A to E are the same as in the detailed inquiry. It must be remarked that information about the turnover and the number of employees could not be assessed in most companies, thus that information was suppressed from all answers.

An interesting characteristic of the answers to this inquiry is that they were very similar among companies. Moreover, as questions are rather direct, information gained from table 4.1 is sufficient for the objectives of the study.
## Table 4.1

| COMPANIES | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U |
| Integration of man. functions? | Y| Y| Y| Y| Y| Y| Y| Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Estimating: document method. | bq| bq| bq| bq| bq| bq| bq| bq | bq| bq| bq| bq| bq| bq| bq| bq| bq| bq| bq| bq| bq| bq| bq |
| Criteria for planning activities. | bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi| bqi | bqi | bqi | bqi |
| Resources in planning: labour? | Y| Y| Y| Y| Y| Y| Y| Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| plant? | N| N| Y| Y| N| N| N| Y | Y | N | Y | Y | N | Y | N | Y | N | Y | N | Y | N | Y | N |
| materials? | N| N| Y| N| N| N| N| Y | Y | N | Y | Y | Y | N | Y | Y | Y | Y | N | Y | N | Y | Y |
| Development of methodology? | Y| Y| Y| Y| Y| Y| Y| Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Computers in estimating? | N| Y| Y| N| Y| N| N| N | N | Y | Y | N | Y | Y | Y | Y | N | Y | N | Y | N | Y | N |
| Specific soft. still required? | Y| Y| Y| Y| Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Computer support for methodology? | Y| Y| Y| Y| Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |

**Key:**  
- **Y:** Yes  
- **N:** No  
- **BC:** Building Construction  
- **PW:** Public Works  
- **bq:** bill of quantities  
- **up:** unit prices  
- **ur:** unit rates  
- **op:** operational estimating  
- **bqi:** items of the bill of quantities  
- **+:** further detail.
The sample involved in this inquiry comprises 21 companies, 4 of which only undertake building construction whilst another 4 only undertake public works. The remaining 13 undertake both building construction and public works. The production sector surveyed in this last group of companies was building construction in 12 companies and public works in one company. This means that 16 building construction production sectors and 5 public works production sectors were surveyed in this inquiry. All the companies declared that the integration among estimating, planning and the preparation of data for control is important.

Estimating is generally based on a bill of quantities. Unit prices for the items of the bill of quantities are supported by a study of costs in all the companies surveyed, though market prices are also used in seven companies. The estimating of direct costs varies according to the type of projects. For building projects all companies use unit rates and also does one company for public works. Four companies declared they use operational estimating for public works.

All the companies stated that the definition of construction activities is mainly based on the items of a bill of quantities and for eleven companies additional criteria are required. All companies declared that the requirements of labour for each activity are always assessed. Moreover, 11 companies estimate the need of plant (all civil engineering contractors and 41% of the building contractors), and 9 companies predict the dates of purchase for the most important materials (all the civil engineering contractors and 29% of the building contractors). The development of the integrated methodology was approved by all the companies.

Unit rate estimating is computer supported in 12 companies (11 of which are building contractors) and scheduling in 5 companies. Operational estimating is done by hand in all the companies surveyed. The development of specific computer software for the construction industry is still important for all the companies. All the companies understood that the integrated methodology should be computer supported.
4.4 Conclusions of the inquiry.

4.4.1 Introduction.

The inquiry helped to clarify how estimating planning and the preparation of data for control should be integrated. In fact, answers from construction companies contributed to a better understanding of what the integrated approach should be like. Unfortunately, suggestions from companies for the improvement of the initial idea were scarce.

During the development of the inquiry, it was decided not to continue with it after answers from 21 companies had been collected. That decision was taken because of the following:

(1) answers collected until that moment were similar and no substantial differences were expected in further interviews;

(2) five more companies had already been approached at the time and during the first talks it appeared that answers would be identical to other companies surveyed;

(3) the resemblance among answers to the questionnaire were not contributing to further understanding of the problem;

(4) larger companies had already been surveyed, so the most accurate approaches to the problem had probably already been captured;

(5) more time would be needed to carry on with the inquiry apparently with little gain;

(6) the statistical relevance of the sample had already been achieved

(7) more companies could be surveyed at a later time if necessary.
The contact with companies was made by using personal contacts with someone from their staff in ten cases (of those, five had already participated in the detailed inquiry), and by an introductory phone-call in sixteen cases. All the companies were receptive to the participation in the inquiry. Most people declared that they would be interested in the evolution of this survey and encouraged further contacts. The originality of this kind of studies in Portugal was remarked on.

4.4.2 General conclusions.

From the twenty one construction companies included in this study, four undertake building projects, three undertake civil engineering projects and fourteen undertake both activities. It was necessary to select the sector to survey in the latter because it was concluded that companies use distinct approaches for building and for civil engineering projects. The criterion used was to decide upon the most important sector in each company. Accordingly, seventeen answers refer to building projects and four to civil engineering projects.

All companies recognised that the integration of estimating planning and control is very important. Moreover, they generally agreed that the first topic to look at in the integration of control should be the preparation of data. Most companies seem to be deeply interested in achieving efficient control on site; thus the idea of having good data to carry it out was generally well accepted.

Integration of estimating and planning was only found to be effective if operational estimating is used. This is restricted to civil engineering projects.

4.4.3 Specific conclusions.

Answers to sections c) and d) of the questionnaire allowed for the following conclusions:

(1) Estimating is generally based on a bill of quantities either supplied
by the client in tender documents or generated by companies. Bills of building projects are generally larger and more complex than those of civil engineering projects. Moreover, bill items are closer to construction activities in the latter than in the former.

(2) Unit prices for the items of the bill of quantities are normally supported by a study of costs, though market prices may be used for reference. However, some companies only use market prices for current work.

(3) The estimating of direct costs varies according to the type of projects. For building projects, unit rates provide the most common approach, whereas for civil engineering projects operational estimating is generally preferred.

(4) The definition of construction activities is mainly based on the items of a bill of quantities. However, building projects often require additional criteria for the most detailed phases of planning, whereas civil engineering projects seldom do.

(5) The main objective of planning is the generation of the construction programme. All companies declared that the requirements of labour for each activity are always assessed. Moreover, 11 companies estimate the need of plant (all civil engineering contractors and 41% of the building contractors), and 9 companies predict the dates of purchase for the most important materials (all the civil engineering contractors and 29% of the building contractors)

(6) Site control for the most important resources should always be imposed.

(7) The development of the suggested integrated approach was generally considered to be useful, especially if it could be computer supported. However, some companies remarked on possible difficulties in achieving this, especially integration of operational estimating.
(8) Unit rate estimating is computer supported in 12 companies (11 of which are building contractors). Operational estimating is generally done by hand, as is planning for definition of activities, precedence relationships, activity duration and allocation of resources. Scheduling is performed by computer in 5 companies.

(9) The development of specific software for construction is still required. Companies believe that current programs can be improved and integrated approaches could be developed.

(10) The development of the suggested integrated approach should be undertaken in a PC environment. Current partial programs could be advantageously integrated, but one company alerted us to possible difficulties in making them compatible with each other.

From the answers to sections c) and d) of the questionnaire, the following conclusions could be drawn:

(1) All the companies declared that the price for a project execution is normally supported with a cost study, though market conditions may also be used for the composition of the priced tender bill of quantities. However, five companies only use market conditions criteria for the establishment of the unit prices of some common bq items.

(2) Methods used in costs studies differ according to the type of project. Unit rate estimating is commonly used for building projects; costs calculations by all the companies; operational estimating is usually preferred for civil engineering works. Therefore, any integrated model suitable for both building projects and civil engineering works should be prepared to deal with these two methods of estimating.

(3) Construction activities considered in planning are mainly related to the items of the bq, though its degree of aggregation was recognised to possibly be different according to the stage of the project development to which the planning activity is directed. Nevertheless, this is more
likely to occur in building projects than in civil engineering projects. Furthermore, building projects often require additional criteria for the definition of activities (as pointed out by 15 companies), while civil engineering projects seldom do (although it may happen, as confirmed by one company). This is due to the greater simplicity of their bills of quantities, which normally have much less items than those of building projects. Moreover they seem to be more adapted to the construction reality and so allow for a tighter relationship between estimating and planning.

(4) The main goal of the planning activity is the generation of the construction programme for the works. All the companies stated that the labour requirements for each activity are always computed (whereas the degree of precision used is expected to be different from company to company). Moreover, 11 companies also include the equipment needs in the construction programme (always stated by the civil engineering contractors and by 41% of the building contractors) and 8 companies pay attention to the forecast dates for the purchase of materials throughout the period of project execution (75% of the civil engineering contractors and 29% of the building contractors). Therefore, the allocation of resources to the construction activities is an important issue to be supported by any integrated model.

(5) The elapse of a long period of time between commitment and the actual start of the project's execution seems to be of special concern to civil engineering contractors.

(6) It was generally recognised that control of the most important resources forecast should always be established, although some aggregations are accepted.

(7) The development of the proposed methodology was generally considered to be useful. Computer support was also well accepted, although the development of the program was recognised to be a difficult task whenever operational estimating is involved, because of the
"human judgement" that is need in the process. Accordingly, an integrated model should take this aspect in careful consideration.

(8) Unit rate estimating is supported by automatic procedures in 12 companies (11 of which are building contractors) Planning is performed by hand, except for scheduling in 5 companies which support the network calculations of their projects with computers. Operational estimating is usually done by hand.

(9) The development of specific computer software for the construction industry is still important for all the companies. The main reasons found were the need for increasing the performance of the existing packages for estimating and planning and the need for integration.

(10) The development of the proposed computer program based on existing solutions was generally well accepted. One company suggested further developments aimed at producing a new integrated package. this should be taken into account in the development of computer support for any integrated model.
CHAPTER FIVE

Inquiry to Portuguese Construction Clients and to Portuguese Software Dealers.

5.1 Inquiry to 5 Portuguese Construction Clients.

5.1.1 Introduction.

5.1.1.1 General characteristics of the Inquiry.

The objective of this inquiry is to survey a sample of Portuguese clients of construction projects about the quality of data delivered by contractors. This follows one of the sub-aims of this thesis and is included in the second step of the research methodology as presented in section 1.4. In order to achieve this, a questionnaire has been produced as listed in section 5.1.3.

5.1.1.2 Objectives of the inquiry.

According to chapter 1, the conclusions of the inquiries administered to construction companies showed that the quality of data interchanged by clients and contractors could possibly be better than it is. Specifically, the following aspects of those inquiries were taken into consideration:

(1) sometimes, project data delivered by clients is not satisfactory to fully support tendering analysis of the projects;

(2) the requirements of clients in tender documents may influence the way contractors do estimating and planning;

(3) the output of tender planning as performed by some contractors does not enable clients to monitor project execution on site with any great certainty;
These aspects led to the following reflections:

1. Tender documents delivered by clients should allow contractors to fully understand the project within the time given for tendering and dispense them from spending significant resources at this stage;

2. The requirements of clients in tender documents should not be exaggerated but details should be sufficient to support their decision about the most advantageous offer;

3. Data delivered by contractors could be improved after commitment in order to facilitate the clients' project control on site.

Following these reflections, the objectives of this inquiry were defined as follows:

1. To survey how clients expect contractors to organise information in tender documents;

2. To find out how clients assess the quality of information collected from contractors;

3. To record possible comments about the development of the integrated approach suggested to contractors.

5.1.1.3 The way the inquiry was conducted.

The inquiry was carried out by means of a questionnaire administered to a set of selected construction clients. The methodology used in the inquiry, the way the questionnaire was constructed, the selection of the clients and the problems of finding the right people to speak to are described in section 5.1.2. The questionnaire is listed in section 5.1.3. The way the answers to the questionnaire were evaluated is briefly explained in section 5.1.4. Conclusions are described in section 5.1.5.
5.1.2 The organisation of the inquiry.

5.1.2.1 Introduction.

This section describes the methodology used for the organisation of the inquiry. The following stages were accomplished:

The first stage was the definition of its objectives. These have already been listed above.

The second stage dealt with the selection of the client organisations to survey. Section 5.1.2.2 describes this work.

The questionnaire was composed afterwards as listed in section 5.1.3.

5.1.2.2 Client selection and approach.

5.1.2.2.1 Client selection.

Clients were initially divided into two groups: Private clients and public clients.

Private clients are normally building clients. The size of their organisations is variable from the individual occasional owners to the regular clients with an expert technical staff. It was decided to exclude the smaller ones, from the survey because their experience is normally restricted to a few projects. On the other hand, very large clients are uncommon in Portugal. Therefore, medium size client organisations were selected.

Public clients may be building clients or civil engineering clients. It was decided to hear from both of them.

Five client organisations were selected. Two of them are private with different dimensions. The other three are public (a school builder, an electric plant constructor and a road constructor).
For the selection criteria the author's direct knowledge of someone in the client's organisation staff also contributed.

5.1.2.2 Approach to the selected client organisations.

People, to talk to were generally easy to find within the clients organisations. However, there were some problems in the case of public clients because their organisations are sometimes rather complicated.

5.1.2.3 Composition of the questionnaire.

The questionnaire is composed of:

(1) a set of questions;

(2) a set of subjects to be discussed;

(3) a set of presentation and connection texts between questions and subjects.

The questionnaire was administered in each selected company, during an interview with their staff.

5.1.3 Questionnaire.

a) First Contact with the Client.

a.1) General informations.

The objective of this inquiry is a survey of the degree of accuracy of data delivered by contractors in the tender stage and during the execution of projects. Data will be used in a research programme being carried out in the Universidade do Minho. There is also collaboration with Loughborough University (UK) and with the Instituto Superior
Técnico (Lisboa), as well as support from Instituto Nacional de Investigação Científica (INIC).

An interview with someone from the staff was needed to determine whether the company was interested in participating in the study.

The general objectives of the work at this stage are:

(1) To inquire about the tendering process, especially:
   - types of projects;
   - types of tender contracts.

(2) To inquire about the quality of data delivered by contractors:
   - during the tender stage;
   - after commitment.

(3) To inquire about the way contractors accomplish project execution.

a.2) Clarifications required.

a.3) Settlement of the first interview.

b) The tendering process.

Which methods of tendering do you normally use?

What documents are delivered to construction companies for tendering?

c) Cost and scheduling data.

What type of cost and schedule data do you demand?
Which price and schedules do you normally demand of contractors at the tender stage? Is all the information satisfactory?

What are the main difficulties you experience when comparing costs and schedules from different contractors?

Comments.

d) The execution of the project.

After commitment, do contractors normally add other information about the way they intend to carry out the project on site? Are these more accurate than those of the tender stage?

Do contractors usually accomplish the execution of the project according to their predictions? What are the main reasons for possible discrepancies?

Comments.

5.1.4 Answers to the Inquiry.

Answers from clients are not presented because those results are secondary to the main objective of the thesis. However, the conclusions drawn were similar to those of the inquiries to construction companies. There were no special difficulties in carrying out this job, because of the small number of companies surveyed and of the resemblance of their answers. Section 5.1.5 lists the conclusions to the inquiry.

5.1.5 Conclusions.

Answers to the questionnaire allowed the following conclusions:
(1) Private clients normally invite a set of selected contractors to submit a tender for their projects. Lump-sum contracts are mostly used but measurement contracts may also be adopted, especially if work quantities cannot be correctly assessed (refurbishment work, for example). Moreover, contractors may be partially lump-sum and partially by measurement. Clients surveyed normally deliver the bill of quantities of work to be undertaken to contractors at the tender stage, but detailed measurements are seldom released.

(2) Public clients only use a selective pre-tender process for large projects or if high specialisation is required for a particular task. In this case, contractors invited to tender are selected after a qualification process takes place. Lump-sum contracts are mostly used except for the cases mentioned above. Clients surveyed generally deliver the bill of quantities of work to be undertaken to contractors at the tender stage. Moreover, detailed measurements are often sent as well.

(3) Contractors are normally asked to illustrate their offer with the priced bill of quantities and the preliminary construction programme. The priced bill of quantities was generally recognised as an important document because: firstly, it allows for comparing among several offers; secondly, it allows for evaluating work on site very easily; thirdly, if necessary, it serves as a basis for the discussion of new unit prices for work not predicted. The construction programme presented by contractors at the tender stage is often poorly detailed and it has many "intermittent" activities which do not make clear how the contractor intends to carry out the work on site. For small private projects however, the total value of the project may be sufficient, especially if no bill of quantities was delivered by the client. In this case payments are agreed between clients and contractors. Normally, payments are made by fixed amounts in agreement with parcels of work undertaken. Some small clients may be happy with just a rough idea of when the project will be finished but in most cases due-dates are agreed between clients and contractors for some project phases. In fact, fixing due-dates is also common among clients now-a-days. One client surveyed goes further and sends contractors a master construction programme with key-dates
assigned where the programmes of all contractors involved in the project must fit.

(4) The most important documents clients look for in order to compare offers from different contractors are the priced bill of quantities, the construction programme and the expected flow of payments. Private clients may not get all that information whereas public clients normally do, because submitting those documents at the tender stage is often compulsory for contractors. Main difficulties in comparing offers arise if these are very different from one another.

(5) After selecting the contractor, a more detailed construction programme is often demanded by public clients. Moreover, contractors are normally allowed to submit a list of errors and omissions in the tender bill of quantities to clients.

(6) Many contractors use efficient estimating techniques these days. Nonetheless, they seem to pay less attention to planning than they should. In practice, construction programmes first submitted to clients are seldom followed on site. Activity durations and resources allocated to them are sometimes very different from predictions. Main discrepancies are not only due to the characteristics of the construction industry but also result from the way contractors conduct projects. Efficient contractors however, tend to finish their projects on schedule and accomplish intermediate key-dates if any. In order to achieve this, contractors end up by allocating more resources than they expected to critical activities because these were behind schedule. This procedure makes it more difficult for clients to follow project execution on site and may lead to some changes in the flow of payments. Moreover, it certainly raises costs for contractors.
5.2 General Inquiry to Portuguese Software Dealers.

5.2.1 Introduction.

5.2.1.1 General characteristics of the inquiry.

The objective of this inquiry is the survey of current computer software programs for estimating and planning of construction projects.

The survey was carried out by means of a set of interviews of selected software dealers.

With this inquiry, the second step of the research methodology as presented in section 1.4 becomes complete.

5.2.1.2 The objectives of the inquiry.

Prior to the definition of the objectives, the following conclusions of the previous inquiries to construction companies were taken into consideration:

(1) Although computer support for unit rate estimating is already in use in most companies, the need to improve current software was generally recognised. Some of the companies use in-house developments and this could mean that commercial programs are not satisfactory. Furthermore, operational estimating was not found to be computer supported in any company.

(2) Computer programs for planning only support the scheduling task. Apparently, a computer could be best used for the planning activity. Moreover, it seems that current solutions were not specifically developed for construction projects and companies feel some lack of adequacy in those programs.

(3) No integrated computer software for estimating and planning could be found on use in any of the companies surveyed.
Nevertheless, answers to the second inquiry showed that this would be a useful tool for the management of construction projects.

(4) As construction companies mainly use PC's, software for these specific machines will be sought.

Hence, it was decided to find out by means of this inquiry if there are commercial software products available which fulfil the requirements of the industry. This led to the definition of the objectives of this inquiry as follows:

(1) to survey current software programs for estimating and planning of construction projects;

(2) to order them into classes according to their possible different characteristics;

(3) to make a short analysis of the most relevant programs;

(4) to search for integrated solutions possibly involving control as well.

5.2.1.3 The way the inquiry was conducted.

Initially, a set of interviews of selected software dealers was carried out. Then the results were analysed and conclusions drawn, with the aim of answering the objectives (2) and (3) above. The selection of the software dealers is described in section 5.2.2. Final conclusions are listed in section 5.2.3.

5.2.2 The organisation of the inquiry.

5.2.2.1 Introduction.

This section describes the methodology used for the organisation of the inquiry. The following stages were accomplished:
The first stage was the definition of its objectives. These have already been listed above.

The second stage dealt with the selection of software dealers. Section 5.2.2.2 describes this work.

No questionnaire was built up to support this inquiry due to the obvious simplicity of questions to be asked. Also no special organisation for the answers was deemed necessary.

5.2.2.2 The selection of the software dealers for the inquiry.

It was decided to survey only Portuguese dealers. However, this covers both Portuguese and any international software they may sell.

The selection was made in two stages:

(1) general information about Portuguese software dealers was searched;

(2) dealers with possible relevant computer solutions were selected.

The following sources were used to get general information about Portuguese software dealers:

(1) previous knowledge of their companies;

(2) references during the previous inquiries and earlier informal meetings;

(3) software exhibitions;

(4) journals and publicity advertisements;
Data from API was not relevant, because, although all Portuguese software dealers are members, information about which products each one sells cannot be easily found in their records. Therefore, sources (1) to (4) were first used in order to select dealers trading in computer software for the construction industry. Afterwards, other companies were approached by phone. All the software dealers in the Porto Páginas Amarelas (yellow pages phone book) 1989 edition were eventually contacted. Moreover, some companies from Lisbon were also sought.

Five software dealers were selected using one of the first four criteria. Thereafter, twenty two other companies were called by phone; two from these were also selected. Finally, seven distinct computer software dealers were surveyed.

No problems were envisaged in approaching these companies because they are naturally prepared to give all the necessary information about the products they want to sell. For the this reason, the preparation of a specific questionnaire was not required.

5.2.3 Conclusions.

5.2.3.1 General conclusions.

The small number of software dealers selected clearly shows that there are only a few companies interested in trading in construction software products. According to those dealers, reasons for this are as follows:

(1) Small construction companies are not yet prepared for computer support for the construction management functions (although some of them already use computers for other purposes eg accounting).
(2) Some medium size construction companies have developed their own computer support based on commercial packages (often worksheets and sometimes data bases). Moreover, some software dealers all sell similar products. Those products are mainly devoted to helping in some aspects of estimating but often fail to support the whole process. However some companies are used to them and refuse to implement more sophisticated approaches. The results of the second inquiry (as listed in Appendix 1.2) confirm this (company N is happy to use one of such products).

(3) There are few large construction companies in Portugal and most of them have been developing their own software best tailored to their needs. This was also found during the previous inquiries.

From the seven selected dealers, two were later rejected because their products were of the type of those mentioned in (2) above.

Portuguese software for estimating was easier to find. Planning software tends to be international though some Portuguese software is also available. Both estimating programs and planning programs surveyed are similar to one another though some are more powerful and sophisticated than others.

It was decided analyse the abilities of estimating programs more thoroughly because references to planning software are easier to find in the literature. Some packages combining more than one function can also be found (eg estimating and planning, estimating and control, etc.). These tend to involve Portuguese software only.
5.2.3.2 Specific conclusions.

5.2.3.2.1 Estimating computer programs.

Five computer programs with some interest could be found. Four of them were designed for PC's and one for a medium system. The latter was specially ordered by a construction company which wanted it to be tailored to the company's computer system (IBM 36). All the programs surveyed are prepared for unit rate estimating. They basically operate with data from three files:

(1) a file of typical construction tasks;

(2) a file of resources;

(3) a file of measurements.

Construction works are represented by several attributes. The most important are the work description, the measuring unit, and a set of resources and corresponding quantities required to perform one unit of work. Each company may use its own build-ups or may adopt any published data on the subject. LNEC IC6 file was being used for demonstration of the five surveyed programs.

The entities of the second file are resources which are basically represented by the resource name and unit cost. The resources included in the file may be single or composite (that is, built up of a set of elementary resources).

The entities of the file of measurements are construction works for a specific project. Their attributes are the work description, the measuring unit, the work quantity, the unit cost and the total cost. The values of the first four data items are usually taken from the bill of quantities. The programs compute the unit cost and the total cost for each construction work.

The way the surveyed estimating programs operate is as follows:

Firstly, the user must identify which construction work of the first file above corresponds to each item of the bill of quantities of the third
file. Then the computer calculates the unit costs for all bq items by multiplying resource build-ups (first file) by the corresponding costs (second file). This information is transferred to the third file and the computer finally calculates the total costs of the items by multiplying unit costs by the measurement quantities.

The computer programs have other facilities not mentioned above which are aimed at helping the user in manipulating data more easily. For example, the user may rapidly change a range of resource costs or rates and the programme automatically updates unit costs; the costs of a group of items of the bill of quantities may be altered by multiplying them by a fixed value, etc. A large number of reports may also be quickly obtained, including the typical bill of quantities and several other reports about the resources required to accomplish the project on site (eg resource allocation to bq items, total quantities of each resource by chapters of the bill of quantities, etc.). These features are usually advertised as good tools for project control on site.

5.2.3.2.2 Planning computer programs.

Three Portuguese-made planning computer programs could be found. They are all based on a "Critical Path" analysis but they allow for reports in a bar chart format as well. Reports about the utilisation of resource throughout the project execution are also possible but they do not cater for levelling and smoothing. International planning software is also available. "Primavera Project Planner" and "Pertmaster" are probably the best known products. Their performances seem to be higher than those of the Portuguese software.

5.2.3.2.3 Integrated software.

Some estimating packages, such as those referred to in 5.2.3.2.1 above, include a control module to be used for project control on site. Planning packages often include such modules as well. Moreover the three planning programs mentioned in section 5.2.3.2.2 are parts of larger computer packages, which also include an estimating module and in two cases, a control module as well.
These packages are sometimes referred to as "Integrated Systems" but in fact they only accomplish some automatic data transfer among distinct modules as described below.

Software computer packages aimed at estimating and control usually have distinct modules for each function. The estimating module has already been discussed in section 5.2.3.2.1. The control module enables the user to record resource consumptions on site. Actual consumptions may be subsequently compared with the resource quantities forecast in the estimating module. According to the possible reports of the estimating module, comparisons can be made for the resource quantities of the whole project or for the resources allocated to each item of the bill of quantities.

The connection between estimating and planning modules is achieved through a relationship between the items of the bill of quantities used in the estimating module with the activities of the construction programme used in the planning module. Accordingly, the user must tell the computer which items should be comprised in each activity. Some programs also allow the user to select parts of items to be merged into distinct activities. For example, 20% of item 1 plus 30% of item 2 are to be merged in activity 3. Thereafter, data about the items that have been merged is automatically transferred from the estimating module to the planning module.

Software for planning which includes a module for control works pretty much like the estimating/control packages. Resource allocation to activities is normally entered by the user.

Software programs comprising estimating planning and control modules use a combination of the procedures described above. Accordingly, data from the estimating module is transferred both to the planning module and to the control module.

In view of the above, it may be stated that integration among management functions is not fully supported by any software product commercially available in Portugal.
5.2.3.2.4 In-house developments.

From the results of this inquiry, it may be concluded that in-house developments found during the inquiries into Portuguese construction companies are similar to the programs referred above.
CHAPTER SIX

Project Management Functions on Behalf of the Construction Companies During the Pre-Tender Stage.

6.1 The decision to tender.

6.1.1 Introduction.

It was assumed in chapter 1 that the construction phase of a project starts when an offer is requested to build a facility which has been previously designed. The participation of a construction company in the project begins when the company decides to submit an offer for it. The tendering process for the construction company takes place between that decision and the submission of the offer. This is the main concern of this chapter which is included in the third step of the research methodology as presented in section 1.4.

Portuguese construction companies submit offers to open tenders and to selective tenders. Information about open tenders is available from advertisements which are normally published in official papers [1]; information about selective tenders is received through direct invitation.

Both the contents of the advertisements and the invitation forms seldom comprise all the details about the project and the contract needed to fully support a tender/non-tender decision (extension of the works, resources required, etc.). Therefore, construction companies normally decide whether or not to request the contract documents based on the available information, although they may review their decision later if necessary after studying the documents. However, companies normally count on tendering if they have requested the contract documents not only because of the money and time involved in the study but also because they would not like to contradict clients' expectations.

Construction project decisions are generally tactical decisions unless the
project represents a large proportion of the company workload [2]. These should be anchored in the strategic plan of the company that should contain a synthesis of the objectives and strategies that the firm will pursue in a stated period of time [2]. Specifically, the decision to submit a tender should result from the implementation of a company tendering policy [3].

Two classes of objectives for business organisations have been widely recognised [4]: economic and non/economic. Furthermore, firms accept certain constraints and responsibilities which may influence their objectives [2].

Strategies are the courses of action needed to pursue those objectives. These will depend on the capability of the firm and the opportunities in the market which the firm is able to exploit [2].

6.1.2 Objectives of a construction firm.

The traditional economic objective of a firm is the maximisation of money profits [5] which may be written as:

\[ \text{max } TP = TR - TC \]

where TP is the profit, TR the total revenue and TC the total costs. Total costs include the normal profit of the company, ie normal return on the entrepreneur's labour and on capital.

However, the profit maximisation approach has been challenged at two levels: the first that there are circumstances in which other objectives may also play a part; and secondly it bears little real relationship to the way firms actually behave [5]. The implications of other objectives such as those related to the growth of the turnover, market share, the utilisation or availability of resources held by the firm and the over balance of their fixed costs should also be taken into account. Therefore, the consideration of a wider range of economic objectives seems closer to the real world firm [6]. The maximisation of the turnover for a certain level of profit seems to be an acceptable alternative.
approach to the upper one. This may be written as:

\[
\text{max TR} \quad \text{subject to } TP \geq L \text{ and } x \geq 0
\]

where \( L \) is some level of profit below the maximum and \( x \) the output. A particular case of this would be \( TP = 0 \) for which only normal profit would be attained. Moreover, construction companies may accept a lower level of profit in the short run (\( eg \) during crises), just to stay in business [5].

The relationship between revenues and outputs for a construction company will be different according to the type of market situation in which the company operates. The classification of a construction market is dependent on a large number of factors, \( eg \) the size of the market (either in a geographical sense or in the number of firms involved), the method of appointing the contractor, etc. [5]. Therefore, the shape of the revenue curve will be different according to the relevance of each of those factors. However, a curve sloping downwards may be acceptable for the aims of this study. This corresponds to a hypothetical market in between the two extreme situations normally considered in economic theory - perfect competition and monopoly.

The relationship between costs and outputs for a construction company will be distinct according to the period under consideration. In the short run fixed costs cannot be altered whereas in the long run they can. Also the technology at which the company operates can be adjusted in the long run but not in the short run. This study is mostly concerned with the short run analysis of construction costs for which a U shape of cost curves is currently accepted [5].

In figure 6.1 below are plotted the following likely cost curves of a hypothetical construction company and the probable revenue curves the company would be facing in a particular moment:

- AR - average revenue curve;
- MR - marginal revenue curve;
- AC - average cost curve;
- MC - marginal cost curve;
- TR - total revenue curve;
TC - total cost curve;
TP - total profit curve.

The short run equilibrium of the company may be derived mathematically for both objectives mentioned above.

Let $TR = f_1(x)$ and $TC = f_2(x)$, $x$ being the output. Then,

(1) If the firm aims at the maximisation of its profit [5]:

a) the first order condition for the maximisation of $TP$ is:

$$\frac{\partial (TP)}{\partial x} = \frac{\partial (TR)}{\partial x} - \frac{\partial (TC)}{\partial x}$$

or

$$\frac{\partial (TR)}{\partial x} = \frac{\partial (TC)}{\partial x}$$

ie $MR = MC$

b) the second order condition writes:

$$\frac{\partial^2 (TP)}{\partial x^2} \geq 0,$$

ie \{slope of $MR\} \geq \{slope of $MC\}$.

Point A in figure 6.1 accomplishes conditions a) and b).

(2) If the firm aims at the maximisation of its revenues for a pre-established profit $L$, the following set of differential equations will give the solution to the problem [7]:

(1) $\frac{\partial Z}{\partial y} = f_1(x) - f_2(x) - L \geq 0$, with $y \geq 0$ and $y (\frac{\partial Z}{\partial y}) = 0$.

(2) $\frac{\partial Z}{\partial x} = \frac{\partial f_1}{\partial x} + y (\frac{\partial f_1}{\partial x} - \frac{\partial f_2}{\partial x}) \leq 0$, with $x \geq 0$ and $x (\frac{\partial Z}{\partial x}) = 0$.

For an output $x > 0$ equation (2) yields $\frac{\partial Z}{\partial x} = 0$.

For $y = 0$, $\frac{\partial f_1}{\partial x} = MR = 0$. Point D in figure 6.1 signals this result.

For $y > 0$, from equation (2), $\frac{\partial f_1}{\partial x} = \frac{y}{1 + y} \times \frac{\partial f_2}{\partial x}$, which means $MC > MR$. Point
B in the figure stands for $L=0$ for which $TR=TC$; point C refers to $TP=200$ (1).

Figure 6.1 Short run equilibrium of the firm [5].

(1) The problem max $TR$, subject to $TP \geq L$ and $x \geq 0$, may be written as:

max $TR$, subject to $TP = g(x) = f_1(x) - f_2(x) \geq L$ and $x \geq 0$, or

max $TR$, subject to $g^*(x) \geq k$ and $x \geq 0$, with $g^*(x) = -g(x)$ and $k = -L$.

Kuhn-Tucker condition writes $Z = f_1(x) + y [k - g^*(x)]$, with $Z$ the Lagrange function and $y$ the Lagrange multiplier. Then:

1. $\frac{\partial Z}{\partial x} = \frac{\partial f_1}{\partial x} - y \frac{\partial g^*}{\partial x} \leq 0$, with $x \geq 0$ and $x (\frac{\partial Z}{\partial x}) = 0$.
2. $\frac{\partial Z}{\partial y} = k - g^*(x) \geq 0$, with $y \geq 0$ and $y (\frac{\partial Z}{\partial y}) = 0$.

Substituting $g^*(x)$ and $k$ by their values yields the above result.
Despite the elegance of the upper formulations, a construction company will not always find it easy to use them to support a tender/non-tender decision. Firstly, it is difficult to anticipate very far in advance the workload of the company. This is owing to the nature of the tendering process which is the way construction companies usually get work [3]; the rate of successful tenders is hardly predictable and may change rather quickly [5]. Secondly, the theoretical shape of the cost curves may be hard to accomplish because of the characteristics of the construction projects as large and generally indivisible lumps spread over a long period of time. Thirdly, demand forecasting is a difficult job in any construction market. Therefore the position of the company in its cost curve may be hard to ascertain, leading to possible errors in its tendering policy.

**Non-economic objectives** are by contrast less tangible and may be influenced by political decisions coming from inside or outside the company. Examples of these are [8]:

- to meet reasonable aspirations of employees and to develop them to their full potential;
- to serve clients and the general community well;
- to maintain a good reputation within the industry.

Also, other benefits for the owners such as gaining local and national respect [5], enlarging the curriculum of the company and the professional satisfaction of its associates etc. may be included in this type of objective (2). Furthermore, construction companies may prefer to offer for a project with no expectations of getting the job than to refuse an invitation from a potential future client.

### 6.2 The tendering process.

If the company decides to tender, it becomes definitely involved in the

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(2) See Appendix 1.1: Detailed Inquiry to 5 Portuguese Construction Companies, answers from company C.
The ultimate objective of the tendering process is to prepare the tender documents for submission. These should conform to the contract conditions and allow the company to realise its expectations if the job is eventually obtained.

The tendering process is supported by the tender documents delivered by the client and possibly complemented by site investigation, enquiries, method statements, etc. As can be seen in chapter 2, the extent and the detail of the tender documents is variable among projects. Moreover, while Public Construction Works are specifically regulated by Portuguese law [9], private projects are regulated by other more general contract arrangements [10]. Therefore the accuracy of the tender documents for the former tends to be higher than for the latter.

Measurements are an important piece of information about the works to be undertaken. They should comprise the forecast of the quantity and the quality of the works necessary to carry out the project [9]. There are no Portuguese measurement method standards for construction works but LNEC criteria [11] were found to be widely used for building projects. However, in most cases these criteria are closer to a description of things constructed than to a description of works involved in performing construction tasks.

Bills of quantities (bq) are the current reporting format for the work measurements of a project. The author is not aware of the adoption of any alternative arrangement to the traditional bills.

Portuguese bills of quantities mainly comprise work items and a grand summary. Occasionally, a daywork schedule may be required for some construction resources. Each item of the bq contains the following information about the construction works to which it refers:

- the written description;
- the unit of measurement;
- the quantity of work.
Items are normally grouped into chapters within the bill of quantities. Two commonly employed formats are:

- by trades - *trade* being a particular labour skill;
- by construction elements.

There are no Portuguese standards for the composition of bills of quantities but the trade criteria of [11] is commonly adopted for building projects. Measured items of construction works included in the traditional bills of quantities used in the UK seem to follow an identical organisation [12]. Moreover, some Portuguese clients have developed specific formats best suited to their projects [13].

Item descriptions tend to report the project outputs prior to the work involved in performing them. The works included in each item are thus explicitly mentioned or implicit in its description. Item descriptions are often based on LNEC IC4 [14] but their degree of aggregation varies among bills and among items within the same bill. The following types of aggregation criteria are often found:

1. identical works to be carried out in distinct locations are joined into the same item;

2. distinct yet sequential or complementary works are included in the same item;

3. subsidiary works are implicit in the descriptions of the main work to which they contribute;

4. a set of distinct works are merged together into the description of their final output.

The measurement unit of each item is selected in agreement with the output described in it. The quantities of all the works included in an item are totalled in its work quantity.
For example, "reinforced concrete in beams" is a possible item description which includes:

a) all the reinforced concrete beams of the project;
b) all the elementary works necessary to perform it, eg shuttering, steel fixing, concreting, etc.
c) all the subsidiary works required to perform each elementary work, eg concrete mixing.

A volume unit would be selected for this item (ie cubic meter) although steel would be measured in kilograms and formwork in square meters. Moreover, the total work quantity allocated to the item comprises the total quantities of concrete, formwork and reinforcement required to perform it.

The complexity of the bills is dependent on the type of project concerned. Bills for civil engineering projects tend to contain less items and less chapters than those for building projects. Moreover, the former are more readily associated to construction operations than the latter [15]. Accordingly, it can be stated that bills for building projects are generally more complex than those for civil engineering projects [16].

In the following paragraphs planning and estimating management functions as performed by Portuguese construction companies during the pre-tender stage will be reviewed. The discussion is supported by the results of the inquiries presented in the previous chapters, namely:

(1) Detailed Inquiry to 5 Portuguese Construction Companies;
(2) Specific Inquiry to 21 Portuguese Construction Companies;
(3) Inquiry to 5 Portuguese Construction Clients;
(4) General Inquiry to Portuguese Software Vendors.

The importance companies attach to planning and estimating depends on the significance of decisions involved and on the clients requirements in the tender documents.

The aim of estimating during this stage is to help in the assessment of the
tender value for the project under consideration. This is closely related to the amount the company will receive if it enters into the contract. Therefore, estimating usually deserves great attention from the construction companies during this stage. The usual output of tender estimating is the priced bill of quantities.

Portuguese construction companies tend to give much more emphasis to estimating than they do to planning. Indeed, the aim of planning during this stage is to a certain extent subsidiary to that of estimating. Most of the planning effort is directed to the generation of data to be used in the estimating process of the project under consideration. The usual output of tender planning is the construction programme for the works.

According to chapter 2, both the offer value and the project duration are two important adjudication criteria. However, clients tend to give less importance to the construction programme for the works than they give to the priced bill of quantities. An elementary construction programme and possibly a simple monthly receipts forecast are often satisfactory. The priced bill of quantities is however more commonly required by clients. For these reasons, estimating will be discussed in the first place.

6.2.1 Estimating.

Estimates are normally based on a bill of quantities either included in the tender documents purchased by the client or generated by the companies. Bills have been generally recognised as an acceptable document for this purpose and they seem to be widely used in Portugal. This generally agrees with the findings of an earlier survey of the British construction industry [12].

Construction-phase estimating methods should be used for tender estimating purposes because only these methods make it possible to achieve an acceptable degree of accuracy [17]. Indeed, at the stage of submitting a tender contractors should be concerned only with detailed cost estimating [18].

However, some Portuguese construction companies may be using design-
phase estimating methods to support their tender estimates in some cases. The danger encountered is that an estimate of a lower accuracy is used as a substitute for one of a higher accuracy. This procedure was found to be acceptable for lump sum contracts of small ordinary building projects if no bill of quantities is available from the tender documents and the submission of the priced bill is not required. Floor area estimating method may then be used. This involves measuring the total floor areas of the project, possibly dividing them into classes of identical price per square meter. Prices are assessed using the past experience on identical projects, market prices, etc. The total value for the offer is simply computed by multiplying areas and the corresponding unit prices. However, information about construction prices per square meter of buildings is hard to find in Portugal.

In general, estimates are based on a bill of quantities but it was found that some companies dispense with a detailed cost study for the most common bq items. The selection of a reasonable price for those items appears to be good enough but this does not provide for any information about the resources involved in production to be obtained. Prices are assessed from the past experience of the company on identical works, current market price rates, sub-contract quotations, etc. Selected unit prices should not be above the current market prices but they must provide for a fair payment for the works involved. Rates for typical building construction works are regularly published by LNEC [19]. They are built up using LNEC IC4 [14] usage rates and average costs of the resources collected from contractors associations and materials suppliers. However, market price rates are hard to find because unit prices from earlier tenders are not currently available though the total offer value of some projects is [20]. Some companies have been building their own data on current prices for typical construction works but seldom following any systematic procedure.

Costs of construction works are usually divided into two main classes:

- **direct costs**;
- **indirect costs**.

**Direct costs** include the costs of all resources directly involved in each construction job; **indirect costs** include on-costs and a general overhead
allowance. Some companies prefer to separate on-costs (which they usually call site costs) from the general overhead allowance included in indirect costs. However, the division into two classes appears to be more widely used in Portugal [21], [22] and thus it is adopted in this study. This classification also seems to be more widely used and understood [2] by the construction industry in the UK, [23] and it is frequently adopted in British literature [3], [24], [25], [26]. Direct costs plus indirect costs total net costs. The tender price is finally established by adding a profit and risk allowance to net costs.

Cost calculation implicitly accounts for a set of reasonably "normal" expectations but this is often insufficient to take risks into consideration [27]. Several methodologies for risk analysis of construction project cost estimates have been suggested in the literature ([27], [28]) but Portuguese construction companies seem to fix a general risk allowance for the project without carrying out a thorough study of the subject.

The profit allowance is assessed according to the prevailing market conditions [3] and taking into consideration the objectives of the company (see section 6.1.2 above). A strategy for assessing the profit allowance to add to the industrial costs (direct costs + on-costs) is suggested in [29]. Practical examples based on data collected from the Portuguese construction industry are described in [30].

The structure of the costs and additions included in the tender price is shown in figure 6.2 below. However, this is seldom translatable for all the items of the priced tender bill of quantities due to some adjustments companies customarily make before submitting the offer. This procedure is also called "rate loading" in the British literature [3]. As a result, most bq item prices eventually bear little relationship to the corresponding calculated costs.

The following discussion is mainly directed to estimating and thus only the calculation process of construction costs will be meant (the shaded area in figure 6.2).
Resources directly involved in production are commonly divided into the following classes:

1. labour;
2. materials;
3. plant;
4. subcontracts.

Unit costs of these resources are assessed as follows:

1. The cost of site operative labour is calculated by adding to the basic wage rate all the expenses resulting directly from the employment of labour (e.g., allowances, statutory contributions etc.). These expenses may be different from company to company but typical costs for all classes of labour are regularly published by contractors associations [31].

2. The determination of materials costs is one of the most complicated aspect of estimating. Firstly because they are highly dependent on the purchasing conditions, the location of the site, the weather and so on. Secondly, as materials are normally measured net, allowances for overlaps must be added. Thirdly, other allowances to cover materials wastage (e.g., off-cuts, loss, damage, etc.) must also be added. All these factors are subject to a high degree of uncertainty.
(3) Plant costs included in direct costs refer to plant which can be easily allocated to specific construction works. A rate is normally assessed by evaluating both fixed and variable costs and by using a suitable costing system [32].

(4) The costs of subcontracts follow from the quotations of the subcontractors for the works the main contractor decides to sub-let. They are added to the other direct costs of the works they refer to.

Two distinct construction-phase estimating methods are used to study the cost of construction works:

unit rate estimating;
operational estimating.

These are also recognised as the two basic methods for contractor's estimating in British literature ([3], [18], [23], [33]).

The main difference between them lies in the calculation process for the direct costs. Specifically, differences are more obvious when the company's own resources are expected to be directly involved in production.

The unit rate approach is based on the calculation of the unit costs for each construction job. First, the necessary resources to perform one unit of that job are estimated. Standard usage rates of the resources involved in each job are often used. Rates are available from the Portuguese literature ([19], [34], [35]) but many companies use data collected from their own production outputs. Unit cost rates are then computed by multiplying usage rates by unit costs of the corresponding resources. This procedure may be summarised as follows:

(1) select/modify/create the set of usage rates fitting each construction job involved in the project;

(2) update the database of unit costs of resources or retrieve an existing one;
(3) perform the necessary calculations.

Usage rates must be suitable for each specific situation. It is up to the estimator to decide on which rates to use, to adapt any standard ones or to compose distinct usage rates of elementary jobs fitting the particular work under consideration. This is a difficult task because rates vary according to a large number of factors (site conditions, weather, labour productivity, etc.).

However, Portuguese companies tend to use an 'average' rate covering those conditions. Alternative methods to deal with the problem have long been suggested in the literature (for example, by using statistical methods based on subjective probabilities [36]) but they have not been found in use. Also, possible productivity gains as a result of work repetitions within the same project are preferably dealt with by means of a lower average rate than by using distinct rates for each repetition.

Published cost rates for building projects are available in Portugal [19], but companies tend to use their own resource costs to build them up and eventually check the rates so obtained with the published ones.

The above scenario seems to apply to the British construction industry too [37], although there are many more sources of information available (for example, [38], [39], [40]). However, not all of them display the usage rates of the resources required to perform each construction work. This information is frequently disguised in the cost elements [37].

Operational estimating, is based on the selection of the set of resources necessary to carry out the total amount of each construction work and on the elapsed time on which these resources will be deployed. In this process, the experience of estimators and production staff is mainly used. Performance rates from equipments' suppliers (eg [41]) or standard unit rates are also used. Later, all the resources are costed leading to a total cost for the work under consideration. Unit costs may be assessed by dividing total costs by total quantities. This procedure may be summarised as follows:
approach of unit rate and operational estimating is used by Portuguese construction companies. For example, the costs of expensive plant used in building projects (cranes, concrete mixers, etc.) are hard to estimate by unit rates for the reasons mentioned in (1) above; also, it may be difficult to ascertain a good criterion to divide the costs incurred with some resources (e.g., foremen) by all the construction works which they are related to in their exact proportion. Operational estimating is commonly used to deal with those problems. Because of the limitations of the bills of quantities, calculated costs are later handled as on-costs. On the other hand, several works often pertaining to civil engineering projects are preferably dealt with by using a unit rate approach. Combining unit rates and operational estimating rates seems to be common among British contractors too [23].

Beyond these two basic methods, some simplified procedures are used in some cases. Unit rates for current construction works, for example, may be used among similar projects. Also, some costs of subsidiary components to a main construction work may be directly assessed from earlier calculations.

Indirect cost calculation completes the study of a project cost. Some companies simply include a lump or a percentage to direct costs to take them into consideration. Nevertheless, most companies often carry out a more detailed study of on costs (or site costs) because of the uncertainty of the above criterion. Therefore, they use to divide them into major headings and list all the items requiring quotations within each division. A possible division of on-costs may be as follows:

1. site management and supervision;
2. erection maintenance and dismantling of the site offices and compound facilities;
3. general plant and major plant items not included in direct costs;
4. site transports;
5. scaffolding;
6. temporary works and services;
7. clerical staff;
8. miscellaneous labour;
9. general items;
(1) select the set of resources necessary to perform each construction job involved in the project;

(2) update the database of unit costs of resources or retrieve an existing one;

(3) perform the necessary calculations.

The selection of the necessary resources must fulfil each specific situation. In order to decide the requirements of labour and plant to allocate to each work, the estimator must have a deep knowledge of construction methods.

Unit rate estimating is normally preferred for building projects whereas operational estimating is mostly used for civil engineering projects. This seems to agree with the British literature as well. Three sets of reasons for this are discussed below:

(1) The different characteristics of both types of projects. Building projects tend to be more labour intensive than civil engineering projects. Therefore, larger amounts and often more expensive plant are assigned to civil engineering projects than to building projects [42]. Plant is susceptible to idle time which accrues costs that are not readily catered for in the unit rate approach [3]. Labour is normally more versatile and less expensive.

(2) The form of the bill of quantities. According to section 6.2.1, bills for civil engineering projects are best suited for operational estimating. Moreover, the usual complexity of the bills for building projects makes unit rate estimating the most reasonable method to be used.

(3) The usual procedures. These also play an important role because both productivity data and cost/price data are commonly organised under a unit rate format. Moreover, companies continuously use and update historical data in their day-to-day work.

The above comments apply as general rules because in most cases a hybrid
(10) taxes and licenses;
(11) sundry requirements.

A set of different criteria is used to assess indirect costs depending on what is included in each item requiring quotation. The past experience of the company is often used for this purpose; unit rate estimating and operational estimating may be used to get the costs of some tasks, etc.

Moreover, on costs are often time-dependent, thus largely related to the duration of the project or of some of its main activities [43]. Therefore an approximate construction schedule is often important for project pricing purposes [44] because it is used by the estimator as the basis for arriving at the cost of many of the major items of work [45].

Portuguese bills of quantities seldom include General Items and so on-costs are usually allocated to the ordinary items to which they relate by using a suitable criterion. Also, costs which have been assessed through an operational estimating approach and which are related to more than one bq item should eventually be assigned to the corresponding set of items.

Computer based procedures for unit rate estimating are currently used by Portuguese construction companies. Commercial computer packages and in-house developed programs could be found in many companies. Operational estimating is generally carried out by hand.

Estimating is normally carried by a specific department within the companies organisations.

6.2.2 Planning.

Tender planning may be perceived as an evolutionary process. Initially, a preliminary planning phase takes place which may lead to the generation of a preliminary programme for the works. The tender construction programme is produced afterwards. However, this does not generally aim at supporting the execution of the works on site because companies do not know if the contract
an outcome from operational estimating they have to be worked out if unit rates have been used. Again, this involves considerable calculations and thus companies often use their past experience instead of a thorough study based on data from unit rate estimating.

Sometimes a straightforward monthly receipts forecast is assessed by totalling the prices of the bq items included within each construction activity. Partitions between successive months for the activities taking place in more than one month are made approximately.

Computer based procedures for planning are not commonly used. However, network-based scheduling computer packages or in-house developed programmes could be found in use in some companies.

Tender planning is normally carried by estimators although discussions with planners and site directors may possibly take place. This is most sensitive in civil engineering contractors' organisations.

6.3 Conclusions.

Estimates are normally based on bills of quantities, which are commonly accepted as a suitable document for this purpose. Bills for civil engineering projects tend to be simpler and more readily associated to the usual construction activities than those for building projects. During the pre-tender stage, planning is mostly directed to the generation of data to be used in the estimating process of the project under consideration.

Two distinct construction-phase estimating methods are used: unit rate and operational estimating. The former is normally used for building projects while the latter is more common for civil engineering projects. Due to the implicit nature of the calculation process, the outcome of operational estimating is more readily translatable to planning than the outcome of unit rate estimating is. Therefore, integration between planning and estimating is more straightforward when operational estimating is used. When unit rate estimating is used, however, the work to achieve integration is both arduous and time
used but network scheduling (ie CPM) was also found.

Construction activities normally correspond to the chapters of the bill of quantities or to some of its main items. These activities were recognised to be reasonably close to the usual site operations for civil engineering projects but not for building projects. Moreover, each construction activity generally aggregates much more items in the case of building projects than in the case of civil engineering projects where a one to one relationship is more common.

Activities durations are assessed according to the following criteria:

1. the requirements of the client on the project duration or on some of its stages;
2. the durations assigned to the same activities in the preliminary programme (if any);
3. the past experience of the planner/estimator;
4. data from estimating.

Companies tend to utilise the last criterion more intensively when operational estimating is used than when unit rate estimating is used. This is because activities durations are an outcome from operational estimating while they have to be worked out from the unit rate approach. Moreover, the conversion from resources usage rates to activities durations involves many calculations. Therefore, in this case, companies often dispense with a thorough study based on data from estimating but they use their past experience to assign approximate activities durations. This is more likely to occur for building projects than for civil engineering projects for the reasons discussed above.

Companies usually allocate the main resources to the construction activities of the tender programme. This is more common for labour, but plant and the most important materials are sometimes included in the construction programme of civil engineering works. Data from estimating is the main source of information for this purpose. However while the resource requirements for each activity are
will be awarded. The planning phases referred to above seem to be consistent with the British literature [3] and so do their aims [46].

The aims of preliminary planning are to evaluate the project under consideration. Construction activities generally correspond with the most significant chapters of the bill of quantities or with the most relevant works to undertake. Their durations are roughly assessed by using the past experience of the companies on identical projects. During this phase, companies decide on general construction methods and on the most important resources that should be involved to carry out the works. Moreover a preliminary construction programme is sometimes drawn up, yielding a first idea of the project duration and of some of its most important activities. Bar-chart schedules are exclusively used during this phase.

Portuguese construction companies do not always assume preliminary planning as a specific planning stage. More often than not, the procedures described above are included in the normal estimating process and performed by estimators: If operational estimating is used, preliminary planning takes place simultaneously with estimating; if unit rate estimating is used, preliminary planning is required at least to help in the assessment of some construction costs as referred to in section 6.2.1. Therefore, preliminary planning is implicitly done by all Portuguese construction companies if a thorough study of the project costs during the pre-tender stage is intended.

The emphasis construction companies place on tender planning was found to be dependent on the type of project concerned. It tends to be greater for civil engineering projects than for building projects. This was found to be related to the estimating approach companies use for each case. For civil engineering projects, operational estimating is mainly used; therefore, the importance of tender planning stems from the need to estimate the project costs. For building projects, unit rate estimating is mainly used which tends to be considered independently from planning.

However, it was found that tender planning is generally made by all Portuguese construction companies. The main goal is the generation of a construction programme suitable for tendering purposes. Bar-charts are mostly
consuming while available time for tendering is normally scarce. Moreover, it may be a rather costly activity and there is no guarantee of refunding costs incurred. Accordingly, integration between tender planning and estimating was found to be easier to achieve in civil engineering projects than in building projects. Furthermore, Portuguese construction companies normally achieve integration for the former type of projects whereas they hardly ever achieve it for the latter type of projects.

Two main reasons for the lack of integration between tender planning and estimating of building projects have been found:

1. The form and complexity of the bills of quantities;

2. The nature of the estimating method used.

Both tender estimating and tender planning are normally carried out by the estimating department, i.e. with no direct intervention from planners.

Computer support comprises unit rate estimating and network-based scheduling. However, while computers are often used for estimating, planning is normally done by hand.
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CHAPTER SEVEN

Project Management Functions on Behalf of the Construction Companies During the Pre-Contract Stage.

7.1 Introduction.

Very often the participation of a construction company in a project does not go further than the tendering process. Actually, most of the offers submitted fail. Sometimes this is an expected result, but on other occasions companies were looking forward to carrying out the project but they were not selected.

However, if the contract has been awarded, the company is supposed to remain involved in the project as long as its execution lasts. Therefore, after commitment the company faces a production problem. Production should be carefully prepared so that the project objectives are likely to be accomplished.

Production preparation is the main concern of this chapter. This is in agreement with the fourth step of the research methodology as presented in section 1.4. As in chapter 6, discussion is supported by the results of the following inquiries listed in the previous chapters, namely:

(1) Detailed Inquiry to 5 Portuguese Construction Companies;
(2) Specific Inquiry to 21 Portuguese Construction Companies;
(3) Inquiry to 5 Portuguese Construction Clients;
(4) General Inquiry to Portuguese Software Vendors.

Additional comments are included to reinforce those results with earlier surveys or opinions from other authors.

7.2 Objectives.

The traditional economic objective in a production problem is to minimise the
total costs without sacrificing other objectives such as product or service quality or employee safety [1]. Accordingly, construction companies should aim at minimising the cost of their projects. In the following paragraphs, the cost minimisation of a single project will be discussed in the first place. The implications for other projects will be dealt with thereafter.

The problem of the cost minimisation of a project may be written as follows [2]:

\[
\text{min } TC = C(x)
\]

subject to \( g(x) = q \) and \( x \geq 0 \).

where \( TC \) is the total cost of the project, \( g(x) \) is the technological function used to produce the output \( q \) (ie the whole project), and \( x \) is a vector of resources. Moreover, it is usual to include in the argument of \( g \) a set of efficiency parameters and a factor of returns to scale [3]. It will be assumed that there is a band of optimum or near-optimum utilisation of resources so that efficiency parameters will be kept apart [4]. Also, returns to scale will not be considered due to the usual originality of construction projects. The restriction to the problem is therefore the production isoquant [3] for the project per unit of time, ie, all the resources are in fact flows.

The solution for the cost minimisation problem may be derived from the following set of differential equations [5]:

\[
\frac{\partial C}{\partial x_1} \gamma \frac{\partial g(x)}{\partial x_1} = 0
\]

\[
\frac{\partial C}{\partial x_2} \gamma \frac{\partial g(x)}{\partial x_2} = 0
\]

\[
\frac{\partial C}{\partial x_n} \gamma \frac{\partial g(x)}{\partial x_n} = 0
\]

\[g(x) - q = 0\]

The solution of the upper system of equations yields the quantities of
each resource that minimise the cost of the project. However, practical problems are hard to deal with using this approach. This follows from the extreme difficulties of building up the production function \( g(x) \) in such a way as to be suitable for mathematical treatment described above.

Planning techniques are currently used to find a sub-optimal alternative solution for the problem by means of a schedule of activities that minimises the total project cost. The following three-steps approach may be used [6]:

Firstly, construction methods to perform each activity are reviewed and the most economical production solution is selected. This leads to the definition of the set of resources necessary to perform it and its duration. Precedence relationships among activities are established and a scheduling technique viz networking, is used to set the preliminary programme for the works.

Secondly, the results of the first step are merged together and a cost-time trade-off analysis is made in order to find the most economical project duration.

Thirdly, a resource allocation technique is used to obtain the loading charts of resources that minimise their total costs.

The selection of the most economical production solution for a project activity is not an easy task because it may be dependent on the construction methods for all the project (or for a substantial part of it) and may also be strongly influenced by the production solutions for other activities. Ideally, the set of resources finally allocated to each activity should correspond to its minimum possible cost and lead to its normal duration. Shorter activity durations, would be obtained either by increasing the number of resources involved or by changing the selected production process. Both approaches are normally admitted to increase the activity costs. The cost-duration relationship for construction activities is usually depicted as shown in figure 7.1 [7], [8]:

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Therefore, an acceptable approach to the problem would be to decide on the construction methods affecting all the project (or a substantial part of it) in the first place. Thereafter the production solutions for each activity would be selected; this follows directly from the previous decisions in most cases. Then the number of resources necessary to achieve a certain production rate would be allocated.

The second step towards the solution of the problem considers the project as a whole. The starting point is the construction programme for the normal durations of the activities. Direct costs and indirect costs are calculated for a set of feasible project durations. Typical cost curves are depicted in figure 7.2, where DC is the direct cost curve, IC is the indirect cost curve and TC is the total cost curve of the project.

The objective is to find the optimal duration for the project which minimises its total costs (point A in the figure). Alternatively, the project duration may be fixed (eg by the client) and the objective will be to find the minimal possible cost for a duration not exceeding the specified.
Figure 7.2: Cost curves of the project.

The mathematical formulation for the problem may be found in [9]. However, its complexity is such that it would normally make the achievement of an optimal solution very hard. Therefore some simplifications to the shape of the functions involved have been proposed [7], [9], so that the problem can be solved using a linear programming approach [10], [11]. Moreover, specific algorithms better suited to the problem than the standard all-purpose methods have long been suggested by several authors (eg Kelley [12], Fulkerson [13], Perera [14], Cusack [15], Harvey et al. [16]). Nevertheless, the search for an optimal solution is often difficult, especially if the project comprises a large number of activities. Therefore, several heuristic methods of tackling this problem have also been suggested (eg Simens [17], Cusack [18]). An alternative heuristic algorithm is presented in [6]. The solution is the set of durations for the project activities and their corresponding costs.

Resource allocation is subsequently reviewed according to the new durations of the construction activities.

Finally, the third step aims at the generation of the loading charts of resources that minimise their total costs. The criterion used for this purpose in [6] is to
minimise the total mobilisation costs of the resources [19]. However, some resource allocation models which have been suggested in the literature do not attempt to minimise costs but they are directed to distinct objectives instead. Probably, the best known are the limited resource allocation models and the resource levelling models [20], [21], [22]. The former are designed to minimise the project duration within bounded resource availability limits; the latter attempt to find a schedule that minimises resource fluctuation within a fixed project duration. The non-constrained resource allocation models seem to fit the real-life construction problem more closely [20]. A thorough discussion on this subject including a review of the traditional mathematical models may be found in [6]. Optimal procedures for dealing with resource allocation problems have been suggested in the literature since the early 1960 (e.g. [23], [24], [25]). However, some of them involve quite expensive algorithms to use [26] (in the sense that they generate many combinations). The use of heuristic rules provides a reasonable alternative solution [27]. Furthermore, resource allocation modules included in some planning software packages now available are normally supported by heuristic algorithms. A reasonable variety of both mainframe [28] and microcomputer based [29], [30] planning packages offering that facility may be found. This subject will be further discussed in a later chapter.

The approach suggested in [6] is based on an integer-linear programming model [31] leading to the optimal solution for the problem of the minimum total mobilisation costs of the resources involved in a project. This is achieved by using a branch and bound seeking algorithm. Computer codes were adapted from [32].

One of the shortcomings of this three-step approach is that the global optimum solution for the cost minimisation problem can hardly be achieved. This follows from the different objective functions used in each step described above. For this reason, the project planning process as a way to generate an acceptable production solution has been criticised [33]. However, the importance of planning for construction project management on the behalf of the construction companies cannot be overstated. This is especially sensitive during the pre-contract stage when companies aim to find a suitable production solution. This is achieved in the course of a production preparation process which is the main
concern of this chapter.

7.3 The production preparation process.

7.3.1 Introduction.

The production preparation process takes place before the actual commencement of work on site. Work quantities are the starting point of the production preparation process. These follow from the measurements of the works to undertake on site but detailed measurements are seldom delivered by the client within the design package. Therefore some companies customarily make them after commitment so that work quantities are established more accurately.

Most companies understand that measuring the works during the pre-contract stage is essential to production preparation. Furthermore, new measurements are useful in applying for correction of errors and omissions in the tender bill if this is possibly admitted in the tender documents.

A new bill of quantities is generated thereafter following the same format as the tender bill. However, some more detail is possibly intended in the new bill in order to facilitate management functions on site. This is normally achieved by the partition of some bq items into smaller sub-items aiming to give further information on work locations, tasks included, etc. Therefore, bills of quantities generated after commitment tend to be more complete than those used for tender purposes. Nevertheless, the same basic criteria are used for the composition of both of them and most of the shortcomings of the tender bills as discussed in chapter 6 remain. Furthermore, the same relationship between the complexity of the bills and the type of project they refer to is still found.

In the following paragraphs, planning estimating and control management functions performed by Portuguese construction companies during the pre-contract stage will be discussed.
The ultimate objective of construction planning is to prepare the project execution. Accordingly, the usual aims of planning are to forecast the utilisation of resources and to facilitate their control on site. Resources comprise financial capital, labour, materials, plant, subcontracts, etc. Therefore, both cost estimating and control preparation may be viewed as two distinct yet closely interrelated aspects of planning. Nevertheless, they will be discussed separately in the following paragraphs for the sake of simplicity.

The aims of estimating are to assess the cost of the project as closed as possible to the real expenditures on site.

Construction control uses data generated by the previous functions to evaluate the performance on site. The operational aspects of site control will not be discussed but they will be kept in mind while discussing the requirements of data to achieve control.

7.3.2 Estimating.

Some companies often make a new assessment of the project costs after commitment. Estimating methods are the same as those of the pre-tender stage but companies use them more accurately in this stage. A closer approximation to the costs of resources is possible due to a better understanding of the site conditions. Also some subcontractors quotations possibly result from the agreements with other companies made meanwhile and thus quotations may be more reliable.

Direct cost rates are possibly split into each resource class - labour, materials, plant and subcontracts - and listed accordingly in the evaluated bill of quantities. On-costs are normally assessed as before but they are not usually allocated to the bq items as in the case of the tender priced bill. Instead, specific items are now created so that on-costs can be easily controlled. Overhead allowances are not included.

Alternative formats to the evaluated bill of quantities could be found. Instead of an item format, a resource format is sometimes used, ie total quantities of each
resource for the whole project and the corresponding unit costs are listed.

Most companies understand that the revision of the project costs during the pre-contract stage is important to enabling them to make a closer approach to expenditure. This is essential for the management of financial capital resources.

Estimating is normally carried out by the same department as at the pre-tender stage.

### 7.3.3 Construction planning.

Construction planning is the culmination of the previous planning phases. This is in itself an evolutionary process because plans are continually improved throughout the project life. The main goal of construction planning is the generation of a construction programme for the works suitable to be used on site. This evidences the inescapable fact that planning and scheduling cannot be dealt with separately because plans are only useful if they are executed i.e. scheduled [34]. This is usually depicted in a bar-chart format but network scheduling (ie CPM) was also found in use in Portuguese construction companies, especially when computer support is available.

Construction planning and scheduling involves a set of tasks which may be summarised under the following headings [35], [36]:

1. determination of the construction activities;
2. ascertainment of the sequential relationships among activities;
3. allocation of resources required to perform activities;
4. estimation of durations for each activity.

Traditionally, these tasks are performed by hand and rely on the knowledge of the planner. However, recent research into planning and related topics led to
the development of several computer systems aiming to support the tasks above. Probably, research into the automatic generation of construction schedules has been of major relevance. A number of Expert Systems (ES) applications in planning and scheduling have been suggested in the literature [37]. This has led researchers to a deep reflection on the reasoning involved in performing the tasks above. It is of interest to compare the current practice of Portuguese construction companies with the main findings of recent research. This will be done in the following paragraphs.

The determination of the construction activities is the basic step in the planning and scheduling process. Construction activities should be detected from a reasonably accurate work breakdown of the project. How fine the breakdown must be may vary from project to project, depending on factors such as the nature of the work involved, the location of the work, the class of labour involved and the overall sequence of the project [38]. A very detailed work breakdown would give a lot of information but this could be too minute even for the purpose of a detailed construction programme. Therefore, a set of aggregation criteria has to be introduced so that the resulting activities may be suitably handled.

Portuguese construction companies normally start the determination of the construction activities from the bill of quantities. This is a particular type of work breakdown of the project which follows from the organisation of the traditional construction measurements into a frame encompassing a specific set of aggregation criteria. As for tender planning, a reasonable correspondence between bq items and construction activities has been usually admitted for civil engineering projects but not for building projects. Therefore, additional detail is often required in order to refine the definition of building construction activities. The extent to which the aggregation criteria are used to build up the items of the bills of quantities match the requirements of activity determination will ascertain the usefulness of the former for the definition of the latter.

Based on experimental analysis, Gray (1986) [39] suggested a rule-based methodology to select construction activities. This was a rational attempt to formalise a heuristic procedure utilised by planners to breakdown the
construction of a facility into activities. The following set of rules was suggested [39]:

(1) **Type of work**: identifiable activities can occur when there is a variation in the use of each of the three resources of trade skills, material and plant.

(2) **Operationally significant function** e.g. vertical, horizontal, etc.

(3) **Operationally significant location**.

(4) **Standard activity**.

(5) **Specified time**.

Moreover, according to the same survey, Cray also found that the splitting of the building into operationally significant functions which were then subdivided by operationally significant locations was the most important rule set.

The O-Plan project has been being conducted at Edinburgh University from 1984 onwards [40]. The generation of construction programmes using O-Plan requires that an initial partial plan is input to the system. O-Plan's task is to continually refine it by using a set of operators [40]. Both initial plans and operators must be specially designed for each type of project. Applications of O-Plan to construction projects are hard to find. However, a former report on NONILLION [41] (from which O-Plan grew up) includes a case study on a house building project. There it can be seen that the process of activity definition is mostly operation oriented.

Construction Plane was developed at Carnegie Mellon University (U.S.A) [42]. Plane aims to identify the different design elements and match each design element with the tasks needed to install it. These tasks are called **element activities** which are aggregated together to form larger activities (construction activities).

This strong relationship between design elements and construction activities...
may also be found in the model suggested by Echeverry et al. [43]. According to the authors, activities are the elements that represent the actions of installing the building components.

More recently Morad [44] suggested the integration of Computer Aided Design (CAD) and AI technology in order to generate construction activities. Using this approach, design information would be directly linked to a knowledge-base to be used for construction activity generation.

Alshawi [45] presented a prototype model (MERCI) where the activity identification codes include two digits which reflect its location within the horizontal and vertical plan. The work content of the activities is described using the code of a standard method of measurement of construction works.

According to Sirajuddin et al. [46] the elements of construction work must be first recognised. In order to do this, the author suggests the division of the site into a grid of rectangular elements of suitable size. Afterwards, finished elements of work that exist in each element of the grid are identified.

Clearly, the above discussion shows that rules normally used to build up traditional bills of quantities (as discussed in chapter 6) hardly match the requirements of activity definition. Main discrepancies are as follows:

(1) Portuguese bills of quantities mainly comprise work items and item descriptions mostly report the project outputs. Activities however, are especially operation-oriented and often include other tasks not directly perceived as project outputs (eg site erection, site clearance, etc.)

(2) Aggregation criteria implicit in bq items do not fit the requirements for definition of activities. For example:

(2.1) a variation in the use of resources can lead to separate activities but distinct works may be included in the same item;

(2.2) operationally significant locations for the same work may obliged
one to separate activities but identical works are often joined into a single item description irrespective of their locations.

Nevertheless, despite the possible discrepancies, the determination of construction activities is normally based on the items of the bill of quantities in the current practice of Portuguese construction companies. However, it was found that additional measurements are often performed by the companies during the pre-contract stage in order to overcome the shortcomings of the aggregation criteria used in traditional bills. This seems to be more needed for building projects - possibly several horizontal layers, distinct locations for identical works, work elements requiring several trades, etc. - than for civil engineering projects.

Therefore, it can be stated that in order to determine construction activities, Portuguese construction companies try to manage on the available bill of quantities and make additional measurements in order to match the activity definition requirements. The same measurement criteria as referred to in section 6.2.1 are used. Additional measurements normally include:

1. refining some items so that distinct work locations can be identified;
2. grouping similar works distributed by a set of distinct items;
3. gathering subsidiary works (eg concrete mixing) into a specific task.

Bills of quantities for civil engineering projects seem to be closer to the activities definition requirements and thus additional measurements are less common in this phase.

Portuguese construction companies establish the sequence among activities based on their understanding of the construction process involved to perform the works to be undertaken. In order to achieve this, a considerable knowledge is required about the relationships among the building components (eg, "supported by", "connected to", etc). This task is allotted to the staff concerned with the planning function within the companies' organisations.
Links among activities are established next. Typically, construction links include **finish-start**, **start-start**, and **finish-finish**. Moreover, lag times are also needed sometimes (e.g., the start of dismoulding a concrete reinforced slab may only begin a certain time after the concreting operation has been finished).

The work of Gray [39] is an excellent contribution in identifying the relationships among building components that dictate activity sequencing. Accordingly, the following precedence selection rules are determinant:

1. Activities providing a fixing base for others must be positioned before.
2. The fixing order for materials is the least flexible followed by the more flexible.
3. In a multi-layer sequence, materials fixed first must be closer to materials fixing.
4. Where a material is to be hidden its fixing must precede its covering.
5. Materials or systems providing a service must be fixed before subsequent activities using the service can be accomplished.
6. Activities needing a protecting environment must not be undertaken until those conditions are provided.

Many AI planning systems being developed also utilise some physical relationships among building components to produce an activity sequence [36], [42], [47], [48]. A revision of the most relevant physical relationships among building components may be found in [49].

Automatic sequencing among construction activities is however a difficult problem to solve due to the complexity of construction planning. The first generation of AI planners configures plans as a linear strictly order sequence of actions (i.e., no parallel activities are allowed). This assumption is unrealistic.
in construction projects in which activities can actually occur in parallel. Kartam and Levitt [47] developed a simplified model (SIPE) which produces what its authors call a least-constrained plan for construction. In other words, the resulting schedules of SIPE show substantial parallelism with the different construction activities. Other planning systems also have this capability (eg, NONILLION [41], O-Plan [40], NOAH [50], etc.).

Resource requirements to perform each construction activity should be assessed from productivity data. In the current practice of Portuguese construction companies, that data has already been manipulated during the estimating process (either at the pre-tender or at the pre-contract stage). Resource allocation should conform to the assumptions made in the course of that estimating process. Therefore, data from estimating should be one of the main sources of information to resource allocation for pre-contract planning. However, operational estimating provides for more readily used data than unit rate estimating does. In this case, data has to be worked out through an arduous calculation procedure particularly when in-house resources are expected to be used. Furthermore, productivity data used in unit rate estimating is mostly directed to cost appraisal (eg [51]) and this makes the process of resource allocation harder to achieve. Therefore, lack of accuracy in resource allocation has been found in most Portuguese construction companies.

Moreover, distinct degrees of detail are used in the resource allocation process. The allocation of all resources required to perform each construction activity is hard to attain and it is a rather costly undertaking. Furthermore it is probably useless for control. Accordingly, most companies only specify the main labour requirements; some also include major plant, but materials are considered more rarely. This follows from the importance of labour and plant as usual key-resources in construction. Furthermore, the allocation of materials requirements to each activity is not suitable for procurement and materials supply because these tasks embrace other aspects not considered here (eg stocks).

The output of resource allocation is generally a set of charts showing the global requirement flows of each type of resource for all the project.
Few AI planners presently deal with resource allocation [43]. Resource allocation models earlier referred to in paragraph 7.2 demand as input a first version of the resource requirements for the project. Other approaches dealing with uncertainty in resource availability also take a resource justified schedule as input [52]. Therefore, extensive work from the planner is required prior to their utilisation. In a way, those models may only be used after an acceptable solution has been found for the problem being discussed here.

In the current practice of Portuguese construction companies, activities durations are assessed according to the following criteria:

(1) the durations assigned to the same activities on the tender programme;

(2) the past experience of the planner;

(3) data from estimating.

Actually, the assessment of the activities durations is a part of the resource allocation process, because distinct quantities of resources are expected to yield distinct durations for the corresponding activities. Data from estimating tends to be more used during the pre-contract stage than at the pre-tender stage because companies seek a higher degree of accuracy after commitment than for tendering purposes. This is a complex task to carry out especially when unit rate estimating has been used. It may be summarised as follows:

(1) Survey key-resources to undertake:
   (1.1) the project as a whole;
   (1.2) groups of construction activities;
   (1.3) elementary activities.

(2) Set the quantities of key-resources.

(3) Find the durations of activities.
The durations of subcontracts are normally agreed with companies involved.

Key-resources set the pace of the project. For example, major plant possibly conditions all the project or large groups of construction activities (eg, a tower crane is often related to the pace of erecting a concrete frame for a building); external subcontracts possibly condition the construction activities concerned (eg the plumbing subcontract is normally related to the pace of water-pipe installations); labour conditions most construction activities. Moreover, for the case of labour, calculations are performed either for single units (eg a bricklayer) or multiple units (eg a bricklayer team).

According to Kahkonen [53], research aiming to develop tools for activity site estimating can be divided into the following categories:

1. simulation programmes;
2. stochastic networks;
3. expert systems.

The calculation of activity durations using simulation programmes is usually based on two types of information: expected duration of an activity in optimal conditions and probable interference factors. Interference factors are presented in the form of distributions. During simulation, the durations of the activities and interference factors which may have the effect of lengthening durations, are selected from the relevant distributions. Several examples of these programmes may be found in the literature (eg [54], [55]).

The incorporation of probabilistic analysis in network scheduling models has led to the development of two approaches [56]. The first approach relates to the variable nature of the activity durations and the resolution of schedules given this variation (eg [57]). The second approach involves the incorporation of variation into the actual logic of the network, the most widely recognised advances in this area have been with GERT [58], [59].

More recently, some tools based on the expert systems approach include
techniques for the estimating of activity durations. They normally rely on average productivity rates ([39], [40], [42]). Moreover, Ratu-aj [53] includes the analysis of the factors having an effect on the unit times considered in those rates. Factors cover for example, the amount of work (learning effect), site conditions, construction details, size of the work crews, capacity and condition of plant and methods of remuneration [53].

According to chapter 6, productivity data used by Portuguese construction companies is mostly deterministic. Moreover, interference factors such as those mentioned above are supposed to be considered in the assessment of the average unit production rates. Therefore, a constant production pace following from average production rates is preferably adopted for each construction activity. These follow from standard rates possibly adapted by the planner for each specific situation.

According to the above discussion, activity durations are mostly dictated by the quantities of key-resources allocated to them. The quantities of key-resources allocated to each activity are assigned within the lower limit of work feasibility and the upper limit of physical restrictions. The amount of available plant or the number of subcontracts which it is possible to mobilise for a specific project in a given time instance are typical restrictions. Space availability on site is the most usual restriction on labour.

It follows from this procedure that companies do not usually consider the relation implicit in figure 7.1 between costs and durations within the same production solution. In other words, the curve of figure 7.1 is viewed as rather flat in the neighbourhood of the normal duration. Above a certain level of output rate, the production solution may possibly become unfeasible (eg due to space availability) and thus another production solution would be selected to achieve a shorter activity duration. In fact, the shape of the curve seems to be much more like a step function from the companies point of view. A possible alternative cost-time relationship for construction activities is suggested in figure 7.3 below. Each level corresponds to a production solution therefore represented by a horizontal or slightly rising line as duration shortens. This slope may be caused by over-intensive use of resources like overtime labour or additional subcontracts. Shortening the activity duration beyond the highest
level of output within a given production solution causes costs to shift upwards due to the change in the production process.

![Graph showing the relationship between costs and durations.](image)

Figure 7.3: Alternative cost-time relationship for construction activities.

Portuguese construction companies seldom use sophisticated methods to refine the results of the resource allocation procedures as described above (viz resource levelling, resource smoothing, etc.). This is in most cases performed by inspection.

Cash-flow forecasting follows from the comparison between the expenditures and the receipts flows forecasting.

Expenditures flow should be assessed adding by up the expected costs of the activities for each time period. The costs of each activity should be calculated by totalling the costs of its resource requirements. However, as resource requirements are seldom fully allocated to activities, this approach is not normally feasible.

Receipts flow should be assessed by adding up the expected receipts from the activities taking place in each valuation period (usually a month). These are hard to obtain because of the difficulties involved in relating construction activities to the items of the priced bill of quantities as described above. Thus, companies normally adopt the tender receipts forecast.
Therefore, both expenditures and receipts for each activity are assessed from the bq items pertaining to that activity. The accuracy of this procedure is normally low and in fact, cash flow forecasting is not commonly performed.

Computer support procedures for planning are normally limited to network based scheduling computer packages or in-house developed programmes. These tend to be more used after commitment than during the tender stage. Some of those packages have many capabilities which are not however fully explored. For example, cash flow forecasting and resource allocation methods are often available but seldom used.

Detailed planning is normally carried out by the production departments or by site directors. However, some companies have a specific planning department.

7.3.4 Control.

Companies were found to be more concerned with cost control than with any other aspect of control.

Exhaustive control of resources is un-realistic and the costs involved in that operation would probably exceed the possible savings. However, companies have generally recognised that the most important resources should always be controlled. Therefore, data should be prepared to enable resources control for selected activities and/or resources to be performed.

Cost control is based on work valuations and on cost estimates.

External work valuations (ie for the client) are normally supported by the tender priced bill of quantities. Internal valuations (ie the assessment of real expenditures) should follow from some form of site monitoring process. However, systems for data collection on site are seldom designed for production control proper, but to provide data for accounting purposes. Therefore, most construction companies realise actual production costs much later after data has been handled by the accounting department. Systems
specially designed for production control are hard to find but when they exist they are more efficient.

Costs estimates made during the pre-contract stage are preferably used for control. If these are not available, data from tender estimating is used in its place. Data is collected from the tender bill of quantities or from a new version of the bill possibly generated after commitment as the case may be.

Some companies normally control labour and plant with a reasonable degree of accuracy. However, in most cases companies are, at most, concerned with the costs of those resources. Therefore, total costs for each resource class are calculated for each bq item and compared to the corresponding cost forecasts. Alternatively, only the total expenditures on each resource are compared.

Time control is performed by inspection.

Control is normally carried out by the production department or by site directors. A specific control and productivity department is more rarely found.

7.4 Conclusions.

Production preparation is one of the major concerns of the companies after commitment. Planning assumes an important role in that process but planning efforts are mainly directed to control.

Portuguese construction companies are mostly concerned with cost control. Therefore, some companies regularly make a new assessment of the project costs during the pre-contract stage. This often involves detailed measurements of the works to undertake and the generation of a new bill of quantities. The format of the new bill as well as the aggregation criteria used for item definition are roughly the same as those of the pre-tender stage although the former is possibly more detailed than the latter. Extra detail is mainly directed to control.

Integration between planning and estimating was found to be difficult to achieve for building projects for the same reasons discussed in chapter 6.
Obstacles to integration between planning and estimating of building projects during the pre-contract stage basically agree with those mentioned in section 6.3, *ie*:

1. the form and complexity of the bill of quantities;

2. the nature of the estimating method used.

Accordingly, it was found that work required to achieve integration when unit rate estimating is used is both arduous and time consuming. Furthermore, this may be a rather costly activity.

However, the limitations of time are not so relevant as before and costs incurred in a detailed study may possibly be compensated by a greater production performance. Therefore, while measurements take both time and money, their usefulness is generally recognised at the pre-contract stage.

Nevertheless, it was found that companies do not fully benefit from this work for the reasons mentioned below:

1. detailed measurements are mostly directed to the generation of the new bill of quantities;

2. the bill of quantities is specially suited to estimating.

Actually, it was found that measurements data is seldom used in planning and lack of relationship between the items of the bill of quantities and construction activities persists. Moreover, some companies often refine the items of the bill by means of additional measurements in order to meet the activities definition requirements. Therefore some duplication of work can possibly occur, as identical measurement criteria are used in both cases.

Some lack of accuracy has been found both in expenses and receipt flow forecasts mainly because of the difficulties of data interchanging between estimating and planning. This probably inhibits cash-flow forecasting from being made more frequently.
Control is mostly cost oriented. Furthermore, some companies control the most important resources in the extent to which they had been planned. The basic document used for control is the bill of quantities and not the construction programme. Reasons for this are as follows:

(1) external valuations are normally based on the tender bill of quantities;

(2) the expenditures flow is seldom sufficiently accurate to support internal work valuations;

(3) resource allocation to activities includes only a few resources and thus it does not provide for sufficient data for activities cost assessment.

Therefore, lack of integration between planning and control is likely to occur especially when unit rate estimating is used for the reasons discussed previously. In that case, production preparation was found not to provide for sufficiently accurate documents so that integration could be easily achieved.

Computer-based procedures include unit-rate estimating and network-based scheduling. The process of handling data between estimating and planning is normally hand-made.

Distinct departments within the companies organisations are often involved in production preparation functions.
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CHAPTER EIGHT


8.1 Introduction

In chapters 6 and 7 a review was made of how Portuguese construction companies perform planning and estimating management function and data generated is prepared in order to support project control on site. The discussion is based on the set of inquiries presented in chapters 3 to 5. Moreover, literature normally corroborates the main conclusions.

In this chapter, the findings of the preceding chapters will be used in order to establish a set of frames for the operations commonly performed by Portuguese construction companies. The main obstacles to achieving integration among management functions will be recalled. A thorough study of the data structures used to perform those functions will help to understand why those obstacles actually exist. A general frame to achieve integration will be suggested and its possible advantages when compared to the current procedures will be discussed.

The object of this chapter corresponds to the seventh step of the research methodology presented in section 1.4 and is directed to the accomplishment of the second sub-aim of section 1.5.

According to chapter 1, the integrated model should be concerned with planning, estimating and the preparation of data for control. In chapters 6 and 7, it was concluded that obstacles to integration between planning and estimating are most sensitive when unit rate estimating is used. In addition, data for control is more poorly prepared in this case.

Unit rate estimating is mostly used in building projects whereas operational estimating is normally preferred for civil engineering projects. Bills of quantities for building projects are usually more complex than for civil engineering projects. This contributes to making integration most difficult to achieve for the
Accordingly, the following discussion will be mostly directed to the projects where unit rate estimating is used. Moreover, the additional difficulties in achieving integration for building projects will be considered.

The way Portuguese construction companies perform the surveyed management functions has been found to vary according to the stage of the project development. Specifically, significant differences have been found between the pre-tender stage and the pre-contract stage. The pre-tender stage will be discussed first. Two distinct approaches for tender planning and estimating will be dealt with. The degree of accuracy followed by the companies during the pre-contract stage has been found to vary widely among companies. Therefore, only the most accurate approach that could be found will be discussed.

In this chapter, data used by Portuguese construction companies to perform management functions will be analysed in two stages [1], [2]:

Firstly, data flow diagrams will be used to depict the logical flow of data among estimating, planning and the preparation of data for control. These diagrams have been built up using information gained from previous chapters on data required to perform those management functions. Moreover, the companies’ charts of Appendix 1.1 were used as a basis for them. The data flow diagrams presented in this chapter are useful in identifying the management functions performed by the companies and the resultant data transformation.

Next, data models will be used in order to discuss the logical data structure more deeply. A graphical representation of data has been adopted in order to support that discussion.

Other approaches to data modelling have been suggested in the literature (eg, [3], [4], [5]) and could be used alternatively to the two stage methodology mentioned above. However, the detail used in the study of data throughout the previous chapters is adequate to the development of the integrated model on the basis of the knowledge acquired from that study.
8.2 The existing systems

The operations performed by Portuguese Construction companies during the pre-tender stage are depicted in figures 8.1 and 8.2. Figure 8.3 refers to the pre-contract stage. Figures are based on companies' charts of Appendix 1.1.

8.2.1 The tender stage

Figure 8.1 below shows the most straightforward approach companies use for tender estimating and planning. Price rates and subcontract quotations are selected for the most common bq items. Activities definition follows from the bill of quantities; their durations are assessed from the companies' past experience and data from subcontractors. Resources planning is not performed. Receipts forecast is made by totalling bq item prices into the corresponding construction activities.

Figure 8.2 shows an alternative approach to the previous one. Productivity data (either the companies' data or published resources usage rates) is used to build up cost rates. Cost rates and subcontract quotations are used to evaluate the direct costs of the items of the bill of quantities. Indirect costs are added afterwards. Activities definition follows from the bill of quantities; their durations are assessed mainly by using the companies past experience and data from subcontractors; data from estimating is seldom used for this purpose. Resource allocation to construction activities is normally confined to labour. The receipts forecast is made by totalling bq item prices into the corresponding construction activities.

According to section 6.3, the obstacles to integration between estimating and planning management functions of building projects during the tender stage may be summarised as follows:

1. the form and complexity of the bill of quantities;
Figure 8.1: Tender estimating and planning: A straightforward approach.
Figure 8.2: Tender estimating and planning: An alternative approach.

Adapted from American National Standards Institute Standard Howchart and their use in Information Processing ANSI, 1971
(2) the nature of estimating methods used.

One of the main weaknesses of both approaches may be derived from the link between the [bill of quantities] block and the [activities break down] block. This may be summarised as follows:

the items of the bill of quantities do not provide for a satisfactory definition of construction activities.

The fundamental weakness of the estimating method used in the first approach may be derived from the path [bill of quantities]-[market price rates] in figure 8.1. This may be summarised under the following heading:

for the items where market price rates are used, no information about their costs is available and no resources data is generated.

The estimating method used in the second approach involves much more work but leads to better yet insufficient results. The main weaknesses of this approach may be deducted from the path [unit cost rates]-[evaluated bill]. This may be summarised as follows:

resources data used to calculate unit cost rates is seldom further allocated to the bq items.

Actually, although resources usage rates are implicit in cost rates, that information is often lost in the course of the estimating process.

It may be concluded that neither the approach of figure 8.1 nor that of figure 8.2 provide for the generation of sufficient information about resources to involve in production. Therefore, neither approaches enable integration of planning and estimating to be easily achieved.

According to section 1.4.1, possible solutions to this problem have long been proposed. These proposals have normally involved significant modifications in the common practice of construction companies. Specifically, the following changes should take place:
An alternative document to the traditional bills of quantities would be adopted;

An alternative method to unit rate estimating would be subsequently used.

Bills of quantities have normally been recognised as the major impediment to integration. The limitations of the bills were found to be most sensitive for building projects. In a way, bills for civil engineering projects tend to be closer to the operational format. However, this does not happen as a result of any intended move in that direction but follows naturally from the intrinsic characteristics of this type of project. Accordingly, most of the work developed on alternative formats to traditional bills has been directed to building projects.

Alternative documents (eg operational bills, activity bills, communicative bills, etc.) are based on construction operations and thus hopefully best suited to estimating and planning. Instead of introducing an innovative document to replace the traditional bills of quantities, it has also been suggested that cost information could be joined to the construction schedule of activities. Therefore, integration would be directly achieved through the utilisation of a single tender document consisting of a list of priced activities.

Despite the criticism of bills of quantities and the continual efforts to replace them by other documents, Portuguese construction industry continues to place heavy reliance upon them. The following advantages of bills of quantities have been found:

(1) they are a comprehensive reporting format for work quantities;

(2) item organisation is suitable for estimating and for work valuations on site;

(3) most item descriptions are common among bills and this provides for cost and price data to be organised accordingly.
These arguments help us to understand the difficulties felt in the implementation of the alternative solutions referred to above. Moreover, Portuguese construction companies have been using bills of quantities for a long time and resistance to change is an important factor to take into consideration.

The form of the bill of quantities has been previously described as one of the conditioning factors for the selection of the estimating method. It is therefore not surprising that operational estimating has been alternatively suggested to unit rate estimating when bills were intended to move in the same direction. However, the utilisation of unit production rates for estimating has been found to be suitable for building projects and it has been in use for a long time.

Despite the difficulties in integrating planning and estimating through the approaches depicted in the previous figures it has been found that Portuguese construction companies normally find them acceptable for tender purposes. Reasons for this have been previously discussed and are summarised below:

(1) the relative importance of estimating to planning;

(2) the usual requirements of the tender documents;

Therefore, although an integrated approach to tender planning and estimating management functions would be useful, the relevance of achieving that result seems less important during this stage than during the pre-contract stage as discussed below.

8.2.2 The production preparation stage.

This is carried during the pre-contract stage and for this reason Portuguese construction companies sometimes call it the production preparation stage.

After commitment, the above process is refined because companies aim to prepare the project execution. However, the basic structure of figures 8.1 and 8.2 may be maintained.
Figure 8.3: Estimating and planning during the production preparation stage.
Figure 8.3 shows the most accurate approach that could be found for production preparation. This includes detailed measurements and the generation of a new bill of quantities. Productivity data is used to allocate resources to the items of the bill of quantities. Unit costs of resources, sub-contract quotations and on-costs are used to evaluate the bill. Activities definition mainly follows from the bill of quantities possibly refined by means of additional measurements. Data from estimating is now more often used than previously in the assessment of durations of activities. Resource allocation possibly includes other resources beyond labour as required for control. Cost forecasting is performed by valuating the construction activities with the unit cost rates that have been estimated before.

According to section 7.3, obstacles to integration between planning and estimating management functions remain during the pre-contract preparation stage. This can be identified in figure 8.3:

The link between the [bill of quantities] block and the [activities break down] block needs to be completed by additional measurements in order to meet the activity definition requirements.

The link between the [productivity data] block and the [resource allocation to activities] block is hard to ascertain.

The paths leading to the [cost forecasts] block do not include the cost evaluation of the construction programme; similarly, the paths leading to the [receipts forecasts] block do not include the price evaluation of the construction programme.

The shortcomings of this approach may be summarised under the following headings:

(1) duplication of work is likely to occur during the generation of data;

(2) resources data is difficult to allocate to construction activities;
(3) both cost and price information are stored in a bq format which makes monitoring on site more difficult;

(4) cash flow forecasting is not sufficiently accurate.

It may be concluded that the approach depicted in figure 8.3 encompasses several obstacles to integration between planning and estimating management functions. This is specially due to the evident lack of interchange of information between those two functions. As a result data for control is poorly prepared.

Possible solutions to this problem early suggested in the literature have already been discussed in the previous section. The difficulties in implementing them apply to the pre-contract stage. The advantages of the bill of quantities and the suitableness of unit rate estimating for building projects have also been recalled in the previous section. Besides, the exclusive use of a construction programme document during the contract stage has proved to be unsatisfactory, especially for the following reasons:

(1) resource allocation is not fully achieved in planning;

(2) price and cost information are available under a bill of quantities format;

(3) external work valuations are normally based on the priced bq.

According to the above discussion, lack of integration between planning and estimating management functions during the pre-contract stage is recognised. This reduces the degree of accuracy of both functions and prevents data for control from being suitably prepared. Moreover, project implementation becomes more difficult.

This is a problem that Portuguese construction companies would like to see resolved. Earlier solutions to this problem have proved to be unsatisfactory. In the following sections an alternative approach for planning estimating and the preparation of data for control is suggested.
8.3 Data structures.

8.3.1 Introduction.

In this section data models are used to clarify the reasons for the lack of integration among management functions. Furthermore, data models will support an approach to tackling the problem(1).

Data pertaining to a given construction project may be stored in a database. A discussion on the advantages of using databases when compared to alternative approaches may be found in section 8.5.2. Data models will be used in order to describe the structure of such a database. A data model is a collection of conceptual tools for describing data, data relationships, data semantics and data constraints [6]. Several of these models have been proposed and may be partitioned into three different groups:

- object-based logical models;
- record-based data models;
- physical data-models.

Both object-based and record-based logical models are used in describing data at the conceptual and view levels. By contrast, physical data models are used to describe data at the lowest level. In this work the former two data models will be used because studying the way data will be physically stored in the database is beyond the scope of this thesis. In this chapter, an object-based data model will be used and in chapter 9 a record-based logical model will be used.

There are several data models that can be included in the class of object-based data models. Some of the more widely known are [6]:

(1) Extensive references to data models may be found in the literature. Some of those used to support the following discussion are listed at the end of this chapter (references [6] to [14]).
In this work the entity-relationship (E-R) data model has been selected in order to describe the structure of the database. This was the selected one because it has gained acceptance as an appropriate model for database design and it is widely used in practice [6].

The E-R model makes use of diagrams in order to express graphically the overall structure of the database. After Chen's original notation, a number of different graphical notations for E-R models have been suggested so far, each with slightly different graphical notations but keeping the basic underlying principles largely the same [15]. In this study, the notation followed by Korth [6] will be adopted under which the following set of graphical components is used in order to express the logical structure of a database:

- rectangles which represent entity sets;
- ellipses which represent attributes;
- diamonds which represent relationships among entity sets;
- lines which link attributes to entity sets and entity sets to relationships.

8.3.2 Entity-Relationship diagrams of the system.

The entity-relationship (E-R) model basically deals with entities and relationships. An entity is represented by a set of attributes. Entities are organised into entity sets.

According to the previous discussion, the following three entity sets basically provide for the data required to perform planning and estimating management functions of a construction project. In order to avoid confusion, single names are used for entity sets.

work, the set of all construction works within the project. The attributes
associated with each construction work are work-code, and work-description.

item, the set of all the items of the bill of quantities for the project. The attributes associated with each bq item are item-code and item-description.

activity, the set of all the construction activities of the project. Each construction activity is described by the attributes activity-code and activity-description.

Relationships are organised into relationship sets. Formally, a relationship set is a mathematical relation of \( n \geq 2 \) (possibly non distinct) entity sets. If \( E_1, E_2, \ldots, E_n \) are entity sets, then a relationship \( R \) is a subset of

\[
\{ (e_1, e_2, \ldots, e_n) : e_1 \in E_1, e_2 \in E_2, \ldots, e_n \in E_n \}
\]

where \( (e_1, e_2, \ldots, e_n) \) is a relationship [6].

An Entity-Relationship scheme may define certain constraints to which the contents of a database must conform. One important constraint is mapping cardinalities among the above entity sets. These express the number of entities to which another entity can be associated via a relationship [1]. Binary relationships sets will be specially dealt with. The following mapping cardinalities between the pairs of entity sets referred to below have been found:

The work-item (wi) relationship set which relates construction works to bq items is often many-to-one. This means that several construction works may be combined within a single bq item according to the aggregation criteria discussed in section 6.2.

The work-activity (wa) relationship set which relates construction works to construction activities is also many-to-one. This means that several construction works may be joined into a single construction activity according to the conclusions of section 7.2.3.
Following the discussion of the previous chapters, no functional dependency normally exists in either direction between the item and activity entity sets. Therefore, the item-activity (ia) relationship set is generally many-to-many.

No descriptive attributes will be selected for the relationships to be discussed below. Therefore, only the code attributes of the entity sets pertaining to each relationship set will be considered.

In order to distinguish among possible mapping cardinalities, lines are drawn either directed or undirected between the relationship set and the entity set concerned. For example, a direct line from the relationship set wi to the entity set item specifies that the item entity set participates in either a one-to-one or a many-to-one relationship with the work entity set (figure 8.4). The same holds for the direct line from the relationship set wa to the entity set activity (figure 8.5). In figure 8.6, the many-to-many relationship set ia between the
item and the activity entity sets is represented according to the same convention.

Figure 8.6: The item-activity (ia) relationship.

Figure 8.4 and 8.5 have been merged together into figure 8.7 below which represents the three entity sets work, item and activity related through the two relationship sets wi and wa. This is not only an effective way of representing wi and wa in a single diagram but also corresponds to the transformation of the many-to-many relationship ia into a two back-to-back one-to-many relationship [13], [1].

Figure 8.7 clearly suggests a way to tackle the problem of the lack of functional dependency between the item and the activity entity sets. This would be
achieved by considering the construction works assigned both to items and to activities using the wi and the wa relationships.

Obviously, the diagrams of the previous figures within this section are a simplification of the actual relationships they intend to represent but for the aims of this chapter their detail is adequate. This subject will be returned to in chapter 9.

The definition of the work entity set presupposes a certain degree of aggregation for the construction works included in each entity. Some aggregation is always needed because the total amount of information would otherwise be difficult to handle. Therefore, relations of construction works to themselves are likely to occur but for the sake of simplicity they were not taken into account in the above discussion.

According to the results of chapters 6 and 7, aggregation criteria for construction works should be set in agreement with the accuracy requirements of items and activities. Therefore, in general, the relationships wi and wa above encompass a set of works and these include within their scope other more elementary construction works.

According to the discussion in previous chapters, operational estimating provides for a more straightforward relationship between items of the bill of quantities and construction activities than unit rate estimating does. In this case, functional dependency may be admitted between item and activity entity sets. Moreover, some Portuguese construction companies also assume functional dependency between items and activities during the pre-tender stage of building projects. Therefore, an additional line could be drawn in figure 8.7 above, linking these two entity sets. In this case, the item-activity (ia) relationship is either one-to-one or many-to-one because each or several items of the bill of quantities may be grouped together into activities. Figure 8.7 has been re-arranged to include ia; the resulting diagram is depicted in figure 8.8 below.

Unfortunately, the diagram of figure 8.8 does not provide for an accurate
approach to the relationships among the three entity sets during the pre-contract stage. Moreover, according to section 8.2.2 lack of integration among management functions is specially felt during that stage. Therefore, only the relationships of figure 8.7 will be further discussed. The alternative diagram shape of figure 8.9 is more suitable for the following discussion.

Figure 8.9: The wi and wa relationships in an alternative diagram to figure 8.7.
8.4 The integrated model.

8.4.1 Findings of the previous discussion.

The problem of integration between planning and estimating management functions may be restricted according to the findings of the previous chapters as summarised below:

(1) obstacles to integration are most sensitive when unit rate estimating is used;

(2) integration is harder to achieve in building projects;

(3) the need for an integrated approach is especially felt during the pre-contract stage in the course of production preparation.

Therefore the approach to integration presented in the following sections should be specially designed in agreement with those findings. Additionally, it should be suitable for the projects where operational estimating is used (chiefly civil engineering projects) and should encompass the pre-tender stage too.

The following guidelines resulting from the discussion in previous chapters should be taken into consideration:

(1) bills of quantities in their current format should be maintained;

(2) unit production rates should be used for estimating.

The following enhancements of the existing systems should be attained:

(1) duplication and re-generation of data should be avoided;

(2) data interchange among management functions should be improved;

(3) data generated by planning and estimating should be upgraded and
better suited to the requirements of control on site.

However, the following restrictions should be taken into consideration:

(1) a significant increase in work required should be avoided;

(2) traditional measurements should be sufficient for the generation of data;

(3) it should not involve significant alterations to the usual planning and estimating procedures.

8.4.2 The suggested model.

The integrated model aims at the integration of planning and estimating management functions and the preparation of data for control. It will be described using the chart in figure 8.10. This is similar to that of figure 8.3 in order to minimise changing to the traditional processes. Main differences are referred to below:

(1) The findings of section 8.3.2 are introduced;

(2) resource allocation to bq items is the basis for cost estimating;

(3) time constraints are included;

(4) cost forecasts are time related.

Specifically, the following differences between figures 8.3 and 8.10 may be identified:

(1) A direct link between the [measurements] block and the [productivity] block has been introduced. This implies that measurements are directed to the identification of construction works and not only for the generation of the bill of quantities as in figure 8.3.
Figure 8.10: An integrated approach for management functions.
(2) The relationships among the [measurements] block, the [bill of quantities] block and the [activity break down] block have been re­formulated. The link between the [bill of quantities] block and the [activity break down] block in figure 8.3, has been replaced by a frame identical to the diagram of figure 8.9

(3) A [resource allocation to bq items] block has been included in the path leading to the [evaluated bill of quantities] block. The [unit cost rates] block of figure 8.3 has been erased.

(4) Time constraints and a loop mechanism to deal with them have been included in figure 8.10.

(5) The cost evaluation of the construction programme is now provided.

The advantages of this model when compared to that referred to in section 8.2.2 may be summarised under the following headings:

(1) Duplication of work during the generation of data is avoided because detailed measurements are used both for the definition of the items of the bill of quantities and for the definition of the construction activities;

(2) Resource allocation is easier to achieve because construction works (included both in the items of the bill of quantities and in the construction activities) have been identified by the measurements.

(3) Cost information is stored both in a bq format and in an activity format because resources data is available in both formats with identical accuracy.

(4) The analysis of time constraints is integrated with the selection of the productivity methods and the resource allocation procedures.

(5) Cash flow forecasting is possibly more accurate than before because it uses cost forecasts anchored to the construction programme.
It may be concluded that the model of figure 8.10 provides for a more effective integration between planning and estimating management functions than the approach of section 8.2.2. Moreover, data generated by these two is better suited for control than before because it is related to the construction programme, thus facilitating project monitoring and control on site [16].

8.5 The utilisation of the new model.

8.5.1 An overview of the model.

The model presented in section 8.4 supports the integration of planning, estimating and the generation of data for control. It has been specially designed for the pre-contract stage but it may also be used during the pre-tender stage because data requirements are normally lighter for this stage. In the following description the pre-contract stage is meant.

The model is based on the initial assessment of the construction works according to the requirements of both the items of the bill of quantities and the construction activities. The way construction works are grouped into the items of the bill of quantities has been discussed in chapter 6; identical discussion about construction activities has taken place in chapter 7. Accordingly, it has been concluded that the minuteness required for the definition of the construction activities depends on a wide number of factors. Nevertheless, the nature of that minuteness is hard to illustrate. Current research tends to rely on the human judgement of the planner to deal with this problem. However, some guidelines may be extracted from the survey of chapters 6 and 7:

(1) Traditional methods of measurement are suitable for the identification of all relevant construction works.

(2) Construction works should be grouped according to the operational function of the construction elements to which they refer. Moreover, a subdivision by work locations is required.
(3) Major construction works involving distinct trade skills, material or plant may require a finer division according to those distinctions.

In order to make the above statements clearer, the example of section 6.2 "reinforced concrete in beams" will be recalled. Accordingly, traditional measurements would be used to assess the elementary construction works required to perform each concrete beam of the project. Data generated would be grouped in agreement with the relevant work locations where beams are expected to be executed. Furthermore, elementary works (eg concreting) would possibly be dealt with separately if the study of concrete mixing works were needed. Eventually, this set of measurements would possibly lead to a single item of the bill of quantities (as in the example of chapter 6) but several construction activities could possibly be generated.

Next step is the allocation of the resources required to perform each construction work. In order to achieve this goal, all the productivity data used in the traditional direct cost estimating process may be utilised. This also includes the empirical procedures mentioned in section 6.2.1. Resource allocation to both items of the bq and construction activities is achieved by adding up the total resource requirements for the works pertaining to each of them.

Direct costs are computed by valuing all resource requirements of both bq items and construction activities. Indirect costs are assessed by following the usual procedures; data generated is used to assess the total costs of the items of the bq and is passed to the construction programme.

The construction programme is built up with the use of traditional scheduling methods.

Either total costs or time constraints may lead to a new selection of construction methods. However, a new assessment of the key-resources allocated to some construction activities may be enough to cope with time constraints. According to figure 7.3, this does not involve significant changes in project costs. Therefore the upper path of figure 8.10 is not affected by this procedure.
The accuracy in cost forecasting is high because the model allows for the cost-valuation of construction activities. Receipts forecasts are assumed to be known from tender documents. However the accuracy in receipts forecasts is expected to be lower because it is difficult to get a price-valuated construction programme from the tender priced bill of quantities. This has been discussed in chapter 6.

8.5.2 The new model in practice.

Management functions referred to above make use of considerable amounts of data. Traditionally, construction data about a specific construction project is kept in a number of distinct files in contractor's organisations [17]. However, according to section 8.3.1, data pertaining to a particular construction project may be stored in a database. This basically includes general data which is common to all or to a large set of construction projects and specific project data. It would therefore be desirable if data could be easily retrieved and stored in the database.

Management functions involve a lot of data transference and manipulation among them. As discussed in chapter 4, Portuguese construction companies make use of some application programs in order to perform operations with data, viz:

- an estimating program (often);
- a scheduling program (sometimes);
- a program to support site control (possibly a spreadsheet);
- accounting programs;
- etc.

These programs may be written in several computer languages and by several people. This environment is a typical file processing system supported by a conventional operating system. This scheme has several disadvantages [18]:

- data redundancy and inconsistency;
- difficulty in accessing data;
data isolation (it may be difficult to find);
multiple users needed, each of each expertise;
security problems difficult to enforce;
integrity problems.

A database management system (DBMS) provides an environment which is both convenient and efficient [6] to support these operations with data. The utilisation of a database system has several advantages [19]:

it contains data which the DBMS can transform into information;
it can be shared among a variety of users;
nomenclature, definitions and formulae are consistent throughout the database;
redundancy of data is avoided;
a database has the flexibility to respond to different requests in differing ways, being able to process disparate data form different tables in a variety of way;
it is possible to safeguard of data from unauthorised access;
users are forced to input data according to a pre-defined manner;
a database may be modified in various ways without this having any impact upon the programs using it;
the existence of a database eases the development of application programs.

How well and how easily a database can display the above benefits depends almost entirely upon the DBMS that is controlling the database. The primary functions of a database management system are [20]:

to enable data storage, retrieval and modification;
to provide mechanisms for establishing and enforcing data integrity;
to create an information dictionary for resources and relationships;
to provide mechanisms allowing concurrent processing;
to allow recovery from hardware or software failure;
to enforce security mechanisms to user access;
to provide utility services.
The implementation of a DBMS requires computer support. At least four languages may be involved in the DBMS [6]:

the Data Application Language (used to write application programs);
the Data Manipulation Language (DML) (used to access or manipulate data as organised by the data model);
the Data Definiton Language (DDL) (describes the global logical data organisations and the way of building up the contents of files);
the Physical Data Description Language.

Besides retrieving and storing data in the database, the model suggested in section 8.4.2 requires a lot of calculations. The practical utilisation of the model would be rather time consuming if all the necessary calculations were to be performed by hand. Therefore, the use of a computer is also needed to support them.

From the above discussion it may be concluded that the practical implementation of the model requires the development of a computer system. A discussion of how this was achieved may be found in chapter 9.
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CHAPTER NINE

A Computer System for the Model.

9.1 Introduction.

In section 8.4.2 a model for the integration of planning and estimating management set functions during the pre-contract stage of construction projects has been presented. The model also enables efficient preparation of data for the project control on site.

The development of the model was based on the appraisal of usual planning and estimating procedures of Portuguese construction companies. Those procedures were maintained in the model or they were at most improved if necessary. This is advantageous for the implementation of the model. Accordingly, the chart of figure 8.10 is similar to the one of figure 8.3.

The practical utilisation of the model has been discussed in section 8.5.2. The following two characteristics of the model have been taken into consideration:

- considerable amounts of information have to be managed;
- a lot of calculations have to be performed.

Accordingly, it was concluded that a database management systems (DBMS) approach provides for a suitable environment for the model. A DBMS will be used in this chapter as the basic frame for an integrated computer system to support the model.

Current computer support for construction management functions has been surveyed by means of an inquiry to Portuguese software dealers. It was concluded that although no integrated programs could be found, some reasonable partial programs for planning and estimating are available. Similarly, Ndekugry et al. [1] consider software packages in existence in the UK excellent for the individual functions they were designed to support but together they would form a veritable Tower of Babel.
The utilisation of partial programs in the integrated computer system could be advantageous for the following main reasons:

- current programs have been extensively tested and they have proved their efficiency;
- some users may be more receptive to some amendment to current programs than to new computer system;
- users of the new system would partially avoid the learning problem;
- some time could be saved in the development of the system.

On the other hand, partial programs may be difficult to merge into an integrated computer system for many reasons [2]. Furthermore, because it was intended to use a specific DBMS, data structures of distinct programs should have been built in accordance with it. This could be difficult to do.

In this chapter the selection of the DBMS used to support the practical utilisation of the integrated model is discussed. Current software solutions and the requirements of the new computer system are compared. Finally, the basic structure of the system is presented.

### 9.2 A Database Management System for the model.

#### 9.2.1 Data models.

According to section 8.3.1, the database contains information about a particular project. Data models are used to describe the structure of the database. In chapter 8 an object-based logical model (the entity-relationship model) was used. In this section a record-based logical model will be used. This type of model aims to specify both the overall logical structure of the database and a higher level description of the implementation [3].

There are three most widely accepted record-based data models: The
The relational model, the network model and the hierarchical model. In the last few years the relational model has deserved great attention both in academic database research and in practical applications. Some advantages of the relational database when compared to the other models have been recognised in the literature [4]:

- **Data independence** (i.e., the ability to change physical logical storage representation of data without having to rewrite application programs);
- Ease of use;
- Ease of modifying the structure and implement the system.

Accordingly, a relational model will be used to represent project data.

### 9.2.2 The relational model.

In section 8.3.2 three entities sets and three relationship sets have been considered:

- Work, item and activity entity sets and
- Wi wa and ia relationship sets.

Relationships were represented by E-R diagrams as shown in figures 8.4 to 8.9. The diagram of figure 8.9 together with the chart of figure 8.3 formed the basis for the model of section 8.4.2 and gave shape to the chart of figure 8.10. However, the diagram of figure 8.9 is a simplification of the actual relationships among data. Information therein included would not be sufficient to support the procedures implicit in figure 8.10.

In this section some more information will be added to the database in order to enable the fundamentals of the model to be achieved. Moreover, the structure of figure 8.9 will be maintained but an alternative model to E-R diagrams for data representation will be used.
A database that conforms to an E-R diagram can also be represented by tables [1]. For each entity set and for each relationship set in the database, there is a unique table (or relation) which is assigned the name of the corresponding entity set or relationship set. Each row in a table (or tuple in the relation) represents a relationship among a set of values.

For each relation, the relation scheme is the list of its attributes and their corresponding domains. Only the attributes of each relation will be discussed in this section. Domains will be dealt with in Appendix 2.

The following relations will be considered: work, item, activity, measurement and resource.

The first three relations have already been dealt with in chapter 8. The measurement relation contains project measurements and the resource relation contains information about the construction resources to be used in the project.

Corresponding relation schemes are as follows:

- **Work-scheme** = (work-code, work-description).
- **Item-scheme** = (item-code, item-description).
- **Activity-scheme** = (activity-code, activity-description).
- **Measurement-scheme** = (work-code, work-unit, work-quantity).

In section 8.3.2 no descriptive attributes have been considered for the relationships wa and wi. Accordingly:

- **wi-scheme** = (work-code, item-code).
wa-scheme = (work-code, activity-code).

From the chart of figure 8.10 construction works are identified from the measurements. Productivity data is used to decide on the resources required to perform each work. This gives rise to the relation \( wq \). The scheme for this relation is:

\[
\text{wq-scheme} = (\text{work-code, resource-code, resource-quantity}).
\]

Relational algebra \([3]\) will be used next in order to request information from the database. Each operation with relational algebra produces as a result a new relation as described below.

The attributes \text{work-code}, \text{activity-code} and \text{item-code} may be associated in a new relation \( \text{wia} \) by the following expression:

\[
\text{wia} = \text{wa} \times \text{wi}.
\]

Moreover, measurements may be added to this relation leading to the \( \text{wiam} \) relation. Accordingly,

\[
\text{wiam} = \Pi_{\text{work-code, work-quantity, act.-code, item-code}} (\text{wia} \times \text{measurements}).
\]

The corresponding table is shown in figure 9.1.

<table>
<thead>
<tr>
<th>work-code</th>
<th>work-quantity</th>
<th>activity-code</th>
<th>item-code</th>
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Figure 9.1: The \( \text{wiam} \) relation
Following the chart of figure 8.10, the next step is the resource allocation to the construction activities and to the items of the bill of quantities. These are essential relations for the utilisation of the model. The following two expressions generate the relations for activities and items respectively:

\[
pact = \Pi_{\text{act-code}, \text{res-code}, \text{res-quantity}} (\text{wia} \times \text{wq} \times \text{activity}).
\]

\[
pbqi = \Pi_{\text{item-code}, \text{res-code}, \text{res-quantity}} (\text{wia} \times \text{wq} \times \text{item}).
\]

The corresponding tables are shown in figures 9.2 and 9.3.

<table>
<thead>
<tr>
<th>activity-code</th>
<th>resource-code</th>
<th>resource-quantity</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

Figure 9.2: The \text{pact} relation

<table>
<thead>
<tr>
<th>item-code</th>
<th>resource-code</th>
<th>resource-quantity</th>
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Figure 9.3: The \text{pbqi} relation

After the above relations have been set, estimating and planning procedures
may start following the upper and the lower paths of figure 8.10 respectively. This involves a set of calculations which cannot be supported by usual relational algebra operators [5].

However, Data Manipulation Languages (DML)(1) used by most DBMS's offer computational abilities. A DBMS may thus stand for the basic frame of the integrated computer system. The discussion about the selection of the database may be found in section 9.4. In section 9.3 the adequacy of current computer software to support some parts of the model (viz estimating and planning functions separately) will be explored.

9.3 Current computer programs.

The model which has been suggested in section 8.4.2 was developed from current planning and estimating procedures have been improved in the model so that integration among management functions could be achieved.

The inquiries discussed in chapters 3 to 5 have shown that construction companies make use of computer support in order to perform some management functions. Referring to the "Specific Inquiry to 21 Portuguese Construction Companies" the following conclusions apply:

personal computers (PC) are mainly used;

computer support for unit rate estimating is used by 57% of the companies;

no computer support has been found for operational estimating;

computer support for planning is restricted to network calculations

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(1) A Data Manipulation Language (DML) is a language that enables users to manipulate data as organised by the appropriate data model [1].
and only 24% of the companies use it.

These results cannot be extrapolated to all Portuguese contractors because of the selection criteria used in the inquiry (see chapter 4). Actually, only reasonably large companies were selected and these tend to be most receptive to computers. These are only a few of the total number of companies (see chapter 2). Therefore, there are reasons to believe that the above figures may be too high for the whole Portuguese construction sector.

Current estimating computer programs have been tailored to the construction industry so they tend to support the estimating procedures companies usually follow. As these procedures have been improved in the model, those programs may not be straightforwardly used in the new system. It was decided to analyse some of those programs in order to determine whether they are adequate for this purpose.

Computer programs used in planning have not generally been specifically developed for construction [6]. Moreover, they only support a limited part of the planning management function (viz network calculations) and they seldom allow for direct input of data from estimating [7]. There is a large number of such programs. Therefore it was decided to summarise the most relevant characteristics of the most widely used.

In the following paragraphs current computer programs for estimating and planning will be reviewed. This aims to find out if some of those programs could be efficiently merged into the new system. The conclusions of the "Inquiry to Portuguese Software Dealers" will be recalled. Moreover, some comments about international and British software will be added. Only micro-based software will be dealt with.

9.3.1 Estimating computer programs.

The way current estimating programs operate has been discussed before. Main features of these programs and the procedures suggested in the integrated model are compared below:
1 Current estimating programs usually operate project data from the bill of quantities. According to chapter 6, an item of the bill of quantities may comprise several distinct works. Therefore, costs are first calculated for a set of works. Alternatively, the integrated model is based on construction works. Costs are assessed for each work separately and added up thereafter.

2 They rely on unit rate estimating alone. According to chapter 2, other estimating approaches (e.g., operational) are also used by Portuguese construction companies but current estimating programs do not support them. The integrated model uses resource allocation to construction works in order to assess costs. Therefore, it stands for several estimating approaches.

3 The unit rate estimating approach followed by those programs presupposes a practice which may contradict the spirit of the integrated model. Relevant issues on this subject are discussed below:

   3.1 Current estimating programs require the user to link each item of the bill of quantities to a specific construction task. Build-ups for typical construction tasks are available but if no task matches a given bq item, the build-up for the task has to be entered in the first place. The integrated model eases this procedure because it stores build-ups for elementary construction works instead.

   3.2 The total cost for each item of the bill of quantities is computed after the unit cost has been assessed. Possible particularities of the works comprised in it have to be catered for in the unit rates and ultimately in the construction tasks. On the other hand, in the integrated model, total costs are calculated in the first place.

   3.3 Resource allocation follows a similar procedure to the total cost assessment. Therefore, identical difficulties arise in current...
estimating programs. In the integrated model, resources required to perform each construction work are first set up and then information is passed to the items of the bill of quantities.

4 Current estimating programs are normally stand-alone computer data transfer from the estimating modules to the planning or control modules. This is achieved by assuming functional dependency between items of the bill of quantities and activities of the construction program. According to chapter 8 this is inconsistent with the construction reality. The integrated model is based on the diagram of figure 8.9 which is an attempt to solve that problem.

5 Information generated by current estimating programs is hard to use outside their scopes. In the integrated model however, once a piece of information is generated, it may be widely interchanged throughout the model.

Similarly, most British estimating software work from the bill of quantities [8]. Some allow contractors to build up their prices from basic labour, materials and plant data [8] but the unit rates approach is the most common [8], [9], [10]. Estimating computer packages written in high level languages [11], [12], [13], and spreadsheet estimating software [14], [15], [16], have long been suggested in the literature. The former often include other modules beyond the estimating module (eg a valuation module [17]) and some of them may be linked to other packages; the latter tend to be stand alone systems. Efforts to assign and apportion items of the bill of quantities to network activities [18] are restricted to civil engineering projects for the reasons discussed in chapter 8. This is the case of TIANAREBA sub-system [18] of INTEREST-CE computer-aided estimating system [19].

In view of the above, current estimating computer programs are difficult to use directly in the integrated computer system. Adaptations would have to be accomplished in order to make them usable. However, some difficulties would be likely to arise in the course of that process. Firstly, the foundations of the programs are essentially distinct from the idea behind the integrated model. Secondly, these programs tend to be self-contained, so problems are likely to
occur in their integration with other programs. Thirdly, information about the
way they actually work (eg data structures they use, how data is manipulated
within the program, etc.) are hard to obtain from purchasers.

Therefore it as decided to abandon the idea of merging current estimating
software into the integrated computer system. Estimating procedures will thus
be supported by the DBMS.

9.3.2 Planning computer programs.

According to chapter 5, current planning computer programs are usually based
on the "Critical Path" analysis and only support the network calculations. The
following information has to be entered by the user [20]:

activities breakdown of the project;
resources allocated to activities;
activity durations;
precedence relationships among activities.

Moreover, some programs allow for several constraints to be added to the
project. Time and resource constraints are the most common [21]. Time
constraints relate to the time sequencing among activities (eg a specific start or
end date can be marked on an activity). Resource constraints take the
availability of resources into consideration in the network design.

Current commercial planning packages tend to be international [22]. A large
number of these have good performances for the network calculation and allow
for several time constraints among activities. Resource assignment and
summation are a common additional feature [4] In addition, some provide for
resource planning techniques as well (eg resource levelling, resource
smoothing, etc.) [6], [23], [24], [25].
However, some differences can be found between the way current planning packages operate and the procedures suggested in the integrated model as discussed below:

1 Current planning packages do not assist the user in the generation of input data. Accordingly, both resource allocation to activities and activities durations have to be entered by the user alone. On the other hand, both procedures are supported by the integrated model.

2 Information entered by the user cannot be modified within current planning packages. These tend to use a specific data set in each run of the project. In the integrated model however, the user may achieve distinct durations for each project activity by modifying the resources allocated to it.

Therefore, it may be concluded that current planning packages cannot be used to fully support the planning procedures suggested in the integrated model. However, they are compatible with those procedures because they can be used as stand alone scheduling packages. Moreover, their abilities may be advantageously joined onto the integrated system (e.g. calculation capabilities, reporting facilities, etc.). Therefore, a commercial planning package may be used in the integrated system for the generation of the construction program whereas input data is supported by the DBMS.

Several criteria may be taken into consideration in order to select the best suited planning computer package [21], [26], [27]. In view of the specific utilisation of the package within the integrated system the following features were looked at:

- calculation capabilities;
- reporting facilities;
- display possibilities;
- data entry procedures;
- popularity among Portuguese contractors;
- ability to communicate with other software;
- availability to the author.
Several reports on the selection of planning packages may be found in the literature [23], [24]. Most of those packages allow for data entry facilities other than the direct input by the user at the keyboard. Moreover, some have interfaces with other software. In what concerns the integrated system, interfaces with databases are very important. Fortunately, most planning packages allow for interface with several commercial databases. Therefore, data transference with the integrated system seems feasible.

In the case of the utilisation of planning packages by Portuguese contractors, the inquiry to software dealers reported in chapter 5 revealed that "Pertmaster" and "Primavera Project Planner" are the most widely used. Both of them are available to the author and both allow for easy interface with several commercial databases [28], [29]. Similarly, the results of a mailed inquiry conducted by Aouad [30] showed that "Pertmaster" was one of the most used planning packages among the British top contractors and that "Primavera Project Planner" was mostly used in the USA.

Taking into consideration the poor use of computer based scheduling by Portuguese contractors(2), it was decided not to merge any specific planning package into the integrated system. Alternatively, the system will be prepared to transfer data in a readable format for more than one planning package or to allow data to be dealt with by hand at will.

9.4 The selection of the Database Management System (DBMS).

According to the above discussion, the basic frame of the integrated computer system will be supported by a DBMS.

Moreover, both estimating procedures and the generation of input data for the Therefore, a relational DBMS should be used to build up the integrated

(2) This contrasts with the findings of Aouad [30] for top contractors in UK and in the USA. Contractors from both countries tend to use micro-based computer support.
scheduling module will be catered for by the DBMS. In addition, the preparation of data for control will also rely on it.

In section 9.2.1 a relational model has been selected to represent project data. In this section a commercial database program for PC will be selected, but none of these can actually be qualified as relational (although some have this concept [31]). However, relational characteristics may be found in most of them. These characteristics are essentially related to the organisation of data into multiple tables and to the utilisation of nonprocedural query languages\(^{(3)}\) to assess data [31]. The extent to which nonprocedural systems are used is variable among commercial databases. Some have a wide nonprocedural support whereas others require programming for several operations. In addition, most of them include a specific programming language that can be used for querying the database.

Several reports on the appraisal of commercial DBMS's may be found in the literature [32]. Their features are often analysed and evaluated with the aim of assessing the best suited to a specific purpose. It may be concluded from those reports that there is a considerable number of them offering good capabilities.

The selection of a DBMS fulfilling the requirements of the integrated system thus seems easy to accomplish. Moreover, these requirements do not include high sophistication from the DBMS mainly because a prototype and not a commercial integrated system is intended to be built up. Therefore, some features related to the speed of data loading into and data manipulation within the database are not very important. In addition, fine appearance of screens and lots of printing options are not relevant selection factors.

Nevertheless, the DBMS to be selected should support the operations among

\(^{(3)}\) In a nonprocedural query language (eg SQL, QBE etc.) the system and not the user decides on the best way to obtain the information desired from the database. Those languages should be best refereed to as DML [3] (see note (1) above).
data which are implicit in the integrated model and allow for an inexperienced user to easily assess data stored in the database. Accordingly, the following criteria were taken into consideration in order to select the package:

it should include a programming language suitable for the development of the applications required;

the interface for the user should not require programming for querying the database and for the generation of reports;

it should be available to the author and should not involve a great learning effort.

Several computer packages fulfilling the first two criteria above are currently available in Portugal [32]. Among those, some are familiar to the author thus requiring little effort to be used. Therefore one of them could be selected.

A version of Ashton-Tate dBASE series has been selected. At the time this decision was taken, the last release of dBASE (dBASE IV version 1.0) was not very popular among users [33]. Therefore, it was decided to use a previous version (ie dBASE III PLUS) instead. Meanwhile, other packages came out another versions of former programs were released [16]. Probably, the development of the integrated system could now be more straightforward or its utilisation become easier. However, possible users of the system can partially benefit from the abilities of latest versions of some programs because these are normally compatible with former versions.

9.5 PECI. A computer program for the model.

PECI is an acronym of Planning, Estimating and Control Integrated. It has been developed in dBASE III PLUS environment using its programming language [34]. PECI uses a set of tables containing data to be handled within a specific construction project. Basically, PECI deals with the relations referred to in section 9.2.2. In some cases however, those have been enlarged in order to support more information and to enable operations with data to be
In next sections, the ability of PECI to support the integrated model of figure 8.10 will be discussed.

9.5.1 Resource classes.

Resources have been defined according to the usual Portuguese classification viz labour, materials, plant and sub-contracts. Resources pertaining to the first three classes will be further refereed to as elementary resources. Sub-contracts have been divided into two sub-classes. Accordingly, PECI recognises the following resources classes:

- elementary resources;
- internal sub-contracts;
- external sub-contracts.

Internal sub-contracts are combinations of elementary resources. Examples of internal sub-contracts are as follows:

A labour gang composed of 70% brickworkers and 30% labourers may be dealt with as a single resource.

Mortar for bricklaying comprises labour, plant, cement, sand and water. This may be handled as a single resource provided that the quantities of elementary resources are combined in the right proportions.

Compositions of elementary resources are advantageous in project management for several reasons, for example:

- they are closer to actual work organisation and they are easier to manage on site;
- in most cases, data about composite resources is easier to deal with.
than the data that would be gathered of elementary resources were considered (eg, to build up unit rates, for control on site, to measure productivity, etc.);

they allow for savings in data storage and thus help to speed data manipulation [35].

External sub-contracts have the usual meaning in construction vocabulary ie work packages to be performed by an organisation outside the company.

Tables 9.4 to 9.6 show how data about the three classes of resources referred above is stored in PECI. Each row of figures 9.4 and 9.6 (thus, each tuple of

<table>
<thead>
<tr>
<th>resource code</th>
<th>resource description</th>
<th>resource cost</th>
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</thead>
<tbody>
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<td></td>
</tr>
</tbody>
</table>

Figure 9.4: The elementary resources relation.

<table>
<thead>
<tr>
<th>int.-sub. code</th>
<th>resource code</th>
<th>resource quantity</th>
<th>int.-sub. cost</th>
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</tbody>
</table>

Figure 9.5: The internal sub-contracts relation.
the relations represented therein) contains data about a specific resource. An internal sub-contract on the other hand may require several rows in the table of figure 9.5. Each row relates to a specific elementary resource possibly comprised in the internal sub-contract build up. Moreover, an identical relation to that of figure 9.6 exists for internal sub-contracts.

<table>
<thead>
<tr>
<th>ext.-sub. code</th>
<th>ext.-sub. description</th>
<th>ext.-sub. cost</th>
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</table>

Figure 9.6: The external sub-contracts relation

9.5.2 Resource allocation.

One of the most important relations of section 9.2.2 refers to resource allocation to construction works (this has been represented by wq-scheme). PECI follows an estimating-like approach in order to achieve resource allocation. This is because resource data has been traditionally built up under an estimating perspective. Accordingly, the user must first decide upon which approach should be followed in order to handle each construction work, viz unit rates or operational. This decision is taken while building up the table of figure 9.7. Figure 9.7 is identical to figure 9.1 but a column for the task-code has been added. PECI understands tasks as unit construction works. The table used for tasks is depicted in figure 9.8.

Each task may require several rows in the table each row relating to a resource it possibly comprises. Resources can pertain to any of the classes defined in section 9.5.1. Comparing figures 9.5 and 9.8 it may be stated that internal
subcontracts are a particular type of task. Therefore, they also represent construction works. This translates the reflexive relations of works as mentioned in section 8.3.2 (although not represented in the ER diagrams). As before, an additional relation exists to provide the description of tasks.

<table>
<thead>
<tr>
<th>work code</th>
<th>work quantity</th>
<th>task code</th>
<th>activity code</th>
<th>item code</th>
</tr>
</thead>
</table>

Figure 9.7: The prel relation.

<table>
<thead>
<tr>
<th>task code</th>
<th>resource code</th>
<th>resource quantity</th>
<th>task cost</th>
</tr>
</thead>
</table>

Figure 9.8: The task relation.

Returning to the resource allocation to construction works, the user may select a task code when building up the table of figure 9.7. PECI will either recognise the code as referring to a specific task previously dealt with or it will ask the user for data. In both cases, an usual unit rate approach will follow: work
quantities and rates will be multiplied yielding the quantities of resources required to perform the work. Alternatively, the user may leave the task code column in blank allowing PECI to interpret that an operational approach should be followed. Consequently, the table of figure 9.9 has to be filled up.

As before, several rows may be required for each work. Resources from any class are allowed.

<table>
<thead>
<tr>
<th>work code</th>
<th>resource code</th>
<th>resource quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Figure 9.9: The ptrr relation.

After resource allocation to construction works has been set out, PECI makes use of pact and pbqi relations in order to allocate resources to construction activities and to bq items respectively. Obviously, several distinct resources may possibly be allocated to each activity and item. Therefore, several rows of pact and pbqi may relate to the same activity or item as the case may be.

9.5.3 Planning procedures.

Figure 9.10 shows a table that summarises resource allocation to construction activities. Each row refers to a specific resource. This is basically the pact relation of figure 9.2 but a new column has been put into for the activity team. Information stored in this column will be explained below.
The work team column contains in each row the number of key-resources required to achieve the duration for the activity. Several distinct key-resources may be selected for each activity thus several rows may refer to the same activity. PECI allows one to balance the number of key-resources and durations so that the user can select the best combination of both. This procedure is in agreement with section 8.2.3. The final decision of the user about the duration of each activity is transferred to the table of figure 9.11.
In order to arrive at activities costs, PECI simply multiplies resource quantities and resource costs for all the resources allocated to each activity.

At this point, the following information may be transferred to the scheduling module:

- activity descriptions and codes;
- resources allocated to activities;
- activity durations.

The user may not wish to perform resource assignment and summation for all resources involved in the project. Therefore, PECI allows for the selection of the most relevant resources.

Data about each activity may be automatically transferred to a scheduling package or can be dealt with by hand. In the former case, precedence relationships among activities may be set out within most commercial scheduling packages.

### 9.5.4 Estimating procedures.

PECI assesses the costs for the bq items using the pbqi relation. Results are summarised in a bill of quantities format yielding the relation depicted in figure 9.12.

<table>
<thead>
<tr>
<th>item code</th>
<th>item description</th>
<th>item quantity</th>
<th>unit cost</th>
<th>item cost</th>
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Figure 9.12: The psqb relation.
Item quantities are firstly confirmed by the user. Thereafter, PECI computes unit costs.

9.5.5 The preparation of data for control.

After planning and estimating procedures have been finished, the following information becomes available:

- activities and bq items break down in elementary construction works;
- total quantities of resources required to perform each construction activity;
- total quantities of resources involved in each item of the bill of quantities;
- activity costs broken down at the resource level;
- evaluated bill of quantities broken down at the resource level.

According to section 8.2.4, this fully supports control procedures.

9.5.6 Loops.

PECI may be used either to deal with a new project or to revise a previous one. In the latter case, the loops depicted in figure 8.10 may be accomplished. Accordingly, PECI allows one to select alternative construction methods (simply by re-designing prel relation) or to get other activity durations (by allocating to them a distinct number of key-resources). Obviously, subsequent procedures to the above, have to be revised accordingly.
9.6 Database design.

An important task in database design, is to specify how entities and relationships are distinguished. In order to achieve this, a superkey is assigned to each entity set. A superkey is a set of one or more attributes, which taken collectively, allow us to identify uniquely an entity in the entity set. Accordingly, if \( K = \{ e_1, e_2, \ldots, e_n \} \) is a superkey using attributes \( e_1, e_2, \ldots, e_n \), then so is any superset of \( K \). Formally, let \( R \) be a relation scheme. A subset \( K \) of \( R \) is a superkey of \( R \) if in any legal relation \( r (R) \), for all pairs \( t_1 \neq t_2, t_1[K] \neq t_2[K] \). That is, no two tuples in any relation \( r (R) \) may have the same value on attribute set \( K \).

Obviously, superkeys for which no proper subset is a superkey are the most useful because these are the smallest possible superkeys. Such minimal superkeys are called candidate keys. The primary key of an entity set is the candidate key selected as the principal means of identifying entities within that entity set. Primary keys selected for the above relations are:

- \( \{ \text{resource-code} \} \) for the elementary resources relation;
- \( \{ \text{int. sub. code}, \text{resource-code} \} \) for the internal subcontracts relation;
- \( \{ \text{ext. sub. code} \} \) for the external subcontracts relation;
- \( \{ \text{work-code} \} \) for the prel relation;
- \( \{ \text{task-code}, \text{resource-code} \} \) for the task relation;
- \( \{ \text{work-code}, \text{resource-code} \} \) for the ptrr relation;
- \( \{ \text{activity-code}, \text{resource-code} \} \) for the pact relation;
- \( \{ \text{activity code} \} \) for the psac relation;
- \( \{ \text{item-code} \} \) for the psbq relation.

Functional dependencies are a particular kind of constraints in database design which lead to several highly desirable normal forms for relational databases. These normal forms represent "good" database designs. The notion of functional dependency is a generalisation of the notion of superkey. Let \( V \subseteq R \) and \( W \subseteq R \) two sets of attributes of the scheme \( R \). The functional dependency \( V \rightarrow W \) holds on \( R \) if in any legal relation \( r (R) \) for all pairs of tuples \( t_1 \) and \( t_2 \) in \( r \) such that \( t_1[V] = t_2[V] \) then \( t_1[W] = t_2[W] \). Using the functional dependency notation \( K \) is a superkey of \( R \) if \( K \rightarrow R \).
There are a large number of normal forms. Of these, one of the more desirable we can obtain is the Boyce-Codd Normal Form (BCNF). A relation scheme $R$ is in BCNF if for all functional dependencies that hold on $R$ of the form $V \rightarrow W$ where $V \subseteq R$ and $W \subseteq R$, at least one of the following holds:

$V \rightarrow W$ is a trivial functional dependency (ie, $W \subseteq V$);  
$V$ is a superkey for scheme $R$.

A database design is in BCNF if each member of the set of relation schemes is in BCNF. It can be seen that except one, all the relation schemes discussed in this chapter accomplish the above condition. The same can be stated for the relation schemes presented in section A2.4 of Appendix 3 which documents all the files used by PECI. Only the $psbq$ relation depicted in figure 9.12 (and file JTPSBQ of Appendix 3) fail the BCNF. This is because the functional dependency $X \rightarrow Y$ holds on the relation $psbq$ with:

$X = \{ \text{item quantity, unit cost} \}$ and $Y = \{ \text{item cost} \}$

$X \subseteq psbq$ and $X \subseteq psbq$

However, it was decided to release the accomplishment of the BCNF conditions to this particular relation, because it aims to represent a traditional document of estimating management function: the bill of quantities. Accordingly, the above table may be understood as a report and not as a relation scheme within the database. Therefore, it may be stated that the database supporting the integrated model is in Boyce Codd Normal Form.

Beyond BCNF, other more restrictive forms for database design have been found. Two of the best known are the Fourth Normal Form (4NF) and the Project Join Normal Form (PJNF). Both are based on other types of constraints for database design. The former uses *multivalued dependencies* and the latter *join dependencies*. Extensive references to this subject may be found in the literature (for example in [3]). However, the above type of constraints could not be found in the design of the database object of this study, thus the corresponding normal forms need not to be discussed here.
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CHAPTER TEN

THE VALIDATION OF THE MODEL

10.1 Introduction.

Validation has been a major concern since the first idea of building up the model. The validation process started immediately after the problem of lack of integration among management functions had been ascertained. However, this process could only be finished after the model had been established and computer support for it had been provided. This corresponds to the last step of the research methodology as presented in section 1.4.

The objectives of validation were to ensure that:

- the model adequately predicts the outcomes of the system it intends to mimic;
- the model significantly increases the efficiency of current system procedures.

Validating the model requires determining if it can reliably predict the actual system's performance [1]. This includes verifying if management functions as currently performed by Portuguese construction companies are fully supported by the model. A common approach for this is to compare the performance of the model with past data available from the actual system. The model will be valid if, under similar input conditions, it can reasonably reproduce the past performance of the system [1]. However, this approach implies that validation can only take place after the model has been built up. It is sometimes convenient to start the validation process earlier, in the course of constructing the model. This corresponds to the reasonableness validation criterion which takes place before the predictive validation criterion can be applied [2].
Because the model is intended to increase the efficiency of current system procedures, its performance on this subject cannot be directly matched against past history of the industry. In order to validate the model, a field test could be conducted so that some real data could be collected and compared with the output of the model [3]. Conducting such a test might involve altering temporarily an existent system (ie the way one of the construction companies surveyed operate), to correspond to the proposals embedded in the model. This means that at least one construction company should be selected and asked to enforce integration among estimating planning and control management functions. The results of this exercise would then be compared with the output of the model using a predictive validation criterion as mentioned above. However, such field tests are frequently too expensive and time consuming to be used [3]. Therefore, it would probably be very difficult to select a company willing to participate in the test. Without any real data as a standard of comparison, the only way to validate the overall model is to have knowledgeable people carefully check the credibility of output data for a variety of situations [3].

In view of the above, it may be concluded that absolute validation is probably unattainable but it is possible to gain confidence in the model by making certain verifications [4]. These verifications can be easier for this model if a philosophy of white box validation is pursued [5]. Under this approach, active cooperation between the designer of the model and potential users is required, for the former has more knowledge of the model and the latter of the system being modelled [5]. The idea of this form of validation is that since the structure of the model is fully known, it can be compared in detail with the structure of the real system [5]. This approach goes beyond the black box approach [5] which tends to rely on the simple comparison of two sets of observations (the system performance and the output of the model). Moreover, the former is more adequate than the latter for the validation of the integrated model, given its characteristics as discussed above.

Accordingly, the validation process of the model has taken place in three phases [6]:

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Firstly, hypotheses have been continuously checked with a view to the definition of the scope of the model.

Secondly, after the model has been fully established, its fitness for the problem has been analysed.

Thirdly, the adequacy of the model to undertake real life projects has been examined.

Each of these phases will be further discussed in the following sections of this chapter.

10.2 Validation of hypothesis.

Validation of hypotheses has been achieved by means of appointments with people involved in management functions in Portuguese construction companies and meetings with professionals of the industry.

Initially people from a set of three construction companies was asked about the importance of integration of estimating and planning management functions. This has taken place in the course of a small inquiry previously to the Detailed Inquiry to 5 Construction Companies as reported in chapter 3. The preliminary inquiry was viewed as a component of the pre-inquiry to the detailed one. Conclusions are discussed in section 3.2.2. It can be seen that the preliminary inquiry allowed to certify the importance of integration among management functions in contractor's practice. Moreover, it also led to the enlargement of the initial objectives of the main inquiry as discussed in section 1.4.2.

Meetings with professionals of the industry were very important for the validation of several options that had to be made during the development of the study. This was especially important in checking results captured from inquiries to the industry as documented in section 1.4.2. Specifically, the two-phases development for the model was accepted by those professionals as a sound approach for the problem of integration among planning, estimating and the preparation of data for control. Additionally, restricting the development of
the model to the first sub-phase was also deemed as a reasonable option by those professionals.

Finally, the methodology followed to survey the current practice in Portuguese construction industry may also be viewed as a continuous validation process of the first research hypothesis. The inquiries reported in chapters 3 to 5 have been not only a valuable source of information but each of them served as a powerful means of validation of the conclusions extracted from the previous ones. The results of the survey based on those inquiries allowed for the supported proposal of the integrated model as presented in chapter 8. This in turn passed through a validation process as described in the next section.

10.3 Fitness of the model.

The validation of the model as an effective approach to the problem, involved several discussions with professionals of construction and researchers. This process followed a reasonableness validation criterion because it took place before the final version of the model has been established.

The model for the integration of estimating, planning and the preparation of data for control has been depicted graphically in figure 8.10. This resulted from previous drafts anchored in the flow charts of the construction companies surveyed during the detailed inquiry which is reported in chapter 3. Those flow charts have been compared with current procedures of both Portuguese and British construction companies and they were recognised as a comprehensive representation of the flow of information within each company surveyed. Therefore, flow charts preliminary to the one of figure 8.10 always deserved reasonable confidence from the author because they were based on other charts which passed through a validation process. However, in order to establish the final version of the model, preliminary versions should be checked by knowledgeable people.

The validation of the model involved several Portuguese professionals of construction who generally had accompanied the author through the previous stages of the model development. Moreover, several researchers from the
following educational institutions have been asked about the reasonableness of the approach:

UMIST, University of Reading, AIAI (Edinburgh) and Loughborough University in the UK;
University of Aachen and Wuppertal Polytechnic in Germany;
MIT, University of California-Berkeley, Stanford University and University of Illinois at Urbana-Champaign in USA.

The latest version of the model as depicted in figure 8.10 reflects the results of those discussions.

10.4 Adequacy of the model.

10.4.1 Methodology.

The last step in the validation process was to check the adequacy of the model for tackling the problem for which it has been designed. Obviously, this validation stage could only be meaningful if the model could be tested with real life data through the utilisation of PECI. Moreover it was decided to perform tests at contractors' organisations thus enabling potential users to contact with the model very closely.

PECI is a prototype, thus the outcomes of this validation step will be useful for further enhancements of the model. Prototyping represents a significant departure from traditional development methodologies which are based on the systems development life-cycle framework [7]. These assume that the users requirements can be completely and correctly determined during the early phases of the application development process. Prototyping involves an evaluation and revision cycle of the potential users' requirements until a satisfactory prototype is obtained [7]. Accordingly, the feedback from the tests at contractors' organisations will be useful for later versions of PECI. Moreover, because PECI is basically a prototype, no significant requirements on the "user friendliness" of the system have been imposed.
Before tests with real life data could take place, PECI itself should pass through an extensive testing procedure. Accordingly, the following methodology for this validation step has been established:

Firstly, PECI has been tested with sample data in order to proof its functionality. This involved two sub-stages viz the evaluation of the solutions given by the system and the appraisal of data entry procedures and reports.

Secondly, PECI has been tested in Portuguese contractors organisations as a tool to support the integrated model.

10.4.2 Program testing.

This section describes how PECI was tested with sample data. This comprised the usual testing of any computer program and may be included in the scope of its development. Program testing means checking if the programmer instructed the computer properly [4]. This involves running the program several times to ensure that the logical relationships and the relational analysis were correctly programmed in the computer [2]. Data used in this process should be similar to the data on which the real is designed to use [8]. Observing the output of the model, program errors can be inferred or inadequacies from anomalies can be detected [8]. Testing a computer program is normally an evolutionary process by which each section of the program is checked as a stand alone module; then several modules are merged together until the whole program is eventually tested [9].

PECI is fully described in Appendix 2. It can be seen that the program has a modular structure. It comprises several sub-programs each of which is used to build up a different relation. Sub-programs and corresponding relations are organised into sets. Control over sets of sub-programs is taken by program managers and these are finally managed by the main program. This structure was especially convenient both for the development and for the test of PECI.
The testing methodology used for the evaluation of the solutions given by the model comprised testing each sub-program as soon as it was generated in order to guarantee that it functioned properly as a unit (unit testing). The following tests took place as a part of unit testing:

**Interface tests** to ensure that information properly flows into and out of the program unit. For the models performing input/output, additional tests were conducted.

The local **data structure** was examined to ensure that data stored temporarily maintains its integrity during all steps in the algorithm's execution.

**Boundary conditions** were tested to ensure that the module operates properly at boundaries to processing as established in Appendix 2. Test cases aimed at exercising data structures, control flow and data values at the minima and maxima allowed by the module. For example, all types of LNEC IC4 unit rate and operational build-ups were tested at the limit of their values; measurement data was used at the upper and lower limits of quantities; resource costs have been put to vary from the lower to the highest allowable limit, etc.

All **independent paths** through the control structure were exercised to ensure that all statements in the module have been executed at least once.

In order to achieve this, sample data was used and the results of the sub-program were compared against those obtained by hand. When a set of sub-programs was complete, the corresponding manager was tested aiming at verifying the efficiency of its control over the sub-programs. The process was repeated for all the sections of PECI until all the program was tested. Frequently, this process involved the development of **driver** and **stub** software. Driver programs were used to manage the utilisation of the case data by each module and stubs served to replace other modules called by the module being tested.
Finally, an incremental integration [10] technique was used to build up PECI by which the program was constructed and tested in small segments. This enabled errors to be isolated and corrected easier. Sample data was then used to run the whole program several times so that confidence could be gained in its results. The theoretical limits for the volume of data that the program can process with were established in Appendix 2. Because the program is supported by dBASE III PLUS, those limits are only dependent on the disk space availability. Such limits have not been reached by any of the tests performed, but no problems could be detected in the program operation when it ran the largest sample tests with more than 300 distinct construction tasks.

The second sub-stage of the testing methodology was the appraisal of data entry procedures and reports. Data entry procedures is an important feature for PECI in which potential users are not expected to fully understand the way the program operates. Therefore, data has to be asked by the program, data formats must be checked, the user should be allowed to correct mistaken entries, etc. Moreover, the program should provide orientation for the user so that all the possible options in each occasion can be easily accessible. Similarly, a wide variety of reports should be catered by the program.

PECI is a menu driven program. This makes it very easy to operate with and to find one's way through it. Entries are usually supported by a data format warning and a confirm option. These were all tested with a variety of possible data entries aiming at simulating several real life situations. Reports were otherwise less tested because it was assumed that possible users of this prototype version could always rely on the report capabilities of dBASE III Plus to generate virtually any report they could possibly want.

10.4.3 The test of PECI in contractors' organisations.

The second testing stage was the most important for the validation of PECI because it involved possible users of the system. Moreover, the successful test of PECI, has probably enforced the favourable opinion of contractors about the adequacy of the model to tackle real life problems. Therefore, it has definitely contributed to the validation of the integrated model supported by PECI.
The test of PECI in Portuguese contractors' organisations and the validation of the model are described in the following sections. Contractors have been selected from the set involved in inquiries 1 and 2, as listed in Appendix 1.

10.4.3.1 The testing methodology.

The objective of the tests was the validation of the integrated model and the test of PECI as a useful tool for the management of construction projects. In order to achieve this, demonstration sessions took place with the staff of a set of selected construction companies. A standard format was used with all companies in order to obtain comparable results. Demonstration sessions comprised:

- the discussion of the integrated approach as presented in chapter 8;
- the presentation of PECI;
- testing the program with sample data from the companies if possible;
- collecting answers to a questionnaire and evaluating both the integrated approach and the computer program.

For the description of the integrated approach, the results of the inquiries presented in chapters 3 and 4 were recalled. The chart of figure 4.10 was used to illustrate data flow among management functions and to explain how PECI supports it.

The presentation of PECI included the description of its main features. The contents of Appendix 2 were used to explain the structure of the system. A sample project in the Portuguese language identical to that in section A2.5.7 was used to show how to operate with the program.
Thereafter, companies were asked to test PECI using their own data. Sometimes, a section of a current project was selected for this purpose but normally companies preferred a small clarifying example. The author monitored data entry, guided the evaluation of the results and helped in the generation of complementary reports at the companies' demand.

Answers to the questionnaire as presented in section 10.4.3.4 were collected from the staff involved in the demonstration sessions. Finally, both the integrated approach as presented in chapter 8 and the computer program which supports it were evaluated according to the set of criteria of table 10.1 of section 10.4.3.5.

10.4.3.2 The selection of the companies involved in the demonstration.

It was decided to restrict demonstration sessions to the companies which had already been surveyed during the previous inquiries. However, the validation of PECI as a prototype computer system does not require a large number of sessions. Therefore only six companies from the above set were selected. The following selection criteria were used:

- companies which had clearly evidenced lack of integration among management functions;
- companies which had encouraged subsequent contacts for testing the model being developed;
- companies which already use computer to support management functions.

Accordingly, companies E, H, J, K, L and M were selected. Companies aliases are the same used in Appendix 1.2.
10.4.3.3 The approach to the companies.

Previous contacts within the companies were recalled. Thereafter, they decided which staff should be involved in the demonstration sessions.

10.4.3.4 Questionnaire.

The questionnaire was administered after the model had been explained and the tests of PECI had been performed. It aimed at collecting descriptive answers and suggestions for further enhancements of both the integrated approach and PECI. Moreover, the questionnaire was designed regarding the evaluation of those two pieces of work, thus questions are close to the evaluation criteria as presented in section 10.4.3.5. Accordingly, the questionnaire comprises a set of presentation texts and related open questions as follows:

**Questionnaire.**

a) The model.

According to the results of an inquiry to a set of Portuguese construction companies, integration among management functions is not achieved in most cases. This is an important problem that companies would like to see solved. This is also the opinion of this company.

Do you believe that increasing the interchange of resource data among management functions is a possible key to the problem?

Do you believe that this integrated model is a reasonable approach to the problem?

Which main difficulties do you find in its practical utilisation?

b) The computer system.
PECI is a prototype computer system which supports the model presented here. Although it has no commercial purposes, it is expected to fully support the model.

Do you think that the use of a system like PECI is likely to make integration easier?

Compare the abilities of PECI with other integrated computer systems you may have used or tested.

Compare the capabilities of PECI in estimating and data manipulation with other stand-alone estimating systems.

Do you think that the practical utilisation of a further version of PECI is feasible in your company? Which main improvements to the present version of PECI would be desirable?

10.4.3.5 Evaluation.

The evaluation of both the integrated model and PECI in contractors' organisations is a difficult problem because of the many intangible aspects that must be taken into account. Ndekugri [11] commented on the difficulties of quantifying the benefits of a new computer aided management system. Some periodicals dealing with the analysis of new software, often adopt a set of criteria for the appraisal of the products under study. However, whilst their quantifiable characteristics (such as capacity and speed) are easily measured, intangible aspects are more difficult to access. Wroe [12] suggested a template for the evaluation of functional stages in the implementation of management information systems in construction companies. The criteria suggested by Wroe [12] cannot be directly used here because of the different nature of the problem being treated.

Eighteen criteria were defined and organised into two sets:
Appraisal of the model.
Appraisal of PECI.

The appraisal of the model includes three criteria which were used for the following reasons:

Validity of the key. It was important to check with companies if increasing the interchange of resource data among management functions is a good key to the problem. Companies could possibly understand that only alternative structures of data for estimating and planning would lead to the solution of the lack of integration among these functions.

Reasonableness of the approach. This criterion aimed at checking whether the model presented in section 8.4.2 is a reasonable approach to the problem or if it contains serious obstacles to its introductions in the industry.

Ease of practical utilisation of the model. Companies should state if the model with no additional support is likely to be used in practice.

The appraisal of PECI contains a set of criteria about each of the following issues:

integration performance;
operational performance;
practical utilisation.

The appraisal of the integration performance of PECI was measured through a set of six criteria. These criteria were defined in agreement with sections 8.4.1 and 8.4.2. Accordingly, they mirror the enhancements to the existing systems that the integrated model should accomplish as defined in section 8.4.1. These in turn follow the investigation to the Portuguese industry. Moreover, they check the advantages of the integrated model described in section 8.4.2. The following criteria were used:
Duplication and regeneration of data. PECI should avoid or at least limit duplication and regeneration of data in order to achieve integration.

Quality of output data. PECI should generate data that should be adequate to the requirements of estimating planning and the preparation of data for control.

Data interchange among management functions. PECI should improve this aspect because it is essential to integration.

Suitability of intermediate data within the program. PECI should deal with suitable data to perform the management functions it supports.

Usefulness of generated data for subsequent management functions. Data generated by the program should be appropriate for subsequent management functions not supported by the program.

Adequacy of data structures. Data structures used by the program should be adequate to support integration.

The appraisal of the operational performance of PECI was subdivide into two subsets of criteria. The first is devoted to the user friendliness of the program and includes usual questions that specialised journals (eg PC Magazine) adopt to measure that feature of computer software. Because they are now familiar to software customers, they were also selected as appraisal criteria of PECI. The following were included:

- quality of "menus";
- generation of reports;
- speed in data processing;
- access to data stored in the database.

The second subset is about the comparison of PECI with stand-alone estimating systems. The following criteria were used for the reasons mentioned below:
Unit rate estimating should be supported with at least an average quality.

Operational estimating should also be supported with an average quality. As estimating software packages seldom include operational estimating, PECI should evidence a significant improvement to current techniques companies use (e.g., spreadsheet processing).

Resource allocation to the items of the bill of quantities should be satisfactory because it is one of the fundamentals of the integrated model.

Data manipulation and data retrieval should be, at least, identical to current estimating software so that PECI can replace it in practice.

Finally, a question about the practical utilisation of PECI was used to check how close the model would be from implementation in the companies surveyed.

For each criterion, three alternative answers are allowed, except for the practical utilisation of PECI which allows for four.
Table 10.1

Evaluation Criteria

1 Appraisal of the model.

• Validity of the key.
  a) yes; b) possibly; c) no.

• Reasonableness of the approach.
  a) yes; b) possibly; c) no.

• Easiness of practical utilisation of the model.
  a) yes; b) possibly; c) no.

2 Appraisal of PECI.

2.1 Integration performance.

• Duplication and regeneration of data.
  a) avoided; b) limited; c) persistent.

• Quality of output data.
  a) high; b) average; c) poor.

• Data interchange among management functions.
  a) greatly improved; b) slightly improved; c) not improved.

• Suitableness of intermediate data within the program.
  a) suitable; b) satisfactory; c) inappropriate.

• Usefulness of generated data for subsequent management functions.
  a) appropriate; b) usable; c) unsuitable.

• Adequacy of data structures.
  a) adequate; b) acceptable; c) inadequate.
2.2 Operational performance.

2.2.1 User friendliness of PEel.

- Quality of "menus".
  a) high; b) average; c) poor.

- Generation of reports.
  a) good; b) satisfactory; c) deficient.

- Speed in data processing.
  a) high; b) ordinary; c) low.

- Access to data stored in the database.
  a) easy; b) moderate; c) difficult.

2.2.2 PEel vs stand alone estimating systems.

- Unit rate estimating.
  a) good; b) average; c) deficient.

- Operational estimating.
  a) good; b) average; c) deficient.

- Resource allocation.
  a) good; b) average; c) deficient.

- Data manipulation and data retrieval.
  a) good; b) average; c) deficient.

2.3 Practical utilisation of PEel.

  a) the demonstration version; b) a further version with small improvement; c) a further version with substantial improvement; d) not usable.
A classification system for the answers was also created so that the degree of satisfaction of each company could be quantified. Criteria allowing for three alternative answers are marked with 2, 1 or 0 depending on the answer selected on the same order. The last criterion which allows for four possible answers is marked with 3, 2, 1 and 0 on the same sequence. Moreover, a weighting system was included in order to evaluate the most relevant criteria. Accordingly, the first nine criteria got weight 2 and the remaining nine got weight 1.

Based on this classification system, the following measures of the companies' satisfaction upon the integrated model and PECI were developed:

- satisfaction profile for each company taken individually and for the average answers;
- satisfaction indices for each company taken individually and for average answers.

The degree of satisfaction of each company can be measured by adding up all the marks multiplied by their corresponding weights and divided by 27.

10.4.3.6 Report of the demonstration sessions.

Demonstration sessions were similar among companies. Staff involved included planners and estimators appointed by each company. Those who had taken part in the previous inquiry were generally present. Demonstration sessions basically comprised three parts: Firstly, the previous inquiry to the company was briefly recalled. This included a general description of the Specific Inquiry as reported in chapter four and the recollection of the answers from the company as summarised in Table A2.2.1 of Appendix 2.2.

Secondly, the test of PECI took place. This comprised the following steps:

- the discussion of the integrated approach as presented in chapter 8;
- the presentation of PECI following chapter nine and Appendix 2;
testing the program with sample data.

The first step aimed at validating the integrated model. This involved discussions with the participants in the inquiry in each company. The objective of this step was to check the credibility of the approach for the integration of estimating, planning and control management functions. The test of PECI with sample data aimed at demonstrating that the program conforms to the requirements of the integrated model as presented in chapter eight and discussed in the previous step. The exhaustive test of the program has already been described in section 10.4.2 and it was not intended in the course of the demonstration sessions. The objective of these was to run a set of real life examples so that PECI could be proved operationally. Suitable data from the companies fully achieving this feature was hard to find thus an example was normally generated in order to perform tests. Occasionally, a section of current project was used but data was adapted in order to show all the capabilities of PECI as in the example of Appendix 2. Accordingly, the options allowed by the program for data handling both in estimating and in planning were simulated using variations to the testing example (eg unit rate vs operational estimating, standard vs specially generated build-ups, distinct composition of work crews leading to distinct activity durations, etc.). Moreover, staff involved could ask for any test that they could think of in order to understand how the program operates. In the course of the demonstration sessions, it was decided that the author should type the data in the keyboard, because the staffs of the companies who attended the demonstration sessions were unfamiliar with the program. This was used to explain how the computer refuses unsuitable data and in which cases it asks for confirmation of data entries. Finally, results obtained from the program were compared among them and to those that could be get by manipulating data with an ordinary calculator.

Thirdly, discussions took place with the staff from the companies. Normally several people from the companies participated in the demonstration sessions. Therefore, this phase took not less than two hours because it was carefully executed. In the course of this phase, companies answered the questionnaire and pronounced on the appraisal criteria. The three parts together took from two to four hours in each company.
Table 10.2 shows the assessment companies made of the appraisal criteria of table 10.1:

Table 10.2

<table>
<thead>
<tr>
<th>Appraisal criteria</th>
<th>E</th>
<th>H</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>validity of the key</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>2.00</td>
</tr>
<tr>
<td>reasonableness of the approach</td>
<td>b</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>1.67</td>
</tr>
<tr>
<td>easiness in practical utilisation</td>
<td>c</td>
<td>b</td>
<td>c</td>
<td>b</td>
<td>b</td>
<td>a</td>
<td>0.83</td>
</tr>
<tr>
<td>duplication and regeneration of data</td>
<td>b</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>1.67</td>
</tr>
<tr>
<td>quality of output data</td>
<td>a</td>
<td>a</td>
<td>b</td>
<td>b</td>
<td>a</td>
<td>a</td>
<td>1.67</td>
</tr>
<tr>
<td>data interchange</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>2.00</td>
</tr>
<tr>
<td>suitableness of intermediate data</td>
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<td>a</td>
<td>1.67</td>
</tr>
<tr>
<td>usefulness of generated data</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>a</td>
<td>1.83</td>
</tr>
<tr>
<td>adequacy of data structures</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>2.00</td>
</tr>
<tr>
<td>quality of &quot;menus&quot;</td>
<td>c</td>
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<td>c</td>
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<td>0.50</td>
</tr>
<tr>
<td>generation of reports</td>
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<td>b</td>
<td>b</td>
<td>b</td>
<td>c</td>
<td>c</td>
<td>0.50</td>
</tr>
<tr>
<td>speed in data processing</td>
<td>c</td>
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<td>b</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>1.33</td>
</tr>
<tr>
<td>access to data stored in the database</td>
<td>b</td>
<td>a</td>
<td>b</td>
<td>b</td>
<td>a</td>
<td>a</td>
<td>1.50</td>
</tr>
<tr>
<td>unit rate estimating</td>
<td>b</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>1.67</td>
</tr>
<tr>
<td>operational estimating</td>
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<td>b</td>
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<td>a</td>
<td>1.83</td>
</tr>
<tr>
<td>resource allocation</td>
<td>b</td>
<td>a</td>
<td>b</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>1.67</td>
</tr>
<tr>
<td>data manipulation and retrieval</td>
<td>b</td>
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<td>a</td>
<td>a</td>
<td>b</td>
<td>b</td>
<td>1.50</td>
</tr>
<tr>
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<td>b</td>
<td>b</td>
<td>c</td>
<td>b</td>
<td>1.67</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>1.07</td>
<td>1.85</td>
<td>1.44</td>
<td>1.67</td>
<td>1.55</td>
<td>1.81</td>
<td>1.56</td>
</tr>
</tbody>
</table>

1 Appraisal of the model. Companies generally agreed that the interchange of resource data among management functions is a good key to the problem.
Therefore, companies recognised that the lack of integration among management functions may be overcome by increasing the interchange of resource data within their organisations. Moreover, four companies stated that this integrated model is a good approach to the problem and two companies considered it as a possible approach. The average mark of this criterion was 1.67 which shows that companies mostly recognised that the approach presented in chapter 8 is reasonable. However, three companies expressed some reservations to the practical utilisation of the model and two stated that it would not be easy to use in practice. Only one company considered it would be easy to use. It can be concluded that companies identified some difficulties to use the model in practice as shows the average mark of 0.83 they gave to this criterion. Answers from companies involved in the demonstration sessions clearly show that increasing the interchange of resource data among management functions is a valuable way through the solution of the problem and that the integrated model presented is a reasonable approach to it. Answers also show that using the model of section 8.4.2 with no additional support may raise some difficulties in its practical utilisation.

2. Appraisal of PECI.

2.1 Integration performance. The integration performance of the system was assessed very favourably by the companies. Four companies understood that duplication and regeneration of data is avoided with the model and two companies considered that PECI manages to limit them. The average mark given to this criterion was 1.67 which demonstrates that companies recognised that PECI succeeded in this criterion. Quality of output data was considered high by four companies and average by two companies, leading to the mark of 1.67. This clearly shows that companies mostly recognised the quality of output data. All the companies surveyed agreed that PECI greatly improves data interchange among management functions. This demonstrates that this computer system is very efficient in this aspect. Intermediate data generated by the program was found suitable by four companies and satisfactory by two. This gave a mark of 1.67 which shows that PECI generates appropriate data to be used by management functions. Moreover, five companies out of six stated that data generated is appropriate for subsequent management functions. One company found that data satisfactory. This result lead to the average mark of 1.83 which
demonstrates that data generated by the program is suitable to be used by subsequent management functions. Companies generally agreed that data structures used by the program are adequate. Answers from companies surveyed clearly demonstrate that PECI achieves efficient integration among estimating, planning and the preparation of data for control. This was measured through a set of criteria which reflect the integration characteristics of the model presented in section 8.4.2.

2.2 Operational performance of PECI was judged less satisfactory by companies involved in the demonstration sessions. The quality of "menus" and the generation of reports were the two criteria more poorly marked (0.50) with the first being below average and the second less than satisfactory. The speed in data processing was considered high by three companies, ordinary by two and low by one company. This lead to the average mark of 1.33 to this criterion. Access to data stored in the database was found easy by three companies and moderate by two. This lead to the average mark of 1.50 to this criterion. These results reflect the nature of the current version of the program (a prototype) for which the user friendliness aspects were less catered for.

2.3 When compared to stand alone estimating systems, companies identified good performance in PECI. None of them found the program deficient in any of the criterion analysed. Unit rate estimating was considered good by four companies and average by two (average mark 1.67). Operational estimating was considered good by five companies and average by one (average mark 1.83). Resource allocation was considered good by four companies and average by two (average mark 1.67). data manipulation was considered good by three companies and average by the other three (average mark 1.50). This results demonstrate the capabilities of PECI to perform the calculations normally supported by stand-alone estimating systems.

3. Practical utilisation of PECI. Companies generally agreed that a further version of the program may be used in a day to day basis. Three companies stated that small improvements to the demonstration version would be enough and two companies stated that substantial improvements would be required. None considered PECI not usable and it was therefore proved that the program is of practical use.
Looking at answers from each company taken individually, it can be concluded that satisfaction their satisfaction is fairly high for all the appraisal criteria except for the user friendliness of Peci. This is an expected result because Peci is just a prototype and these aspects were intentionally less developed. Therefore, the satisfaction profile of each company is considered good.

The satisfaction profile of the average answers is identical to that of each company taken individually. This is because the standard deviation of answers for each appraisal criteria is generally low.

The satisfaction index of all the companies involved in the demonstration sessions is placed between 1 and 2. This is also a good result that can also be found in the index taken form the average answers companies (1.56).

**10.4.3.7 Conclusions.**

The integrated model was clearly understood by all the companies and its fundamentals were very well accepted. Peci was recognised as a valuable contribution for the integration among management functions in construction companies. Staff form the construction companies involved in the demonstration sessions showed interesting the subject and willingness to participate in the test of the program.

Table 10.2 shows the results of the evaluation done by the companies according to the criteria presented in table 10.1. It should be noted that this is a subjective assessment of each company.

Figures depicted in table 10.2 evidence that companies judged both the integrated model and Peci quite satisfactory. The approach of Peci was above expectations. Companies recognised it as a useful tool to support the integrated model as they marked integration performance criteria rather favourably. Moreover, some companies admitted that they could use the current version of the computer system with just a few enhancements in a day to day basis. The operational performance of Peci was also marked satisfactory by the
companies, except for the criteria related to the user friendliness of the system. This was expected because the current version of the program is just a prototype thus those aspects were less taken into consideration in the course of its development.

The model was clearly understood by all the companies and its fundamentals were very well accepted.

Specifically, companies generally agreed that the only possible approach to the integration of estimating and planning is the organisation of project measurements according to the requirements of both the bill of quantities and the activities break down.

The appraisal of PECI was above expectations: Not only was it generally recognised as a useful tool to support the integrated model but its practical utilisation in the companies was readily admitted by some.

Answers to the questionnaire evidenced the following main enhancements of PECI when compared to current computer packages for project management were evidenced:

Contrary to current packages, PECI was built upon a relational database environment. This makes data manipulation and data retrieval easier.

PECI achieves integration of management functions whereas current packages tend to work as stand alone systems.

For the above reasons, companies considered that these abilities of PECI are a significant improvement on current computer packages.

Despite the positive opinion construction companies evinced about PECI, this was clearly understood as a prototype computer system. Accordingly, some improvements were suggested aimed at its development towards a commercial system. The following suggestions were the most relevant:
an alternative DBMS to dBASE III PLUS could be used in order to gain speed in data processing;

the "menus" of the program should be improved;

the generation of reports should be looked at;

the access to data stored in the files used by the program should be easier to display on the screen;

the operational approach followed by the program could be upgraded with a small effort;

a hybrid approach of the unit rates and the operational approaches could be included: after deciding for the operational approach, a task could be selected to give the user a first hint of the resources required to perform given construction task.

10.5 Limitations of the model.

As any other model, the integrated model presented in chapter 8 is a simplification of the system it purports to mimic. This implies it cannot be possibly valid for all purposes. This does not mean that it is useless; rather it implies that it should be used with some care and should certainly not be pushed beyond the limits of its validity [105].

The starting conditions from which the model has been built, imposed a set of limitations to it from the beginning. Moreover, as validation has been a continuous process parallel to the development of the model, the limits to its validity were thoroughly analysed while developing it. Specifically, the test of PECI allowed to assess those limits more clearly because this computer program supports the practical utilisation of the model. Finally, the test of PECI at contractors' organisations added some valuable suggestions about further enhancements to it. All this information allowed for the following limitations to the model to be established:
In order to use the model, detailed measurements of the project have to be done. Therefore, the design has to be developed accordingly. Additionally, measurements must be structured in such a way that construction works can be identified.

The model is most useful for the pre-contract stage because data required is more readily accessible.

The model was designed to achieve integration among estimating, planning and the preparation of data for control. Accordingly, PECI supports the above three functions and is more efficient if all its facilities are used.

The model admits that a bill of quantities is produced to support estimating and that planning is based on a set of construction activities. If other approaches to these functions are followed, the model cannot be used.

Data generated by the model is based on a resource allocation procedure to construction works. If resource information input in the model is scarce, the quality of the output is low.

The above limitations deserve some discussion:

Firstly, the utilisation of stand alone systems may in fact be more efficient if only part of the facilities of PECI are intended to be used. This is because the volume of data required would probably be smaller, quicker to input in the computer and easier to deal with. This is specially true if only the estimating module of the program is to be used. Measurements would not need to be so detailed and so carefully organised as when PECI was fully used, but getting to costs would probably be slower with PECI than with a stand alone system. The same applies if only the planning module is used. However, in this case, stand alone systems may be rather time consuming if resources are to be allocated to activities and if activity costs are to be evaluated form resource costs.
Secondly, the above discussion illustrates that PECI is more suitable for the pre-contract stage when all the facilities of the program are required. Measuring the project with the detail needed by the program may take a long time. In any case, this will be more efficient than measuring the project more than once and repeating data input for several stand alone systems. Moreover, the measuring process can be speeded up if the quantities take off is computer supported based on Computer Aided Design. This obviously requires that designers use such systems and this is increasingly current nowadays.

Thirdly, the calculations performed by PECI are based on resource allocation to the construction works which would have been identified for the project under study. The importance of resource allocation may be neglected by some companies in some cases. For example, resources used by subcontractors may be ignored for estimating and planning the project. However, resource allocation is still an important piece of information for monitoring the cost and the duration of activities performed by subcontractors.

Finally, system limitations of the model should also be mentioned. In order to run PECI, a current personal computer with 640 Kbytes capacity and a version of dBASE III Plus is sufficient. Capacity calculations for a sample project may be found in Appendix 2.

10.6 Case study.

The following case study was used in company K for the demonstration of PECI. It was a five storey building project the company was bidding for at the time the demonstration session took place. The section of the project analysed covered the internal walls of the building. Measurements had already been made by the company but it was necessary to refine them in order to make them suitable to be used by PECI. Measurements are summarised in the following table:
<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Un</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Internal walls 0.07 thick on the second basement.</td>
<td>m2</td>
<td>97.50</td>
</tr>
<tr>
<td>2. Internal walls 0.07 thick on the first basement.</td>
<td>m2</td>
<td>102.50</td>
</tr>
<tr>
<td>3. Internal walls 0.11 thick on the first basement.</td>
<td>m2</td>
<td>17.00</td>
</tr>
<tr>
<td>4. Internal walls 0.07 thick on the ground floor.</td>
<td>m2</td>
<td>100.00</td>
</tr>
<tr>
<td>5. Internal walls 0.11 thick on the ground floor.</td>
<td>m2</td>
<td>95.70</td>
</tr>
<tr>
<td>6. Internal walls 0.15 thick on the ground floor.</td>
<td>m2</td>
<td>6.72</td>
</tr>
<tr>
<td>7. Internal walls 0.07 thick on floors 1st to 4th. (4x)</td>
<td>m2</td>
<td>119.25</td>
</tr>
<tr>
<td>8. Internal walls 0.11 thick on floors 1st to 4th. (4x)</td>
<td>m2</td>
<td>108.1</td>
</tr>
<tr>
<td>9. Internal walls 0.15 thick on floors 1st to 4th. (4x)</td>
<td>m2</td>
<td>6.72</td>
</tr>
<tr>
<td>10. Internal walls 0.07 thick on the 5th floor.</td>
<td>m2</td>
<td>101.00</td>
</tr>
<tr>
<td>11. Internal walls 0.11 thick on the 5th floor.</td>
<td>m2</td>
<td>86.00</td>
</tr>
<tr>
<td>12. Internal walls 0.07 thick on the 5th floor.</td>
<td>m2</td>
<td>6.72</td>
</tr>
</tbody>
</table>

Figure 10.1 Measurements for the case study.

The section of the bill of quantities used for the above works is depicted in figure 10.2 below.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Un</th>
<th>Quantity</th>
<th>Unit-cost</th>
<th>Item-cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Internal walls 0.07 thick including mortar.</td>
<td>m2</td>
<td>880.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Internal walls 0.11 thick including mortar.</td>
<td>m2</td>
<td>631.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Internal walls 0.15 thick including mortar.</td>
<td>m2</td>
<td>403.20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 10.2 Bill of quantities for the case study.
The company was asked about which construction activities would possibly be considered to carry out this section of the project on site. The following activity set was admitted by the company:

<table>
<thead>
<tr>
<th>ACTIVITY DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Internal walls on the basements.</td>
</tr>
<tr>
<td>2. Internal walls on the ground floor.</td>
</tr>
<tr>
<td>3. Internal walls on the 1st floor.</td>
</tr>
<tr>
<td>4. Internal walls on the 2nd floor.</td>
</tr>
<tr>
<td>5. Internal walls on the 3rd floor.</td>
</tr>
<tr>
<td>6. Internal walls on the 4th floor.</td>
</tr>
<tr>
<td>7. Internal walls on the 5th floor.</td>
</tr>
</tbody>
</table>

Figure 10.3 List of activities for the case study.
The above data was entered in the computer. Moreover, a code was added to each measurement, item of the bill of quantities and construction activity. The output of the computer is displayed in the following figures. Productivity data used in the calculations was that from LNEC IC4. Figure 10.4 lists the output of the file JTPSAC.dbf which includes the code, description, cost and duration of each construction activity.

<table>
<thead>
<tr>
<th>ACTCODE</th>
<th>ACTDISC</th>
<th>ACTUNIT</th>
<th>ACTCOST</th>
<th>ACTDURA</th>
</tr>
</thead>
<tbody>
<tr>
<td>00001.BS.E</td>
<td>Internal walls on the basement</td>
<td>m2</td>
<td>244576</td>
<td>4.00</td>
</tr>
<tr>
<td>00002.GF.E</td>
<td>Internal walls on the gr. floor.</td>
<td>m2</td>
<td>247795</td>
<td>3.00</td>
</tr>
<tr>
<td>00003.1F.E</td>
<td>Internal walls on the 1 floor.</td>
<td>m2</td>
<td>285549</td>
<td>3.00</td>
</tr>
<tr>
<td>00004.2F.E</td>
<td>Internal walls on the 2 floor.</td>
<td>m2</td>
<td>285549</td>
<td>3.00</td>
</tr>
<tr>
<td>00005.3F.E</td>
<td>Internal walls on the 3 floor.</td>
<td>m2</td>
<td>285549</td>
<td>3.00</td>
</tr>
<tr>
<td>00006.4F.E</td>
<td>Internal walls on the 4 floor.</td>
<td>m2</td>
<td>285549</td>
<td>3.00</td>
</tr>
<tr>
<td>00007.5F.E</td>
<td>Internal walls on the 5 floor.</td>
<td>m2</td>
<td>236173</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Figure 10.4 Construction activities (from JTPSAC.dbf).

Figure 10.5 lists the output of the file JTPSBQ.dbf and summarises the bill of quantities in its traditional format.

<table>
<thead>
<tr>
<th>BQICODE</th>
<th>BQIDISC</th>
<th>BQIUNIT</th>
<th>BQIQUAN</th>
<th>BQIUNCO</th>
<th>BQICOST</th>
</tr>
</thead>
<tbody>
<tr>
<td>02.001.01</td>
<td>Internal walls 0.07 thick.</td>
<td>m2</td>
<td>878.000</td>
<td>1110.98</td>
<td>975444</td>
</tr>
<tr>
<td>02.001.02</td>
<td>Internal walls 0.11 thick.</td>
<td>m2</td>
<td>631.100</td>
<td>1316.51</td>
<td>830848</td>
</tr>
<tr>
<td>02.001.03</td>
<td>Internal walls 0.15 thick.</td>
<td>m2</td>
<td>40.320</td>
<td>1598.44</td>
<td>64449</td>
</tr>
</tbody>
</table>

Figure 10.5 Bill of quantities (from JTPSBQ.dbf).

Figure 10.6 shows relevant project data about the construction activities selected for this section of the project (output of the file JTPACT.dbf). This includes the allocation of resources necessary to perform each activity and their corresponding costs. The file also gives an indication of which key-resources were selected by the user (KEY-RES), the size of the team to carry out each activity (ACTTEAM) and the loading charts to be considered in the
construction program (one for each resource type marked with an Y in PALLRES field).

<table>
<thead>
<tr>
<th>ACTCODE</th>
<th>RESCODE</th>
<th>RESALLA</th>
<th>ACTCOST</th>
<th>KEY_RES</th>
<th>ACTTEAM</th>
<th>PALLRES</th>
</tr>
</thead>
<tbody>
<tr>
<td>00001.BS.E I.00.001</td>
<td>1.00.001</td>
<td>2.272</td>
<td>12716.70</td>
<td>N</td>
<td>0</td>
<td>Y</td>
</tr>
<tr>
<td>00001.BS.E L.00.001</td>
<td>131.390</td>
<td>78834.00</td>
<td>Y</td>
<td>4</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>00001.BS.E L.00.018</td>
<td>65.780</td>
<td>29601.00</td>
<td>Y</td>
<td>2</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>00002.GF.E I.00.001</td>
<td>112000.00</td>
<td>N</td>
<td>0</td>
<td>0</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>00002.GF.E I.00.018</td>
<td>129.139</td>
<td>77483.40</td>
<td>Y</td>
<td>6</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>00002.GF.E L.00.018</td>
<td>131.390</td>
<td>78834.00</td>
<td>Y</td>
<td>4</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>00002.GF.E L.00.001</td>
<td>64.544</td>
<td>29044.80</td>
<td>Y</td>
<td>3</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>

Figure 10.6 Data on the construction activities (from JTPACT.dbf).
Figure 10.6 shows relevant project data about the items of the bill of quantities form the output of the file JTPBQl.dbf). This includes the summary of all resources allocated to each item and their costs.

<table>
<thead>
<tr>
<th>BQICODE</th>
<th>RESCODE</th>
<th>RESALLI</th>
<th>BQICOST</th>
</tr>
</thead>
<tbody>
<tr>
<td>02.001.01</td>
<td>L.00.001</td>
<td>8.782</td>
<td>49154.08</td>
</tr>
<tr>
<td>02.001.01</td>
<td>L.00.018</td>
<td>526.800</td>
<td>316080.0</td>
</tr>
<tr>
<td>02.001.01</td>
<td>M.00.042</td>
<td>14048.0</td>
<td>491680.0</td>
</tr>
<tr>
<td>02.001.02</td>
<td>L.00.001</td>
<td>10.099</td>
<td>56525.52</td>
</tr>
<tr>
<td>02.001.02</td>
<td>L.00.018</td>
<td>422.817</td>
<td>253690.2</td>
</tr>
<tr>
<td>02.001.02</td>
<td>M.00.043</td>
<td>10097.1</td>
<td>424078.2</td>
</tr>
<tr>
<td>02.001.03</td>
<td>L.00.001</td>
<td>0.846</td>
<td>4735.18</td>
</tr>
<tr>
<td>02.001.03</td>
<td>L.00.018</td>
<td>30.240</td>
<td>18144.00</td>
</tr>
<tr>
<td>02.001.03</td>
<td>M.00.044</td>
<td>12.096</td>
<td>5443.20</td>
</tr>
<tr>
<td>02.001.03</td>
<td>M.00.044</td>
<td>645.120</td>
<td>36126.72</td>
</tr>
</tbody>
</table>

Figure 10.7. Data on the items of the bill of quantities (from JTPBQl.dbf).

Project drawings used to support this case study are depicted in the next pages. These were used to make the measurements and to decide on the items of the bill of quantities and on the construction activities to be considered.
Planta da 2ª Cave (esc 1/200)

Planta da 1ª Cave (esc 1/200)
Planta do 5º Piso (esc 1/200)

Corte C3 (esc 1/200)
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CHAPTER ELEVEN

Conclusions.

11.1 Summary of the work undertaken and main findings.

The idea behind this thesis was the integration of management functions in construction projects. Specifically, integration among planning, estimating and control management functions form the construction companies' perspective has been studied.

The bibliographic survey presented in chapter 1 evidences that the problem of the lack of integration among contractors' management functions has been widely discussed in the literature. Furthermore, although several attempts have been made, no fully satisfactory solution for this problem has been reported so far.

A survey of the way Portuguese contractors perform management functions has been undertaken by means of two inquiries to a set of selected construction companies. This work has been complemented with two more inquiries, one sent to software dealers and the other to Portuguese clients. Inquiries confirmed lack of integration among management functions in the current practice of companies surveyed. Existing software has been recognised as not fully supporting an integrated approach to those management functions.

In view of the conclusions of the inquiries, it was decided to restrict the study to the integration of planning, estimating and the preparation of data for control. This has been analysed into two distinct stages of the project development: the pre-tender stage and the pre-contract stage. Data from the inquiries to Portuguese construction companies has been used. Significant differences between those two stages have been found in the companies' practices. Moreover, it has been concluded that integration during the pre-contract stage is the most important in the companies' perspective.
Following the previous results, a model for the integration among the management functions mentioned above has been established, by adapting current management procedures to the requirements of integration. Data systems analysis has been used in this process and it proved to be a powerful technique to tackle the problem. Accordingly, it has been concluded that a database management system (DBMS) would provide for an adequate environment for the problem.

In order to support the practical utilisation of the model and to enable its use in the industry, computer support has been provided in the dBASE III environment. A computer program was developed and named PECI as an acronym of Planning, Estimating and Control Integrated.

The validation of the model and the test of PECI have been performed throughout their development. The final validation stage has taken place in six Portuguese construction companies. These were selected from those which had previously participated in the inquiries. The validation process revealed the adequacy of the model and the usefulness of PECI. Specifically, the computer system was validated through controlled practical tests at the six contractors, using the same basic data to perform estimating planning and the preparation of data for control. It clearly showed to support these management functions to, at least, the standard of the existing systems. Moreover, companies surveyed recognised that PECI supports the enhancements to those exiting systems, as defined for the integrated model in section 8.4.1. Therefore it was shown that PECI executes the functions required by the integrated model. Finally, companies helped to evidence the limitations of the program, discussed its practical utilisation and made several suggestions aiming at further developments of it.

11.2 Conclusions.

11.2.1 Planning, estimating and control management functions on the contractors' behalf.
Portuguese literature on this topic has been hard to find. Therefore, it was decided to make inquiries to construction companies in order to clarify how those management functions are performed in practice. This turned out to be a valuable source of information which led to several conclusions about the current practices of Portuguese construction companies. These conclusions are listed in chapters 3 and 4. The most important are summarised below:

1 Estimates are normally based on traditional bills of quantities (bq) either purchased by the client or specifically generated by the contractor. No alternative arrangement to the traditional bill of quantities could be found in use by the companies surveyed. Unit rate estimating is typically used for building projects and operational estimating is often used for civil engineering projects. Computer based estimating using unit rates is now current.

2 The accuracy of planning is variable throughout the project development. Planning efforts are usually greater after commitment than during the pre-tender stage. Computer based planning is normally restricted to network scheduling.

3 Companies recognise that re-analysing the project after commitment (including new measurements, a new assessment of the project costs and a bigger effort in planning) is advantageous for production preparation.

4 Production control is generally supported by the information contained in the bill of quantities and tends to mostly rely on the outputs of estimating.

Moreover, the inquiries allowed to fully understand the way companies surveyed perform estimating, planning and control management functions. Using these results, the methodology followed by Portuguese construction companies in performing those functions could be set. This corresponded to the accomplishment of the first sub-aim of this study as stated in chapter 1.

Another important contribution of these inquiries was to ascertain the reasons for the lack of integration among management functions in the companies surveyed. This could be extracted from the current practice of those companies. Accordingly, main reasons for lack of integration are as follows:
1 Planning and estimating are done separately, in different time instances, and often performed by different people throughout the project life. Information flows typically from estimating to planning and not the other way.

2 Information generated by estimating has to be re-arranged in order to be used by planning, because of the different structures of data in these two management functions.

3 The outputs of planning and estimating are not directly related, because, in the general case, the items of the bill of quantities and the activities of the construction program do not match the same construction works.

4 Production control mostly uses the outputs of estimating whereas information generated by planning is less used.

Companies surveyed in the course of the second inquiry recognised lack of integration among planning, estimating and control in their current practice. Furthermore, they generally agreed with the idea of integrating them.

Regarding the utilisation of computer support for management functions in contractors' organisations, the inquiries showed that:

1 Companies use stand alone programs to support some management functions as mentioned above.

2 No integrated computer approach dealing with estimating, planning and control could be found in use.

3 Companies understand that the development of specific construction computer software is still needed.

In order to certify these results, a survey to Portuguese software vendors was undertaken. Conclusions of this work are fully reported in chapter 5 but some of the most important are summarised here:
1 Satisfactory software packages for unit rate estimating and for scheduling could be found but integration between estimating and planning is not acceptably achieved by any of them.

2 Some estimating packages include the preparation of data for control, but it is solely based on the bill of quantities.

The perspective of the clients during the construction phase is relevant for this study because they use data generated by the contractors. Accordingly, an inquiry to Portuguese client organisations has also been carried out. Clients confirmed the importance of integration between estimating and planning because this would help contractors to produce more reliable data which could match the interests of both clients and contractors. Conclusions of this inquiry are fully reported in chapter 5.

A remarkable feature of the above inquiries is the fact that they appear to have been the first conducted in Portugal. Actually, all construction companies declared that they were first participating in this type of survey and the same happened with clients. As for software dealers, although they had been previously asked about their products, the purpose of inquiries never had been a research survey before.

Moreover, the singularity of inquiries together with the shortage of literature on the topic evidences the originality of the subject of this thesis in Portugal.

Significant differences in the contractors current practices have been found between the pre-tender stage and the pre-contract stage. Therefore, it was decided to analyse the most relevant aspects of management functions during these two stages separately. Sections 6.3 and 7.4 summarise those aspects and consider on the obstacles to integration among management functions in both stages. Main obstacles are:

(1) The form and complexity of the bills of quantities.

(2) The nature of the estimating method used.
Additionally, it was concluded that the outcome of unit rate estimating is hardly translatable to planning, thus the work to achieve integration is both arduous and time consuming. On the contrary, the outcome of operational estimating is more readily translatable to planning. Therefore, integration between planning and estimating is more straightforward when operational estimating is used. Accordingly, integration between tender planning and estimating was found to be easier to achieve in civil engineering projects than in building projects.

In chapter 7, it was found that companies do not fully benefit from the work undertaken for production preparation during the pre-tender stage. According to the findings reported in chapter 7, this work includes new measurements, a new assessment of the project costs and a bigger effort in planning. Main reasons for this are mentioned below:

(1) detailed measurements are mostly directed to the generation of the new bill of quantities;

(2) the bill of quantities is specially suited to estimating.

Actually, it was found that measurement data is seldom used in planning and lack of relationship between the items of the bill of quantities and construction activities persists. Moreover, some companies often refine the items of the bill by means of additional measurements in order to meet the activities definition requirements. Therefore some duplication of work can possibly occur, as identical measurement criteria are used in both cases.

Moreover, it was concluded in chapter 7 that the difficulties of data interchanging between estimating and planning are the main cause for the lack of accuracy found both in expenses and receipt flow forecasts.

11.2.2 The development of the model.

The review of the literature as presented in chapter 1 shows that several attempts to achieve integration among contractors’ management functions have been made in the past. However, a definite approach to the problem has
not been suggested so far. Actually, lack of integration has been extensively reported in the literature and this has been clearly confirmed by the inquiries addressed to Portuguese construction companies.

The results of inquiries were used to settle the way Portuguese construction companies perform estimating, planning and control management functions at the pre-tender stage and at the pre-contract stage. Then, data systems analysis has been used in chapter 8 in order to clarify the reasons for the lack of integration among management functions. This has proved to be a powerful tool for the understanding of those reasons. Lack of functional dependency between the items of the bill of quantities and the activities of the construction program has been concluded. Furthermore, a data systems approach proved to be efficient to tackle the problem. This has been based on the generation of relationships linking directly both items and activities to elementary construction works. The integrated model presented in chapter 8.4.2 has been established on the basis of these findings.

This approach for the problem overcomes the difficulties of different data structures used by management functions, because data is now structured in an elementary format that can be handled by any of those functions. Therefore, extensive interchange of data is now possible among them. The settlement of an integrated model accomplishing these conditions proves the first research hypothesis as presented in section 1.2. The generation of the model is in agreement with the second sub-aim of this thesis.

Subsequently, a database management system (DBMS) environment has been selected in order to support the model in practice.

Some features of the model development methodology should be highlighted:

- the originality of data systems approach in the study of construction management functions;
- the adequacy of data systems in the clarification of the problem;
- the efficiency of the approach in building up the model;
the suitability of DBMS’s to support the model in practice.

Additionally, the following two aspects should be highlighted because according to inquiries, they are not common in Portugal:

the use of a relational database to represent project data;

the use of a DBMS to support construction management functions.

The successive validation of the model proved to be a valuable technique for achieving the expected results.

Finally, computer support for the model has been provided. This led to the generation of PECI on the basis of a current commercial DBMS. Although PECI is able to fully support the features of the model, the selection of a more powerful database together with some more programming expertise from the author could have led to even better results. This corresponded to the accomplishment of the third sub-aim of the thesis.

The validation of the model and the test of PECI are discussed on chapter 10. The participation of six construction companies in this process has been very important although some more time would have been useful to extend validation a little more. Main results of that validation stage are summarised below:

1 Companies generally agreed that the organisation of project measurements according to the requirements of management functions is an efficient approach to integration.

2 Companies considered that the abilities of PECI are a significant improvement on current computer packages for the following main reasons:

Contrary to current packages, PECI was built upon a relational database environment. This makes data manipulation and data retrieval easier.
PECI achieves integration of management functions whereas current packages tend to work as stand alone systems.

3 Companies suggested some improvements in PECI aiming at its development towards a commercial system.

The appraisal of both the integrated model and the computer program in the six contractors organisations is shown in table 10.2. The following conclusions may be drawn:

1 Appraisal of the model. Companies recognised that the lack of integration among management functions may be overcome by increasing the interchange of resource data within their organisations. The integrated model is a good approach to the problem for 2/3 of the companies and a possible approach to 1/3, but most of them expressed some reservations about its practical utilisation without any additional support.

2 Appraisal of PECI.
2.1 PECI achieves good integration performance among estimating planning and the preparation of data for control as it was demonstrated by the assessment of the companies to the corresponding criteria of table 10.1: 2/3 of the companies understood that it avoids duplication and regeneration of data and 1/3 understood that it limits it; quality of output data was considered high by 2/3 of the companies and average by 1/3; all the companies agreed that it greatly improves data interchange among management functions; intermediate data generated by PECI was found suitable by 2/3 of the companies and satisfactory by 1/3; five companies recognised that data generated by the program is appropriate for subsequent management functions and one company found it satisfactory; data structures used were judged adequate by all the companies.
2.2 Operational performance of PECI.
2.2.1 The user friendliness of the program was judged less favourably by the companies, especially, the quality of menus and the generation of
reports. The speed in data processing and the access to data stored in
the database had moderate results.

2.2.2 PECI demonstrated good capabilities to perform the calculations
usually supported by stand alone estimating systems because it was not
considered deficient in any criteria by any company. Data manipulation
and retrieval was considered good by three companies, unit rate
estimating and resource allocation by four and operational estimating by
five.

2.3 Practical utilisation of PECI. It was proved that the program is of
practical use as no company considered it not usable.

The test of PECI in construction companies showed that it supports the
integrated model and it is of practical use by the industry, leading to the
integration among management functions in real life projects. Moreover, the
efficiency of the computer system was proved through a set of defined criteria as
established in the second research hypothesis. Therefore, the second research
hypothesis as presented in section 1.2 becomes proved.

The limitations of the model could also be assessed from the validation process.
A thorough discussion on these limitations may be found in chapter 10.

11.2.3 The implementation of the model.

The validation of the model in construction companies showed that its practical
implementation seems possible. Nevertheless, according to those companies,
the following difficulties are expected in that process:

The model is suitable for the pre-contract stage. On the other hand, it is
hard to use for tender purposes because of the lack of time available
during the pretender stage.

However, the model will be difficult to implement if not much attention is
devoted to production preparation. The role of planning prior to the
project execution on site is not always recognised. Therefore, detail
planning may not be relevant for some people during the production preparation stage.

The organisation of the project measurements as required by the model may be difficult to achieve in some cases viz,

if project measurements used for tendering are not usually reviewed;

if lack of communication exists between estimators and planners.

Beyond those aspects related to the companies understanding of construction management functions, the need for detailed measurements in order to use the model appears to be a relevant factor. However, due to recent software developments, detailed project measurements will probably be easier to assess in the future. Moreover, they will certainly tend to be automatically transferred from designers, thus reducing the measurement work performed by contractors.

11.3 Future work.

The time available to write this thesis has not been enough to include here so much work as desired. However, the author expects to continue this research line in the near future. Accordingly, the following guidelines for that work will be taken into consideration:

Improve PECI. This follows from the receptiveness of the first version of the program from potential users. Suggestions presented therein should be followed. This could lead to a commercial version of PECI which would make it easier to utilise.

Establish links to control. According to section 1.4.2, this would be the second phase of the model development. It would certainly expand the utility of the model for project implementation.
Extend the scope of the model to the pre-tender stage. Although the present version of the model may be used in all phases of project development, it could be upgraded in order to include some specific aspects of the pre-tender stage. The model as a whole would probably benefit from that extension.

Moreover, during the development of this thesis, the author realised that a lot of research work is still required on the topics discussed herein. As in the Portuguese saying "when you seem to have closed a door, a lot of others open behind you"
APPENDICES
APPENDIX 1

Inquiries. Answers from participants.

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The author is grateful to all people that disinterestedly helped him to carry out these inquiries. This includes those with whom discussions took place during and the staffs of the companies directly involved in inquiries. The author is specially grateful to the following persons and companies:

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Mota & Companhia, SA.
Novopca, Construtores Associados, Lda.
Sociedade de Construções Campo Alegre, Lda.
Construções Técnicas, SA.
Conduril, Construtora Duriense, SA.
Exporgrano, exportação de Mármores e Granitos e Industriais de Construção Civil e obras Públicas, Lda.
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Somague, SA Sociedade de Empreitadas.
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Teixeira Duarte, SA.
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CINCLUS, Planeamento e Gestão de Projectos, SA.
William Graham SA, Sociedade de Construções.
IPERSOFT, Informática Técnica, Lda.
Barbedo Costa Informática, Lda.
CIBER-SI, Sistemas de Informática, Lda.
APPENDIX 1.1

Detailed Inquiry to 5 Portuguese Construction Companies. Answers to the questionnaire.

Answers to the questionnaire are listed in the following pages separately for each company surveyed. Companies names were omitted at their request. They have been replaced by aliases (companies A to E).
COMPANY A

a) Contact with the company.

a.1) The contact was made through a member of the staff of the company who is known personally to the author.

a.2) Clarifications required.

a.3 ) Interlocutors.

It was concluded that it would be possible to do all the necessary interviews. The director of the "Departamento de Orçamentação" (estimating division) was selected as the first person to speak to.

b) Production management.

A graphical sketch of the flow of information in the company is presented at the end of this report.

b.1) General characteristics of the company.

Turnover: No information collected.
Number of employees: No information collected.
Geographical area of activity:
North-Central region of the country and a branch in Lisbon.
b.2) The organization of the company.

The carpentry, the metalwork and the precast concrete workshops are included in the Main Site. These only produce for the projects of the company.
b.3) Field of activity.

The company mainly undertakes building projects.

The company is prepared to respond to calls for open tenders and for selective tenders for private clients (90% of the total offer value). Banks are the most important clients.

The size of the projects is variable because the company policy is to submit a bid in response to all the invitations of major clients (even for low project values). This is the case of refurbishment works in bank branches in which the company has been specializing in the last few years. However, the largest projects may reach several hundreds of thousands of contos (well over a million pounds).

The reasons that influence the company to submit an offer for a project are chiefly: the importance of the client, the importance of the project, the availability of resources and the market conditions.

b.4) Management of construction projects.

The company believes that its structure is sufficiently well organized for estimating, planning and production control management functions to be satisfactory performed.

Estimates are done by the Technical-Commercial Division. The company makes an effort to use its own data for unit cost calculations, but published rates and the estimator's experience are often used for the same purpose.

Planning is mostly carried out by the site director with the participation of the estimator.

Production control is exercised by each site director for the most important resources. Cost control is performed by the Accounting Division after valuing the resources used in the project. The balance between costs forecast and real costs is only possible after the conclusion of the project.
c) Estimating.

c.1) General characteristics.

Estimates are made by a section of the Division of Studies.

c.2) How estimates are made.

Estimates are based on the bill of quantities (bq), which is generally included in the tender documents supplied by the client. In this case, no additional measurements are made for tendering, unless significant errors or omissions are detected in the bill.

If no bill of quantities is available, it is generated by measuring the project. The following criteria are used:

(1) Exhaustive measurements of all works involving the company's resources are always made. Subcontractors are provided with the part of the tender documents relevant to their estimates; they are responsible for the measurements they make.

(2) Measurements are structured into items and these are organized into sections of the bill of quantities.

(3) Identical construction works are joined up into the same bq item irrespective of their location.

(4) Item contents are defined according to the company's criteria which are close to LNEC's. The same stands for the definition of the chapters of the bill of quantities in which items are included.

(5) The bill of quantities generated as described above is used for estimating.

Bills of quantities normally supplied by clients are similar to those generated by
the company. However, the former may be insufficiently detailed in some cases. This often obliges the company to make extra measurements in order to enable proper estimating to be performed.

The first stage in estimating is the preliminary study of how the project would be carried out on site. For this purpose, some discussions may take place with the production staff of the company. Other basic data is also assessed at this stage, such as the spot location, availability of local labour, plant, subcontractors and materials supplies etc.

Unit prices for each bq item are calculated differently depending on whether works included are to be carried out with the company's resources or subcontracted. If works are to be done with the company's resources, unit prices always follow from a cost study. If works are to be subcontracted, unit prices follow from the rates of subcontractors. Moreover, the company also has its own workshops for carpentry, metalwork and electricity. These are also issued with the corresponding tender documents for quotation.

Costs are divided into two classes: direct costs and indirect costs.

Direct costs include the costs of all resources directly involved in production, viz, labour, materials, plant and subcontracts. Direct costs for the works involving the company's resources are computed by multiplying unit rates by unit costs. Rates are preferably supported by available data from the past experience of the company but published data is often used.

Indirect costs comprise all costs that were not handled in direct cost calculation. This includes the costs of site offices and compound facilities, general and major plant items not included in direct costs, other general costs (services, site transports, licenses etc.), allowances for supervision and clerical staff etc. Indirect costs are calculated by several approaches depending on the nature of costs concerned. For example, costs of erecting site offices may be assessed by unit rates, costs with transport may be allocated as a lump sum following from the previous experience of the company, the supervision of subcontractors may be covered by a percentage over their costs, etc. Indirect costs also include an allowance for the general overheads of the organization.
Data used by the company in tender estimating is derived from:

(1) general tender documents supplied by the client;

(2) exhaustive measurements and the bill of quantities specially generated by the company if not included in the tender documents;

(3) unit rates for labour and plant, materials usage rates and wastage factors;

(4) resource cost data and subcontract rates;

(5) current market unit prices;

(6) spot visit report including information about expected local work conditions, site layout, materials suppliers etc.;

(8) allowances for company overheads and for management markups.

After net costs are known, profit and risk are fixed during the tender meeting. The final offer value is decided according to the interest of the company in carrying out the project and to market conditions. Afterwards, profit and risk allowances are distributed among all bq items, yielding the final priced bq. The priced bill of quantities is normally sent to the client, unless it is neither demanded in the tender documents nor convenient for the company.

Sometimes, discussions may take place with the client before commitment. This is more likely to occur with private clients or with general contractors acting as clients to the company. It may include some changes in the project (substitution of materials, modifications of construction methods, etc), which may lead to the re-analysis of the offer. Only after this stage, does the definitive offer become known.

Tender estimating generates the following information:
(1) general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);

(2) a tender-priced bill of quantities (or just the total value of the offer) and possible subsequent revisions;

(3) studies of direct costs including resources unit rates and costs, subcontracts costs, construction methods considered in estimating, etc.;

(4) preliminary design of the site layout and corresponding costs, according to the tender programme and to the spot visit report;

(5) indirect costs studies;

(6) overheads and allowances included in the offer.

If the company wins the contract, measurements are made again if it is possible to apply for errors and omissions of the tender bq. The re-measurement of the project is performed according to the same criteria described above and taking into account later modifications of the project.

The company is presently implementing a commercial computer program for PC to support unit rate estimating.

d) Planning.

d.1) General characteristics.

Planning is made on several occasions:

**Tender Planning** by the Division of Studies in the tender stage;

**Detailed Planning** by the site director during the execution of the project.

d.2) How planning is made.
Construction activities in tender planning are generally in agreement with the headings of the bq or with major works of the project. However, some activities may be further detailed, if it is recognized that a particular item should preferably be broken down before the tender programme is drawn up.

The degree of precision aimed at in tender planning is in agreement with the requirements of the tender documents. Moreover, a minimum level of detail is necessary at this stage so that site costs and indirect costs can be computed. Besides, the tender programme is often submitted to the client. Therefore, it has to be done carefully because the company is bound to carry it out in full.

Available data is the output of the tender estimate, but it is seldom fully used, because the degree of precision aimed at in tender planning does not require all the large volume of information generated in estimating.

Data used by the company in tender planning is:

(1) tender documents supplied by the client;

(2) project measurements and the bill of quantities generated by the company if these were not included in the tender documents;

(3) general contract information (contract conditions additional to those included in the tender documents; payment methods, price revision etc.);

(4) priced bill of quantities;

(5) cost studies made in tender estimating;

(6) expected durations of subcontracts according to the inquiries to subcontractors;

(8) spot visit reports;

(9) preliminary design of the site layout.
The objective of tender planning is the generation of the following information:

1. the tender programme for the works;
2. labour charts for the main work categories;
3. the time the main plant stays on site.

Durations of activities are established according to the following criteria:

1. Due dates for the project or for any project stages possibly fixed in the tender documents.
2. Time required to perform the tasks pertaining to each activity is considered. The experience of the planner is used for the tasks to be carried out directly by the company. If tasks are to be subcontracted, expected duration (based on the inquiries made among subcontractors or on earlier experiences) is used.
3. The experience of the planner.

Labour requirements for the most important categories are allocated to each activity. This is achieved by considering approximate unit rates for the works included in each activity. Work crews are composed by the planner using past experience. Aggregation charts are drawn up directly by adding up the labour requirements of simultaneous activities but they may be further worked out to even out labour demand throughout the project.

The requirements of plant are decided by the planner according to past experience.

The construction programme generated at this stage may have some intermittent activities - which may or may not be current in a given time instance but that only take place within defined limits. It is generally drawn in a bar chart format.
Construction activities in detailed planning are normally in agreement with the items of the bill of quantities. However, some activities may be further detailed, if it is recognized that a particular item should preferably be broken down before the tender programme is drawn up. Furthermore, the construction programme generated at this stage must be fairly accurate because it will be used to carry out the project on site.

Available data includes the output of the tender estimate, and information generated in earlier planning stages:

(1) tender documents supplied by the client;

(2) project measurements and the bill of quantities generated by the company during the pre-contract stage;

(3) general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);

(4) priced bill of quantities;

(5) cost studies made in tender estimating;

(6) expected durations of subcontracts according both to the inquiries to subcontractors and also to possible contracts made meanwhile;

(7) costs for supplies and subcontracts resulting from any contracts made meanwhile;

(8) spot visit reports;

(9) the tender programme for the works;

(10) the preliminary design of the site layout.

The objective of detailed planning is the generation of the following information:
(1) the general construction programme for the works;

(2) The allocation of resources to activities and the design of site layout.

The construction programme generated at this stage should not differ greatly from the tender programme, because the company is already committed to its accomplishment by this time.

Activity durations are established according to the same criteria referred to above. Moreover, they may be examined more thoroughly because there is more data available about the project at this stage.

Resource requirements for each activity are decided by using data from estimating as follows:

(1) Labour: Labour requirements for the most important classes are allocated to each activity. This is achieved basically by using the experience of the site director as explained above. Work crews are composed by the planner using past experience. Aggregation charts for the most important labour classes are drawn up directly by adding up labour requirements of simultaneous activities, but they may be further worked out to smooth out labour demand throughout the project.

(2) Materials: Total quantities of the most significant materials are evaluated for each activity. Aggregation charts for the most important materials are drawn as above.

(3) Plant: The requirements of plant for the most important equipment are estimated by following an identical procedure to labour.

(4) Subcontracts: Start and completion dates for the main subcontracts are defined according to the construction programme.

The scheduling technique used for the generation of the general programme is the CPM. However, information generated is transferred to a bar chart format so that it can be best understood on site. Resource requirements are depicted at
the bottom of the bar chart.

Data passed on by the planning activity is very important for all departments of the company involved in production, viz:

(1) Labour: The site director sends total labour requirements to the Labour Division. This is checked against the availability of employees of the company and appropriate action is taken.

(2) Materials: The materials charts are sent to the Supply Division.

(3) Plant: Forecasts of the utilization of plant are discussed with the production director of the company.

(4) Site facilities and plant: Information generated is sent to all departments involved and discussed with the production director of the company.

Planning for projects taking place at the same time is made at the level of each department involved.

No difficulties were reported in project planning. Moreover, the way it is done has led to good results. However, this is a rather time-consuming activity, especially in the most detailed stages.

No computer support is used for planning.

e) Production Control.

e.1) General characteristics

Production control is done for all projects and it is mainly about cost control. This is exercised by the Accounting Division.
e.2) How production control is performed.

In order to control costs, total expenditures in labour, materials, plant and subcontracts are evaluated monthly. The utilization of resources on site is analysed as follows:

(1) Labour: The consumption of each labour class is assessed for the whole project.

(2) Materials: Materials are organized in classes as defined by the accounting division. The consumption of the materials pertaining to each class is totaled for the whole project.

(3) Plant: Each plant unit is analysed separately for the whole project.

(4) Subcontracts: Subcontracts are also analysed separately for the whole project.

The appraisal of production costs is made every month by valuing data collected on site in accordance with real costs. These are provided by the company's "central services" or directly from the invoices of suppliers. Subcontracts and other services (eg electricity, telephone, etc.) are also valued from invoices.

Some comparisons between costs forecast and actual costs are done by the site director and the production director as the project is being carried out. At the same time they check to see if the project is on schedule. However, the global analysis of all costs incurred is only possible at the end of the project when the accounting division has appraised all information required for it.

Site information is also used in other departments of the company.

The company believes that the system could be improved if data from site could be more readily assessed.
PLANS TAKEN FROM HERE
COMPANY B

a) Contact with the company.

a.1) The contact was made through one of the directors of the Porto branch of the company who is known personally to the author. The productive organization of this branch is almost independent from the head office in Lisboa.

a.2) Clarifications required.

a.3) Interlocutors.

It was concluded that it would be possible to do all the necessary interviews. The person responsible for the Direcção de Apoio às Obras (DAO) (Production Support Division) was selected as the first person to speak to.

b) Production management.

A graphical sketch of the flow of information in the company is presented at the end of this report.

b.1) General characteristics of the company.

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Number of employees:

- Administrative: 40
- Technical: 90
- Main Site: 55
- Production: 480
- Total: 665
Geographical area of activity:

The projects of the Northern Region of the country are handled by the Porto branch. Moreover, the company is active all over the country and abroad.

2.2 The organization of the company.

The Marketing Department is in charge of procurement. It also helps in the
contracts with clients. The Estimating Department performs the usual estimating and tendering tasks.

The organization of the Production Support Division is as follows:

The three departments above are responsible for the preparation of the projects execution on site: cost planning by the SPC, material and subcontract quotations by the SCA and technical preparation of the project design by the Preparation.

Site directors report to their corresponding Director of Sector and this reports to the Production Director. Each division has two or three engineers, each of them in charge of one or more sites.
The organization of the main Site Department is as follows:

- **ESTALEIRO**
  - **MAIN SITE**

  **SERVIÇOS ADMINISTRATIVOS E SECÇÃO PESSOAL**
  - **ADMINISTRATIVE DIVISION AND LABOUR DEPARTMENT**
    - **PESOAL**
      - **LABOUR**
    - **COMPRAS**
      - **SUPPLIERS**
    - **TRANSPORTES**
      - **TRANSPORTS**
    - **SERVIÇOS ELECTROMECÂNICOS**
      - **ELECTROMECANIC SUPPORT**
    - **DIVEROS, ESCORAMENTOS E COFRAÇÕES**
      - **VARIOUS, SHUTTERING AND SCAFFOLDING**

The organization of the Administrative Division is as follows:

- **SERVIÇOS ADMINISTRATIVOS**
  - **ADMINISTRATIVE DIVISION**
    - **CONTABILIDADE**
      - **ACCOUNTING**
    - **FACTURAÇÃO**
      - **INVOICES**
    - **AN. FINANCEIRA**
      - **FINANCIAL ANALYSIS**
    - **SECRETARIADO**
      - **SECRETARY**
b.3 Field of activity.

The company is able to carry out almost all types of construction projects. In 1988 the Porto branch handled the following types of projects:

- Housing: 49% of the turnover
- Industrial buildings: 20% of the turnover
- Concrete Silos: 5% of the turnover
- Various1(1): 15% of the turnover
- Various2(2): 12% of the turnover

(1): Civil engineering works.
(2): Public buildings.

The company is prepared to respond to calls both for open tenders and for selective tenders for private clients. It is also beginning with in-house construction for sale through a promoting company which belongs to the same group.

The sizes of projects vary a lot: the largest may reach several million contos.

The reasons that influence the company to submit an offer for a project execution, are chiefly the balance of fixed charges and expectation of making a profit. Other reasons are related to company strategy, the use of resources, the type of client and payment conditions.

b.4) Management of construction projects.

The company believes that its structure is well organized, enabling it to perform estimating, planning and production control management functions rather efficiently.

Estimates are made by the Technical-Commercial Division. Unit rates are
especially based on the company's own data which is collected from production.

Construction management is mainly supported by the "Caderno de Planeamento" (planning book). This document is initially created by the DAO for the new contracts and is used for production control.

Production control is carried out by DAO. The volume of information generated allows for acceptable evaluation of the work undertaken.

Possible deviations between forecast costs and real costs mainly result from subcontractors' participation in the works and to unpredictable events.

Time for tender studies is generally enough.

d) Estimating.

d.1) General characteristics.

Tender estimates are made by a specific department of the Technical-Commercial Division. If the company wins the contract, a new study is made which is included in the "planning book". This work is done by the Production-Support Division (DAO).

d.2) How estimates are made.

Estimates are based on the bill of quantities (bq), which is generally included in the tender documents supplied by the client. In this case, no additional measurements are made for tendering, unless significant errors or omissions are detected in the bill.

If no bill of quantities is available, it is generated by measuring the project. The following criteria are used:

(1) Exhaustive measurements of all works involving the company'
resources are always made. Subcontractors are provided with the part of the tender documents relevant for their estimates; they are responsible for the measurements they make.

(2) Measurements are structured into items and these are organized into sections of the bill of quantities.

(3) Identical construction works are joined up into the same bq item irrespective of their location.

(4) Item contents are defined according to the company’s criteria which are close to LNEC’s. The same stands for the definition of the chapters of the bill of quantities in which items are included.

(5) The bill of quantities generated as described above is used for estimating.

Bills of quantities normally supplied by clients are similar to those generated by the company. However, the former may be insufficiently detailed in some cases. This often obliges the company to make extra measurements in order to enable proper estimating to be performed.

The first stage in estimating is the preliminary study of how the project would be carried out on site. For this purpose, some discussions may take place with the production staff of the company. Other basic data is also assessed at this stage, such as the spot location, availability of local labour, plant, subcontractors and materials supplies etc.

Unit prices for each bq item are calculated differently depending on whether works included are to be carried out with the company’s resources or subcontracted. If the company’s resources are to be used, unit prices are assessed according to the following criteria:

(1) In lump sum contracts, for the items of the bill of quantities for which the company has sufficient past experience, market unit prices are simply adopted. Obviously, this has to be done carefully to prevent
losses if the company wins the contract. Therefore, unit prices are based on recent offers from the usual subcontractors of the company. Accordingly, works may be subcontracted if necessary in order to assure costs below expenses. The company believes that this approach increases the chances of winning the contract.

(2) Unit prices always result from a cost study if the above criterion is not suitable.

If works are to be subcontracted, unit prices follow from the rates of subcontractors.

Costs are divided into two classes: direct costs and indirect costs.

Direct costs include the costs of all resources directly involved in production viz, labour, materials, plant and subcontracts. Direct costs for the works involving the company's resources are computed by multiplying unit rates by unit costs. Rates are preferably supported by available data from the past experience of the company but published data is often used.

Indirect costs comprehend all costs that were not handled in direct costs calculation. This includes the costs of site offices and compound facilities, general and major plant items not included in direct costs, other general costs (services, site transports, licenses etc.), allowances for supervision and clerical staff etc. Indirect costs are calculated by several approaches depending on the nature of costs concerned. For example, costs of erecting site offices may be assessed by unit rates, costs with transports may be allocated as a lump sum following from the previous experience of the company, the supervision of subcontractors may be covered by percentage over their costs, etc. Indirect costs also include an allowance for the general overheads of the organization.

Data used by the company in tender estimating is derived from:

(1) general tender documents supplied by the client;

(2) exhaustive measurements and the bill of quantities specially
generated by the company if not included in the tender documents;

(3) unit rates for labour and plant, materials usage rates and wastage factors;

(4) resource cost data and subcontracts rates;

(5) current market unit prices;

(6) spot visit reports including information about expected local work conditions, site layout, materials suppliers etc.;

(7) a preliminary programme for the works;

(8) allowances for company overheads and for management markups.

After net costs are known, profit and risk are fixed during the tender meeting. The final offer value is decided according to the interest of the company in carrying out the project and to market conditions. Afterwards, profit and risk allowances are distributed among all bq items, yielding the final priced bq. The priced bill of quantities is normally sent to the client, unless it is neither demanded in the tender documents nor convenient for the company.

Sometimes, discussions may take place with the client before commitment. This is more likely to occur with private clients or with general contractors acting as clients to the company. It may include some changes in the project (substitution of materials, modifications of construction methods, etc), which may lead to the re-analysis of the offer. Only after this stage, does the definitive offer become known.

Tender estimating generates the following information:

(1) general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);
(2) a tender priced bill of quantities (or just the total value of the offer) and possible subsequent revisions;

(3) direct costs studies including resources unit rates and costs, subcontracts costs, construction methods considered in estimating, etc.;

(4) preliminary design of the site layout and corresponding costs, according to the tender programme and to the spot visit report;

(5) indirect costs studies;

(6) overheads and allowances included in the offer.

If the company wins the contract, an initial meeting takes place involving the estimator, the site director and someone from the DAO. Data generated during the tender stage is discussed and passed to the Serviços de Planeamento e Controlo (SPC) (planning and control services) for the composition of the "planning book".

In the first place, measurements are made again, according to the same criteria described above and considering possible modifications decided so far. However, in some cases, re-measurements are only made for further versions of the "planning book" so that additional data about the project may also be included (soil characteristics, project definition, etc.). Re-measuring the project is also important when it is possible to apply for errors and omissions in the tender bq.

Next, previous calculations of direct costs for all items are looked over. The process is identical to the one described above but costs are possibly assessed more accurately at this stage. For example: unit rates are adapted more closely to the spot conditions; local costs of labour, plant and materials are considered more minutely; costs for supplies and subcontracts may follow from contracts made meanwhile etc.

The bill of quantities generated at this stage includes other items further to those considered in the tender bq. These are especially related to site costs
and are organized under the following headings:

(1) basic materials for site erection;

(2) plant;

(3) mechanical equipment and maintenance;

(4) scaffolding and shuttering materials;

(5) clerical and technical staff on site;

(6) consumption, transport and other expenditures.

Corresponding costs are evaluated as explained above though they can be more detailed at this stage.

The "planning book" is composed of the following parts:

(1) Contents, general remarks on take-off data, summary of costs, summary of receipts and industrial cost.

(2) Full description of items, item costs, work quantities, unit costs and total costs of the bq items.

(3) Costs of the resources used in the project including description, unit cost, total cost and percentual weight in the project's total cost. Resources are organized into sections viz, labour, plant, classes of materials, total subcontracts and labour subcontracts, consumptions, laboratory tests, designs, etc.

(4) Programme for the works, the activities of which basically correspond to the priced bq items, (a little more detailed sometimes).

(5) Labour aggregation charts.
(6) Resource costs considered in the study.

The contents of parts (4) and (5) will be further discussed in section 4 below.

The company believes that looking over the estimate after commitment and the generation of the "planning book" is very important for getting more accurate costs. This is essential because the company wishes to know exactly how much money will be spent on the project. Besides, revenues are already fixed at this stage; thus how much will be left for profit and risk just depends on project costs. Moreover, corrective actions may taken if necessary.

Tender estimating and the generation of the "planning book" are computer supported. A computer program specially developed by the company is in use.

d) Planning.

d.1) General Characteristics.

Planning is done on several occasions:

Tender Planning by the Estimates Department as a tender document;

Initial Planning by the Planning and Control Services, (SPC) and the site director in the pre-contract stage;

Detailed Planning by the site director during the execution of the project.

d.2) How planning is done.

Construction activities in tender planning are generally in agreement with the headings of the bq or with major works of the project. However, some activities may be further detailed, if it is recognized that a particular item should preferably be broken down before the tender programme is drawn up.
The degree of precision aimed at tender planning is in agreement with the requirements of the tender documents. Moreover, a minimum level of detail is necessary at this stage so that site costs and indirect costs can be computed. Besides, the tender programme is often submitted to the client. Therefore, it has to be done carefully because the company becomes bound to its accomplishment.

Available data is the output of the tender estimate, but it is seldom fully used, because the degree of precision aimed at in tender planning does not require all the large volume of data generated in estimating.

Data used by the company in tender planning is:

1. tender documents supplied by the client;
2. project measurements and the bill of quantities generated by the company if these were not included in the tender documents;
3. general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);
4. priced bill of quantities;
5. cost studies made in tender estimating;
6. expected durations of subcontracts according to the inquiries to subcontractors;
7. spot visit reports;
8. preliminary design of the site layout.

The objective of tender planning is the generation of the following information:

1. the tender programme for the works;
(2) labour charts for the main work categories;

(3) the time the main plant stays on site.

Durations of activities are established according to the following criteria:

(1) Due dates for the project or for any project stages possibly fixed in the tender documents.

(2) Time required to perform the tasks pertaining to each activity is considered. The experience of the planner is used for the tasks to be carried out directly by the company. If tasks are to be subcontracted, expected duration (based on to the inquiries to subcontractors or to earlier experiences is used.

(3) The experience of the planner.

Labour requirements for the most relevant categories are allocated to each activity. This is achieved by considering approximate unit rates for the works included in each activity. Work crews are composed by the planner using past experience. Aggregation charts are drawn up directly by adding up labour requirements of simultaneous activities but they may be further worked out to even out labour demand throughout the project.

The requirements of plant are decided by the planner according to past experiences.

The construction programme generated at this stage may have some intermittent activities - which may or may not be current in a given time instance but that only take place within defined limits. It is generally drawn in a bar chart format.

The "planning book" is the main support for initial planning. Construction activities are normally coincident with the items of the bq. However, some activities may be further detailed, if it is recognized that a particular item
should preferably be broken down to build up the tender programme. According to the estimating section above, resource forecasting is made with some detail in the "planning book". However, the utilization of resources during the project is not carefully forecast.

Actually, the company pays little attention to time planning, so the construction programme included in the "planning book" is not very precise. It may be stated that the company does not really schedule the projects at this stage.

Available data includes the output of the tender estimate, and information generated in earlier planning stages:

(1) tender documents supplied by the client;

(2) project measurements and the bill of quantities generated by the company during the pre-contract stage;

(3) general contract information (additional contract conditions to those included in the tender documents, payment methods, price revision etc.);

(4) priced bill of quantities;

(5) cost studies made in tender estimating;

(6) expected durations of subcontracts according to the inquiries to subcontractors and to possible contracts made meanwhile;

(7) costs for supplies and subcontracts resulting from any contracts made meanwhile;

(8) spot visit reports;

(9) the tender programme for the works;

(10) the preliminary design of the site layout.
The construction programme generated at this stage should not differ greatly from the tender programme, because the company is already committed to following it out at this stage.

Activity durations are established according to the same criteria referred to above. Moreover, they may be looked at more thoroughly because there is more data available about the project at this stage.

**Detailed planning**, is based on the "planning book". However, site directors are free to generate their construction programmes. The only constraints is that the upper limits on total resource utilization (as defined in the planning book) and possible due dates for the project should not be surpassed.

Data in the "planning book" is very important for all departments of the company involved in production, viz:

1. **Labour**: The site director sends total labour requirements to the Labour Department. This is checked against the availability of employees of the company and appropriate action is taken.

2. **Materials**: The materials charts are sent to the Supply Services.

3. **Plant**: Forecasts on the utilization of plant are discussed with the production director of the company.

4. **Site facilities and plant**: Information generated is sent to all departments involved and discussed with the production director of the company.

Planning for projects taking place at the same time is made at the level of each department involved.

No difficulties were reported in project planning. Moreover, the way it is done has led to good results.
Although the generation of most of the "planning book" is supported by computer, scheduling is carried out by hand.

e) Production control.

e.1) General Characteristics.

Production control is done for all projects and it is mainly about costs control. This is performed by DAO.

e.2) How production control is performed.

In order to control costs, total expenditures in labour, materials, plant and subcontracts, are evaluated monthly. The utilization of resources on site is analysed as follows:

(1) Labour: The consumption of each labour class is assessed for the whole project.

(2) Materials: Materials are organized in classes as defined by the Accounting Department. The consumption of the materials pertaining to each class is totaled for the whole project.

(3) Plant: Each plant unit is analysed separately for the whole project.

(4) Subcontracts: Subcontracts are analysed separately for the whole project.

The appraisal of production costs is made every month by valuing data collected on site in accordance with real costs. These are provided by the company's "central services" or directly from the invoices of suppliers. Subcontracts and other services (eg electricity, telephone, etc.) are also valued from invoices.

Data collected is used to complete the "planning book" which allows for comparisons to be made between costs forecast and actual costs. At the same
time, the site director and the production director check to see if the project is on schedule. Appropriate action may be taken if necessary.

Site information is also used in other departments of the company.

The company believes that the system is good.
PLANS TAKEN FROM HERE
COMPANY C

a) Contact with the company.

a.1) The contact was made through the personal knowledge of a member of the staff of the company.

a.2) Clarifications required.

a.3) Interlocutors.

It was concluded that it would be possible to make all the necessary interviews. The first interview was settled with the chairman of the board of directors. He happens to be a person very interested in the field of production in construction companies, with published material on this subject.

b) Production management.

A graphical sketch of the flow of information in the company is presented at the end of this report.

b.1) General characteristics of the company.

Turnover: The company began its activity in May 1988 with a corresponding turnover of 200,000 contos.

Number of employees:

- Administrative & Technical: 15
- Production: 18
- Total: 33

Geographical area of activity:

North Region of the country especially the region of Porto.
b.2) The organization of the company.

b.3) Field of activity.

The company is involved in both building and civil engineering projects.

The company is prepared to respond to calls for open tenders and for selective tenders of private clients. Although it only began working a short time ago, it already has licenses for bridges, dams and industrial projects.

The size of the projects is variable. Private projects range from 5 000 to 350 000 contos.
The reasons that influence the company to submit an offer for a project, are chiefly the balance of fixed charges and the enlargement of its "curriculum". The selection of the type of projects to submit an offer to, is based on the professional satisfaction of the partners and is influenced by the type of client. Profit is placed on a secondary level.

b.4) Management of construction projects.

The company believes that its structure is well organized. This enables it to perform estimating, planning and production control management functions rather efficiently.

Estimates are made by the Technical-Commercial Department. Unit rates are especially based on the company's own data, which is collected from production.

Production control is carried out by each site director. The volume of information generated allows for acceptable evaluations of the work being carried out. The company believes that the production control system is rather efficient, because it is supported by an effective preparation of site works.

Possible divergences between forecast costs and real costs mainly result from delays while carrying out the works. However, delays do not usually follow from forecasting errors, but from unpredictable site conditions.

Time for tendering is generally enough.

The way project management is carried does not yet fulfill the aims of the directors of the company. The system being introduced is based on a book of Mr. Mota Cardoso [1], which followed from his past experience in site direction. This system is already being partially used, but it has not been possible to fully implement it so far. The main difficulty is related to the time necessary for collecting and processing production data.
c) Estimating.

c.1) General characteristics.

Estimates are made by the Technical-Commercial Department in two stages: Tender estimate and the generation of the "estimate adapted chart" after commitment.

c.2) How estimates are made.

Estimates are based on the bill of quantities (bq), which is generally included in the tender documents supplied by the client. In this case, no additional measurements are made for tendering, unless significant errors or omissions are detected in the bill.

If no bill of quantities is available, it is generated by measuring the project. The following criteria are used:

(1) Exhaustive measurements of all works involving the company's resources are always made. Subcontractors are provided with the part of the tender documents relevant for to their estimates; they are responsible for the measurements they make.

(2) Measurements are structured into items and these are organized into chapters of the bill of quantities.

(3) Identical construction works are joined up into the same bq item irrespective of their location.

(4) Item contents are defined according to the company's criteria which are close to LNEC's. The same stands for the definition of the chapters of the bill of quantities in which items are included.

(5) The bill of quantities generated as described above is used for
estimating.

Bills of quantities normally supplied by clients are similar to those generated by the company. However, the former may be insufficiently detailed in some cases. This often obliges the company to make extra measurements before they can arrive at reliable estimates.

The first stage in estimating is the preliminary study of how the project would be carried out on site. For this purpose, some discussions may take place with the production staff of the company. This preliminary study involves the evaluation of the approximate quantities of the most relevant works. A preliminary work schedule is also drawn up on the basis of those quantities. This is helpful for the initial appraisal of work sequencing and the total duration of the project. Other basic data is also assessed at this stage such as the spot location, availability of local labour, plant, subcontractors and materials supplies etc.

Unit prices for each bq item are calculated differently depending whether works included are to be carried out with the company's resources or subcontracted. If works are to be done with the company's resources, unit prices always follow from a cost study. If works are to be subcontracted, unit prices follow from the rates of subcontractors.

Costs are divided into two classes: direct costs and indirect costs.

Direct costs include the costs of all resources directly involved in production viz, labour, materials, plant and subcontracts. Direct costs for the works involving the company's resources are computed by multiplying unit rates by unit costs. Rates are usually supported by available data from the past experience of the company. Published data may be used as well. The calculation of direct costs for each bq item is summarized in the "estimates worksheets", where all meaningful information is registered.

Indirect costs include all costs that cannot be allocated to just one activity, because the precise determination of the part consumed or used in each task is difficult to appraise [1]. This includes the costs of site offices and compound
facilities, general and major plant items not included in direct costs, other general costs (services, site transport, licenses etc.), allowances for supervision and clerical staff etc. Indirect costs are calculated by various approaches depending on the nature of costs concerned. For example, costs of erecting site offices may be assessed by unit rates, costs with transport may be allocated as a lump sum following from the previous experience of the company, the supervision of subcontractors may be covered by percentage over their costs, etc. Indirect costs also include an allowance for general overheads of the organization.

Data used by the company in tender estimating is:

(1) general tender documents supplied by the client;

(2) exhaustive measurements and bill of quantities specially generated by the company if not included in the tender documents;

(3) unit rates for labour and plant, materials usage rates and wastage factors;

(4) resource cost data and subcontract rates;

(5) current market unit prices;

(6) spot visit report including information about expected local work conditions, site layout, materials suppliers etc.;

(7) preliminary programme for the works;

(9) allowances for company overheads and for management markups.

After net costs are known, profit and risk are fixed during the tender meeting. The final offer value is decided according to the interest of the company in carrying out the project and to market conditions. Afterwards, profit and risk allowances are distributed among all bq items, yielding the final priced bq. The priced bill of quantities is normally sent to the client, unless it is neither
demanded in the tender documents nor convenient for the company.

Sometimes, discussions may take place with the client before commitment. This is more likely to occur with private clients or with general contractors acting as clients to the company. It may include some changes in the project (substitution of materials, modifications of construction methods, etc), which may lead to the re-analysis of the offer. Only after this stage, does the definitive offer become known.

Tender estimating generates the following information:

(1) general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);

(2) tender priced bill of quantities (or just the total value of the offer) and possible subsequent revisions;

(3) direct cost studies including resource unit rates and costs, subcontract costs, construction methods considered in estimating, etc.;

(4) preliminary design of the site layout and corresponding costs, according to the tender programme and to the spot visit report;

(5) indirect cost studies;

(6) overheads and allowances included in the offer.

If the company wins the contract, the "preparation stage" of the project takes place. In present, the estimating department is involved in this work but in the future this will be done by other people within the company.

In the first place, measurements are made again according to the same criteria described above and taking into account later modifications of the project. Re-measuring is also important when it is possible to apply for errors and omissions of the tender bq. Items are the same as those in the tender bq, but
some are possibly made more detailed by separating the elementary tasks they may comprise.

Next, previous calculations of direct costs for all items are looked over. The process is identical to the one described above but costs are possibly assessed more accurately at this stage. For example: unit rates are adapted more closely to the spot conditions; local costs of labour, plant and materials are considered more carefully; costs for supplies and subcontracts may follow from contracts made meanwhile etc. The costs of each resource class (viz, labour, materials, plant and subcontracts) are listed separately in a kind of enlarged bill of quantities which the company calls "estimate-adapted chart".

Indirect costs are reviewed and possibly further detailed in this stage. Cost calculations are made as before but spot conditions are possibly considered more extensively.

The company believes that looking over the estimate after commitment and the generation of the "estimate-adapted chart" is very important for meeting more accurate costs. This is essential because the company wishes to know exactly how much money will be spent on the project. Besides, revenues are already fixed at this stage, thus how much will be left for profit and risk just depends on project costs. Moreover, corrective actions may taken if necessary.

The company believes that the way estimating is performed leads to good results. Significant differences between estimated rates and final costs of the project are seldom found.

Tender estimating and the generation of the "estimate-adapted chart" are computer supported. A computer program for PC specially developed by the company is used.
d) Planning.

d.1) General characteristics.

Planning is done in several occasions:

- **Preliminary Planning** by the Technical-Commercial Division in early stages of estimating;
- **Tender Planning** by the Technical-Commercial Division in the tender stage;
- **General Planning** by the Technical-Commercial Division and the site director in the pre-contract stage;
- **Detailed Planning** by the site director during the execution of the project.

d.2) How planning is done.

Construction activities in **preliminary planning** are defined with a high level of aggregation. They generally correspond with the most significant headings of the bill of quantities or with major works of the project. The degree of precision is low. Available data is scarce. Activity durations are established according to the experience of the planner. Precedence relationships among activities are not studied with much detail at this stage. Data generated is basically a preliminary programme for the works. Some initial forecasts for site installations may be included as well.

Construction activities in **tender planning** are generally in agreement with the sections of the bq or with major works of the project. However, some activities may be further detailed, if it is recognized that a particular item should preferably be broken down before the tender programme is prepared.

The degree of precision aimed at in tender planning is higher than in
preliminary planning because more information about the project is already available. Moreover, a minimum level of detail is necessary at this stage so that site costs and indirect costs can be computed. Besides, the tender programme is often submitted to the client. Therefore, it has to be made carefully, because the company becomes bound to its accomplishment.

Available data is the output of the tender estimate, but it is seldom fully used, because the degree aimed at in tender planning does not require all then large volume of information generated in estimating.

Data used by the company in Tender Planning is:

(1) tender documents supplied by the client;

(2) project measurements and the bill of quantities generated by the company if these were not included in the tender documents;

(3) general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);

(4) priced bill of quantities;

(5) cost studies made in tender estimating;

(6) expected durations of subcontracts according to the inquiries to subcontractors;

(7) preliminary programme for the works;

(8) spot visit reports;

(9) preliminary design of the site layout.

The objective of tender planning is the generation of the following information:
Activity durations are established according to the following criteria:

(1) Due dates for the project or for any project stages possibly fixed in the tender documents.

(2) Time required to perform the tasks pertaining to each activity is considered. If tasks are to be carried directly by the company, time-consuming resources required to perform them are allocated to the activity using the same rates of estimating. The number of resources required by the activity and the duration of it are balanced together in order to get an acceptable result. If tasks are to be subcontracted, expected durations according to the inquiries to subcontractors or to earlier experiences are used.

(3) The durations assigned to the same activities in the preliminary programme.

(4) The experience of the planner.

Labour aggregation charts are drawn up directly by adding up labour requirements of simultaneous activities but they may be further worked out to level labour demand throughout the project.

The requirements of plant are decided by the planner according to past experiences.

The construction programme generated at this stage may have some intermittent activities - which may or may not be current in a given time instance but that only take place within defined limits. Moreover it should not differ greatly from the preliminary programme, because this is used as a basis
for cost studies. It is generally drawn in a bar chart format.

Construction activities in **general planning** are normally in agreement with the items of the "estimate adapted chart". Therefore, it is done with a considerable degree of precision because it is based on a substantially detailed work breakdown structure. Furthermore, the construction programme generated in this stage must be fairly accurate because it will be used to carry out the project on site.

Available data includes the output of the tender estimate, and information generated in earlier planning stages:

1. tender documents supplied by the client;
2. project measurements and the bill of quantities generated by the company during the pre-contract stage;
3. general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);
4. priced bill of quantities;
5. cost studies made in tender estimating;
6. expected durations of subcontracts according to the inquiries to subcontractors and to possible contracts made meanwhile;
7. costs for supplies and subcontracts resulting from any contracts made meanwhile;
8. spot visit report;
9. the tender programme for the works;
10. the preliminary design of the site layout.
The objective of general planning is the generation of the following information:

(1) the general construction programme for the works;

(2) the allocation of resources to activities and the design of site layout.

The construction programme generated at this stage should not differ greatly from the tender programme, because the company is already committed to its accomplishment at this stage.

Activity durations are established according to the same criteria referred to above. Moreover, they may be looked at more thoroughly because there is more data available about the project at this stage.

Resource requirements for each activity are decided by using data from estimating as follows:

(1) Labour: Labour requirements for the most important classes are allocated to each activity. This is achieved by balancing together activity durations and corresponding labour quantities as explained above. Work crews are composed by the planner using past experience. Aggregation charts for the most relevant labour classes are drawn up directly by adding up labour requirements of simultaneous activities, but they may be further worked out to level labour demand throughout the project. This may lead to the modification of the duration of some activities and to the re-arrangement of the construction programme. Finally, labour costs are computed using information generated.

(2) Materials: Total quantities of each material are calculated for each activity. Aggregation charts for the most important materials are drawn as above.

(3) Plant: The requirements of plant for the most important equipments are estimated by following an identical procedure to labour. Aggregation charts are also drawn as above. However, restraints may have to be
imposed on the number of units of some equipment to be used, according to their availability in the company. Plant costs are computed using information generated.

(4) Subcontracts: Start and completion dates of the main subcontracts are defined according to the construction programme.

Planning of the resources not directly involved in production - thus, not included in direct costs - is done according to the way the costs of those resources were estimated. This may lead to the definition of other activities in the construction programme (for example, site erection), to which resources are allocated. Costs of these activities are computed afterwards. The costs of other resources which were not allocated to specific activities (for example, supervision labour) are allotted in fixed amounts.

Finally the cash flow of the project costs is computed according to the construction programme. The receipts cash flow is established by checking the works included in each activity and valuing them in the priced bill of quantities.

The scheduling technique used for the generation of the general programme is the CPM. However, information generated is transferred to a bar chart format so that it can be best understood on site. Resources requirements are depicted on the bottom of the bar chart.

**Detailed planning** follows from the development of general planning for the same activities. Data used is basically the same. Nevertheless, a smaller time unit may be adopted, or it may be convenient to make small modifications in order to meet production reality more closely.

Data passed by the planning activity is very important for all departments of the company involved in production, viz:

(1) Labour: The site director sends total labour requirements to the Labour Division. This is checked against the availability of employees of the company and appropriate action is taken. Forecasts of the total labour costs are sent to the Administrative and Finance Division.
(2) Materials: The materials charts are sent to the Supply Services.

(3) Plant: Forecasts of the utilization of plant are sent to the Plant Services, and discussed with the production director of the company.

(4) Site facilities and plant: Information generated is sent to all departments involved and discussed with the production director of the company.

Planning for projects taking place at the same time is made at the level of each department involved.

No difficulties were reported in project planning. Moreover, the way it is done has been leading to good results. However, this is a rather time-consuming activity, especially in the most detailed stages.

Scheduling is computer supported in a personal computer. The package used was especially developed for the company.

e) Production control.

e.1) General characteristics.

Production control is established for all projects and includes resources control and costs control. This is carried out by the site director.

e.2) How production control is performed.

Resources are controlled by comparing forecasts with their actual utilization on site. Expenditures in labour, materials, plant and subcontracts, are evaluated monthly for all items of the "estimate adapted chart" mentioned above. This is recorded in the "production chart" which is an extension of the "estimate adapted chart" with additional rows where actual production costs are registered. The utilization of resources on site is analysed as follows:
(1) Labour: The consumption of each labour class is assessed for each task.

(2) Materials: The consumption of each material is appraised for each item of the "production chart". However, materials used for concrete are studied apart.

(3) Plant: Each plant unit is analysed separately for each item of the "production chart". Operators, and materials which have been consumed in operation, are allocated to the corresponding equipment.

(4) Subcontracts: Subcontracts are also analysed separately for each item of the "production chart".

Actual utilization of resources on site is compared to the forecasts for each item of the "production chart".

The appraisal of production costs is made every month by valuing data collected on site with actual costs. These are provided by the company's "central services" or directly from the invoices of suppliers. Subcontracts and other services (eg electricity, telephone, etc.) are also valued from invoices. This information allows the site director to fill up the rows of the "production chart" which refer to actual production costs in each month.

Direct costs forecast for each month are obtained by multiplying works carried in that particular month by unit costs. Indirect costs are evaluated identically.

The comparison between costs forecast and actual costs yields the "economic position" of the project, which is analyzed by the site director and the production director. At the same time they check to see if the project is on schedule. Appropriate action may be taken if necessary.

Site information is also used in other departments of the company.

The company believes that the system is good, but it would be more efficient if
the time necessary for data collection and manipulation could be reduced.

References.

Direcção de Obra. Organização e controlo
Biblioteca AECOPS nº1. Lisboa.
PLANS TAKEN FROM HERE
COMPANY D

a) Contact with the company.

a.1) The contact followed a demand for consultancy the company made to the Departamento de Engenharia Civil da Universidade do Minho (DECUM) (Department of Civil Engineering of the University of Minho). The company asked for advice on computer packages for estimating and production control. The DECUM suggested the study of the production process of the company beforehand. Therefore, the company was asked to participate in the inquiry, the results of which could also be used for the study the DECUM suggested.

a.2) Clarifications required.

The company stipulated that data to be collected might not be used in the scope of any private consulting activity.

a.3) Interlocutors.

It was concluded that it would be possible to hold all the necessary interviews. The person responsible for the Gabinete Técnico (Technical Office) was selected as the first person to speak to.

b) Production management.

A graphical sketch of the flow of information in the company is presented at the end of this report.

b.1) General characteristics of the company.

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<thead>
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<tbody>
<tr>
<td>(1000 contos)</td>
<td>184</td>
<td>370</td>
<td>511</td>
<td>684</td>
<td>1300</td>
</tr>
</tbody>
</table>
Number of employees:

Main Office: 13
Production: 131 (6 technical)
Total: 144

Geographical area of activity:

Northern Region of the country.

b.2) The organization of the company.

There is no director in charge either for the Projects Department or for the Supplies Department. Consequently, site directors and the sub-departments of the Supplies Office report directly to the management of the company. Therefore, the above chart is merely formal in these aspects. The Administrative
Services include "Contabilidade" (Accounting Department) and the "Sector de Pessoal" (Labour Sector).

The Technical Office also designs building structures for the projects of a real estate firm associated with the company.

b.3) Field of activity

The company mainly undertakes building projects. The company responds to calls for open tenders (80% of the total) and for selective tenders of private clients. The most important clients are housing cooperatives.

The size of the projects is variable. Private projects normally range from 100,000 to 300,000 contos. However, the company may offer to undertake smaller projects for important clients. The productive structure of the company is basically directed towards housing projects (80% of the total turnover).

The reasons that influence the company to submit an offer for a project, are chiefly: the company strategy, the balance of the fixed charges, the importance of the project and the availability of resources to carry it out.

In 1988 the company got the contract for one in each six bids submitted. The company believes that this score follows from its tendering expertise (especially for cooperative building projects).

b.3) Management of construction projects.

The company believes that its structure is well organized. However, there are some difficulties which persist in carrying out management functions adequately.

Estimates are made by the Gabinete Técnico (Technical Office). Unit rates are mainly based on published data because they are not yet available from the company's own production. Moreover, as the company often works with many subcontractors (especially for finishing works), market prices are also used in drawing up the tender.
Planning is normally done by the site director with the participation of the estimator.

Production control is exercised by each site director for the most important resources. Cost control is carried out by the Contabilidade (accounting department) after valuation of the resources used in each project. The balance between costs forecast and production costs is only possible after the conclusion of the project.

Projects are normally on schedule because the building frame (which is generally constructed directly by the company) seldom delays the project and subcontracted works may be accelerated by increasing the number of subcontracts on site.

Time given for tender studies is generally enough.

c) Estimating.

c.1) General characteristics.

Estimates are made by a specific sub-department of the Technical Office.

c.2) How estimates are made.

Estimates are based on the bill of quantities (bq), which is generally included in the tender documents supplied by the client. In this case, no additional measurements are made for tendering, unless significant errors or omissions are detected in the bill.

If no bill of quantities is available, it is generated by measuring the project. The following criteria are used:

(1) Exhaustive measurements of all works involving the company's resources are always made. Subcontractors are provided with the part of the tender documents relevant to their estimates; they are responsible for
This often obliges the company to make extra measurements in order to enable proper estimating to be performed.

The first stage in estimating is the preliminary study of how the project would be carried out on site. For this purpose, some discussions may take place with the production staff of the company. Other basic data is also assessed at this stage, such as the spot location, availability of local labour, plant, subcontractors and materials supplies etc.

Unit prices for each bq item are calculated differently depending on whether works included are to be carried out with the company's resources or subcontracted. If the company's resources are to be used, unit prices are assessed according to the following criteria:

(1) For the items of the bill of quantities for which the company has sufficient past experience, market unit prices are simply adopted. Obviously, this has to be done carefully to prevent losses if the company wins the contract. Therefore, unit prices are based on recent offers from the usual subcontractors of the company. Accordingly, works may be subcontracted if necessary in order to assure costs below expenses. The company believes that this approach increases the chances of winning the contract.

(2) Unit prices always result from a cost study if the above criterion is not suitable. Moreover, cost studies are also performed for the most important items of the bill of quantities. Unit costs are preferably computed by using rates from the past experience of the company but published data is often used. Markups are added to unit costs to take into account other expenses not considered in rates (eg costs of the site facilities, supervision, etc).

If works are to be subcontracted, unit prices follow from the rates of subcontractors.

Data used by the company in tender estimating is derived form:
(1) general tender documents supplied by the client;

(2) exhaustive measurements and the bill of quantities specially generated by the company if not included in the tender documents;

(3) unit rates for labour and plant, materials usage rates and wastage factors;

(4) resource cost data and subcontract rates;

(5) current market unit prices;

(6) spot visit reports including information about expected local work conditions, site layout, materials suppliers etc.;

After net costs are known, profit and risk are fixed during the tender meeting. The final offer value is decided according to the interest of the company in carrying out the project and to market conditions. Afterwards, profit and risk allowances are distributed among all bq items, yielding the final priced bq. The priced bill of quantities is normally sent to the client, unless it is neither demanded in the tender documents nor convenient for the company.

Sometimes, discussions may take place with the client before commitment. This is more likely to occur with private clients or with general contractors acting as clients to the company. It may include some changes in the project (substitution of materials, modifications of construction methods, etc), which may lead to the re-analysis of the offer. Only after this stage, does the definitive offer become known.

Tender estimating generates the following information:

(1) general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);

(2) a tender priced bill of quantities (or just the total value of the offer) and possible subsequent revisions;
If the company wins the contract, measurements are made again, according to the same criteria described above and taking into account later modifications of the project. Re-measuring is also important when it is possible to apply for errors and omissions in the tender bq.

The company is now implementing a commercial computer package for PC to support unit rate estimating.

d) Planning.

d.1) General characteristics.

Planning is done in several occasions:

**Tender Planning** by the Technical Office.

**Detailed Planning** by the site director during the project execution.

d.2) How planning is done.

Construction activities in **tender planning** are generally in agreement with the headings of the bq or with major works of the project. However, some activities may be further detailed, if it is recognized that a particular item should preferably be broken down before the tender programme is drawn up.

The degree of precision aimed at in tender planning is in agreement with the requirements of the tender documents. Moreover, a minimum level of detail is necessary at this stage so that site costs and indirect costs can be computed. Besides, the tender programme is often submitted to the client. Therefore, it has to be done carefully because the company becomes bound to its accomplishment.

Available data is the output of the tender estimate, but it is seldom fully used, because the degree of precision aimed at in tender planning does not require all
the large volume of information generated in estimating.

Data used by the company in tender planning is:

(1) tender documents supplied by the client;

(2) project measurements and the bill of quantities generated by the company if these were not included in the tender documents;

(3) general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);

(4) priced bill of quantities;

(5) cost studies made in tender estimating;

(6) expected durations of subcontracts according to the inquiries to subcontractors;

(7) spot visit report;

(8) preliminary design of the site layout.

The objective of tender planning is the generation of the following information:

(1) the tender programme for the works;

(2) labour charts for the main work categories;

(3) the time the main plant stays on site.

Durations of activities are established according to the following criteria:

(1) Due dates for the project or for any project stages possibly fixed in the tender documents.
(2) Time required to perform the tasks pertaining to each activity is considered. The experience of the planner is used for the tasks to be carried out directly by the company. If tasks are to be subcontracted, expected duration (based on the inquiries to subcontractors or earlier experiences) is used.

(3) The experience of the planner.

Labour requirements for the most relevant categories are allocated to each activity. This is achieved by considering approximate unit rates for the works included in each activity. Work crews are composed by the planner using past experience. Aggregation charts are drawn up directly by adding up labour requirements of simultaneous activities but they may be further worked out to even out labour demand throughout the project.

The requirements of plant are decided by the planner according to past experience.

The construction programme generated at this stage may have some intermittent activities - which may or may not be current in a given time instance but that only take place within defined limits. It is generally drawn in a bar chart format.

Construction activities in detailed planning are normally in agreement with the items of the bill of quantities. However, some activities may be further detailed, if it is recognized that a particular item should preferably be broken down before the tender programme is drawn up. Furthermore, the construction programme generated at this stage must be fairly accurate because it will be used to carry out the project on site.

Available data includes the output of the tender estimate, and information generated in earlier planning stages:

(1) tender documents supplied by the client;

(2) project measurements and the bill of quantities generated by the company during the pre-contract stage;
(3) general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);

(4) priced bill of quantities;

(5) cost studies made in tender estimating;

(6) expected durations of subcontracts according to the inquiries to subcontractors and to possible contracts made meanwhile;

(7) costs for supplies and subcontracts resulting from any contracts made meanwhile;

(8) spot visit reports;

(9) the tender programme for the works;

(10) the preliminary design of the site layout.

The objective of general planning is the generation of the following information:

(1) the general construction programme for the works;

(2) allocation of resources to activities and the design of site layout.

The construction programme generated at this stage should not differ greatly from the tender programme, because the company is already committed to following it out.

Activity durations are established according to the same criteria referred to above. Moreover, they may be looked at more thoroughly because there is more data available about the project at this stage.

Resource requirements for each activity are decided using data from estimating as follows:
(1) Labour: Labour requirements for the most important classes are allocated to each activity. This is achieved basically by using the experience of the site director as explained above. Work crews are composed by the planner using past experience. Aggregation charts for the most important labour classes are drawn up directly by adding up labour requirements of simultaneous activities but they may be further worked out to level labour demand throughout the project.

(2) Materials: Total quantities of the most significant materials are evaluated for each activity. Aggregation charts for the most important materials are drawn as above.

(3) Plant: The requirements of plant for the most important equipment are estimated by following an identical procedure to labour.

(4) Subcontracts: Start and completion dates of the main subcontracts are defined according to the construction programme.

The scheduling technique used for the generation of the general programme is the bar chart. Resource requirements are listed separately.

Data passed by the planning activity is very important for all departments of the company involved in production, viz:

(1) Labour: The site director sends total labour requirements to the Labour Department. This is checked against the availability of employees of the company and appropriate action is taken.

(2) Materials: The materials charts are sent to the Supplies Department.

(3) Plant: Forecasts on the utilization of plant are discussed with the production director of the company.

(4) Site facilities and plant: Information generated is sent to all departments involved and discussed with the production director of the
Planning for projects taking place at the same time is done at the level of each department involved.

No difficulties were reported in project planning. Moreover, the way it is done led to good results. However, this is a rather time consuming activity, especially in the most detailed stages.

No computer support is used for planning.

e) Production Control.

e.1) General characteristics.

Production control is made for all projects and it is mainly about cost control. This is performed by the Accounting Department.

e.2) How production control is performed.

In order to control costs, total expenditures in labour, materials, plant and subcontracts, are evaluated monthly. The utilization of resources on site is analysed as follows:

(1) Labour: The consumption of each labour class is assessed for the whole project.

(2) Materials: Materials are organized in classes as defined by the Accounting Department. The consumption of the materials pertaining to each class is totaled for the whole project.

(3) Plant: Each plant unit is analysed separately for the whole project.

(4) Subcontracts: Subcontracts are also analysed separately for the whole project.
The appraisal of production costs is made every month by valuing data collected on site in accordance with real costs. These are provided by the company's "central services" or directly from the invoices of suppliers. Subcontracts and other services (eg electricity, telephone, etc.) are also valued from invoices.

Some comparisons between costs forecast and actual costs are made by the site director and the production director as the project is being carried out. At the same time, they check to see if the project is on schedule. However, the global analysis of all costs incurred is only possible at the end of the project, when the Accounting Department has appraised all information required for it.

The company believes that the system could be improved if data from site could be more readily assessed.
PLANS TAKEN FROM HERE
COMPANY E

a) Contact with the company.

a.1) The contact was made through one of the directors of the company who is known personally to the author. Besides, the author had worked in the company for some time in the past and thus retains some direct knowledge of its workings.

a.2) Clarifications required.

It was necessary to formalize the contact with a letter from "Universidade do Minho" (University of Minho) asking for collaboration.

a.3) Interlocutors.

The first person to speak to was the director mentioned above.

b) Production management.

A graphical sketch of the flow of information in the company is presented at the end of this report.

b.1) General characteristics of the company.


(1000 contos) 17 675 22 629 27 079

Number of employees:
Staff: 314
Foremen: 421
Skilled workers: 3483
Unskilled workers: 1429
Apprentices: 579
Total: 6226
Geographical area:

All the country and abroad.

b.2) The organization of the company.

The company is divided into several sectors each one headed by a member of the board of directors. Additionally, sectors are further divided into a number of subsectors each of which has a specific person in charge. For the aims of this study, relevant sectors are those concerned with building projects in the North Region of the country. Specifically, the executive area "Sector Continente Norte e Algarve" Sub-sector Norte" (operations, northern Portugal and the Algarve - north branch) will be surveyed.

The "Sub-sector Norte" is supported by three offices:

"Gabinete de Programação" (Planning Office);
"Gabinete de Preparação" (Preparation Office);
"Gabinete de Apoio Obras" (Production-Support Office).

b.3) Field of activity.

The company undertakes both building and civil engineering projects. However, it normally prefers tendering in association with specialized companies if projects include large earth movements or paving works.

The company is prepared to respond to calls for open tenders and for selective tenders of private clients.

The size of the projects is variable. The largest may reach several million contos (ten million pounds or more).
Several factors influence the company in deciding whether or not to submit an offer to a project. However, the balance of fixed charges and the maintenance of its position in the market are probably the most important.

b.4) Management of construction projects.

The company believes that its structure is well organized. This enables it to perform estimating, planning and production-control management functions rather efficiently.

Estimates are made by the "Direcção Técnico-Comercial" (Technical-Commercial Division). Unit rates are specially based on the company's own data which is collected from production.

Planning is made by the "Gabinete de Programação" (Planning Office) with the participation of the site director.

Production control is carried by the "Área de Meios Operacionais" (Operations Means Area). This works independently of the site director though its staff on site depends on him/her. The volume of information generated allows for acceptable evaluation to be made of the works being carried out, though this data may take some time to become available.

Occasionally, some significant deviations between forecast costs and real costs may occur. This mainly follows from the specific characteristics of the construction industry.

Time for tendering is generally insufficient for a careful study of the project. This is because many projects are not detailed enough and the company has to complete them so that they can be usable. Moreover, bills of quantities are often not delivered by clients so they have to be generated by the company. Sometimes, the company is also responsible for the measurements and this implies additional care in the study. All this involves a lot of time seldom available in the tender stage and large sums of money which may not be refunded. Furthermore, in the case of turnkey projects, risk involved in tendering
is even greater because the company is required to make the preliminary design of the project and this implies more money to spend.

c) Estimating.

c.1) General characteristics.

Estimates are made by a specific department of the Technical-Commercial Division).

c.2) How estimates are made.

Estimates are based on the bill of quantities (bq), which is generally included in the tender documents supplied by the client. In this case, no additional measurements are made for tendering, unless significant errors or omissions are detected in the bill.

If no bill of quantities is available, it is generated by measuring the project. The following criteria are used:

(1) Exhaustive measurements of all works involving the company's resources are always made. Subcontractors are provided with the part of the tender documents relevant to their estimates; they are responsible for the measurements they make.

(2) Measurements are structured into items and these are organized into sections of the bill of quantities.

(3) Identical construction works are joined up into the same bq item irrespective of their location.

(4) Item contents are defined according to the company's criteria which are close to LNEC's. The same stands for the definition of the chapters of the bill of quantities in which items are included.
The bill of quantities generated as described above is used for estimating.

Occasionally, it may not be possible to achieve a great depth of detail in the bill of quantities because of the lack of design data of some projects. Moreover, in some cases, projects have to be further designed in the company before they can be carried out on site. Accordingly, tender estimating has to be done just on the basis of approximate quantities.

Bills of quantities normally supplied by clients are similar to those generated by the company. However, the former may be insufficiently detailed in some cases. This often obliges the company to make extra measurements in order to enable them to make a proper estimate.

The first stage in estimating is the preliminary study of how the project would be carried out on site. For this purpose, some discussions may take place with the production staff of the company. Other basic data is also assessed at this stage, such as the spot location, availability of local labour, plant, subcontractors and materials supplies etc.

Unit prices for each bq item are calculated differently depending on whether works included are to be carried out with the company's resources or subcontracted. If works are to be done with the company's resources, unit prices always follow from a cost study. If works are to be subcontracted, unit prices follow from the rates of subcontractors.

Costs are divided into three classes: direct costs, site costs and indirect costs.

Direct costs include the costs of all resources directly involved in production: viz, labour, materials, plant and subcontracts. Direct costs for the works involving the company's resources are computed by multiplying unit rates by unit costs. Rates are usually supported by available data from the past experience of the company. Published data may be used as well.

Site costs include the costs of site offices and compound facilities, general and major plant items not included in direct costs, other general costs (services, site
transports, licenses etc.), allowances for supervision and clerical staff etc. Site costs are calculated by several approaches depending on the nature of costs concerned. For example, costs of erecting site offices may be assessed by unit rates, transport costs may be allocated as a lump sum following from the previous experience of the company, etc.

Indirect costs include the costs of the supervision of subcontractors, which are covered by a percentage over their costs, and allowances for general overheads of the organization.

Data used by the company in tender estimating is:

1. general tender documents supplied by the client;
2. exhaustive measurements and bill of quantities, specially generated by the company if not included in the tender documents;
3. unit rates for labour and plant, materials usage rates and wastage factors;
4. resource cost data and subcontract rates;
5. current market unit prices;
6. spot visit report including information about expected local work conditions, site layout, materials suppliers etc.;
7. allowances for company overheads and for management markups.

After net costs are known, profit and risk are fixed during the tender meeting. The final offer value is decided according to the interest of the company in carrying out the project and to market conditions. Afterwards, profit and risk allowances are distributed among all bq items, yielding the final priced bq. The priced bill of quantities is normally sent to the client, unless it is neither demanded in the tender documents nor convenient for the company.
Sometimes, discussions may take place with the client before commitment. This is more likely to occur with private clients or with general contractors acting as clients to the company. It may include some changes in the project (substitution of materials, modifications of construction methods, etc), which may lead to the re-analysis of the offer. Only after this stage, does the definitive offer become known.

Tender estimating generates the following information:

(1) general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);

(2) tender-priced bill of quantities (or just the total value of the offer) and possible subsequent revisions;

(3) direct cost studies including resource unit rates and costs, subcontract costs, construction methods considered in estimating, etc.;

(4) preliminary design of the site layout and corresponding costs, according to the tender programme and to the spot visit report;

(5) indirect cost studies;

(6) overheads and allowances included in the offer.

If the company wins the contract, measurements are made again (according to the same criteria described above if) it is possible to apply for errors and omissions of the tender bq.

Tender estimating is supported by a computer program written specially by the company for "main frame" machines.
d) Planning.

d.1) General characteristics.

Planning is done in several occasions:

- **Tender Planning** by the Technical-Commercial Division in the tender stage;

- **General Planning** after commitment by the Planning Office and the site director, in the pre-contract stage;

- **Detailed Planning** by the site director during the project execution.

d.2 How planning is performed.

Construction activities in tender planning are generally in agreement with the headings of the bq or with major works of the project. However, some activities may be further detailed, if it is recognized that a particular item should preferably be broken down before the tender programme is prepared.

The degree of precision aimed at in tender planning is in agreement with the requirements of the tender documents. Moreover, a minimum level of detail is necessary at this stage so that site costs and indirect costs can be computed. Besides, the tender programme is often submitted to the client. Therefore, it has to be done carefully because the company is committed to following it out.

Available data is the output of the tender estimate, but it is seldom fully used because the degree of precision aimed at in tender planning does not require all the large volume of information generated in estimating.

Data used by the company in tender planning is:

1. tender documents supplied by the client;

2. project measurements and the bill of quantities generated by the
company if these were not included in the tender documents;

(3) general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);

(4) priced bill of quantities;

(5) cost studies made in tender estimating;

(6) expected durations of subcontracts according to the inquiries made to subcontractors;

(7) spot visit reports;

(8) preliminary design of the site layout.

The objective of tender planning is the generation of the following information:

(1) the tender programme for the works;

(2) labour charts for the main work categories;

(3) the time the main plant stays on site.

Durations of activities are established according to the following criteria:

(1) Due dates for the project or for any project stages possibly fixed in the tender documents.

(2) Time required to perform the tasks pertaining to each activity is considered. The experience of the planner is used for the tasks to be carried out directly by the company. If tasks are to be subcontracted, expected duration (based on the inquiries made among subcontractors or on previous experiences) is used.

(3) The experience of the planner.
Labour requirements for the most important categories are allocated to each activity. This is achieved by considering approximate unit rates for the works included in each activity. Work crews are composed by the planner, using past experience. Aggregation charts are drawn up directly by adding up labour requirements of simultaneous activities, but they may be further adjusted to even out labour demand throughout the project.

The requirements of plant are decided by the planner according to past experience.

The construction programme generated at this stage may have some intermittent activities - which may or may not be current in a given time instance, but that only take place within defined limits. It is generally drawn in a bar chart format.

Construction activities in general planning are normally in agreement with the items of the bill of quantities. However, some activities may be further detailed if it is recognized that a particular item should preferably be broken down before the tender programme is drawn up. Furthermore, the construction programme generated at this stage must be fairly accurate because it will be used to carry out the project on site.

Available data includes the output of the tender estimate, and information generated in earlier planning stages:

(1) tender documents supplied by the client;

(2) project measurements and the bill of quantities generated by the company during the pre-contract stage;

(3) general contract information (contract conditions additional to those included in the tender documents, payment methods, price revision etc.);

(4) priced bill of quantities;

(5) cost studies made in tender estimating;
(6) expected durations of subcontracts according to the inquiries to subcontractors and to possible contracts made meanwhile;

(7) costs for supplies and subcontracts resulting from any contracts made meanwhile;

(8) spot visit reports;

(9) the tender programme for the works;

(10) the preliminary design of the site layout.

The objective of general planning is the generation of the following information:

(1) the general construction programme for the works;

(2) Allocation of resources to activities and the design of site layout.

The construction programme should not differ greatly from the tender programme, because the company is already committed to its accomplishment at this stage.

The durations of activities are established according to the following criteria:

(1) Due dates for the project or for any project stages possibly fixed in the tender documents.

(2) Time required to perform the tasks pertaining to each activity is considered. If tasks are to be carried out directly by the company, time-consuming resources required to perform them are allocated to the activity by using the same rates of estimating. The number of resources required by the activity and the duration of it are balanced together in order to get an acceptable result. If tasks are to be subcontracted, expected durations according to the inquiries to subcontractors or to earlier experiences are used.
the measurements they make.

(2) Measurements are structured into items and these are organized into sections of the bill of quantities.

(3) Identical construction works are united in the same bq item irrespective of their location.

(4) Item contents are defined according to the company’s criteria which are close to LNEC’s. The same stands for the definition of the sections of the bill of quantities in which items are included.

(5) The bill of quantities generated as described above is used for estimating.

In the case of lump sum contracts when no bq is available from the tender documents, and if the submission of a priced bq is not specifically requested in the tender documents, previous criteria may be simplified as follows:

(1) Exhaustive measurements are restricted to the most cost relevant works and to those involving a higher risk to cost evaluation.

(2) Simplified methods of measurement are adopted for the other construction works enabling straightforward estimating methods to be used. One of the most common approaches used for building projects is the assessment of the price per square meter of slab. This just involves the measurement of the plant areas, possibly divided into classes with distinct unit prices.

However, this is a rather risky approach to estimating. Therefore, it is seldom used and restricted to small projects.

Bills of quantities normally supplied by clients are similar to those generated by the company. However, the former may be insufficiently detailed in some cases.
(3) The durations assigned to the same activities in the preliminary programme.

(4) The experience of the planner.

Resource requirements for each activity are decided by using data from estimating as follows:

(1) Labour: Labour requirements for the most important classes are allocated to each activity. This is achieved by balancing together activity durations and corresponding labour quantities as explained above. Work crews are composed by the planner using past experience. Aggregation charts for the most relevant labour classes are drawn up directly by adding up labour requirements of simultaneous activities, but they may be further worked out to even out labour demands throughout the project. This may lead to the modification of the duration of some activities and to the re-arrangement of the construction programme.

(2) Materials: Total quantities of each material are calculated for each activity. Aggregation charts for the most important materials are drawn up as above.

(3) Plant: The plant requirements for the most important equipment are estimated by following an identical procedure to labour. Aggregation charts are also drawn as above. However, restraints may have to be imposed on the number of units of some equipment to be used, according to their availability in the company.

(4) Subcontracts: Start and completion dates of the main subcontracts are defined according to the construction programme.

Planning of the resources not directly involved in production - thus, not included in direct costs - is done according to the way the costs of those resources were estimated. This may lead to the definition of other activities in the construction programme (for example, site erection), to which resources are allocated. Costs
of these activities are computed afterwards. The costs of other resources which were not allocated to specific activities (for example, supervision labour) are allotted in fixed amounts.

Finally the cash flow of the project costs is computed according to the construction programme.

The scheduling technique used for the generation of the general programme is the CPM. However, information generated is transferred to a bar chart format so that it can be best understood on site. Resources requirements are depicted at the bottom of the bar chart.

**Detailed planning** follows from the development of general planning for the same activities. Data used is basically the same. Nevertheless, a smaller time unit may be adopted, or it may be convenient to make small modifications in order to meet production reality more closely.

Data passed by the planning activity is very important for all departments of the company involved in production, viz:

1. **Labour**: The site director sends total labour requirements to the Labour Division). This is checked against the availability of employees of the company and appropriate action is taken.

2. **Materials**: The materials charts are sent to the Supply Services.

3. **Plant**: Forecasts of the utilization of plant are sent to the "Serviços de Equipamento Centrais" (Plant and Equipment Services), and discussed with the production director of the company.

4. **Site facilities and plant**: Information generated is sent to all departments involved and discussed with the production director of the company.

Planning for projects taking place at the same time is made at the level of each
department involved.

No difficulties were reported in project planning. Moreover, the way it is done led to good results. However, this is a rather time-consuming activity, especially in the most detailed stages.

Scheduling is computer supported in a "main frame" machine. A commercial package is used. However, the company has just decided to start using PC's, so a different package will soon be adopted.

e) Production control.

e.1) General characteristics.

Production control is established for all projects and includes resource control and cost control. This is carried out by the Operations Means Area.

e.2) How production control is performed.

Resources are controlled by comparing forecasts with their actual utilization on site. Expenditures in labour, materials, plant and subcontracts, are evaluated monthly for all items of the bill of quantities. The utilization of resources on site is analysed as follows:

(1) Labour: The consumption of each labour class is assessed for each task.

(2) Materials: Materials are organized in classes as defined by the Accounting Department. The consumption of the materials pertaining to each class is totaled for the whole project. However, the consumptions of the most expensive materials are specifically controlled. Moreover, materials used for concrete are studied apart.

(3) Plant: Each plant unit is analysed separately for the whole project. However, the most expensive ones are controlled for each bq item.
Operators, and materials which have been consumed in operation are allocated to the corresponding equipment.

(4) Subcontracts: Subcontracts are also analysed separately for each item of the "production chart".

Actual utilization of labour and major plant items on site are compared to the forecasts for each item of the bill of quantities.

The appraisal of production costs is made every month by valuing data collected on site with actual costs. These are provided by the company's "central services" or directly from the invoices of suppliers. Subcontracts and other services (e.g. electricity, telephone, etc.) are also valued from invoices.

After total site expenditures are computed, production costs are refined in order to avoid some possible distortions. This includes considering stocks (both materials stocks and works partially completed), some plant costs and indirect costs not directly assessed by the above approaches. "Correct economic positions" for the project are generated thereafter, and they are then analysed by the site director and the production division director.

The Gabinete de Controlo Económico (Economic Control Office) compares the revenues and costs for all projects being carried out by the company. This allows for the composition of the "economic position" of the whole building sector of the company. Other sectors are analysed similarly in order to reveal how the company is running the projects. Moreover, this study is helpful for the definition of the proportion of the company's overheads to allocate to each project.

Direct cost forecast for each month are obtained by multiplying works carried in that particular month by unit costs. Indirect costs are evaluated identically.

Each site director is required to make the predict the cash flow of the projects running under his/her direction for the following months. This is based on earlier information and on his own perception of the project evolution.
Every two weeks, the Planning Office checks to see if the project is running on schedule. This is discussed with the site director and the production division director and appropriate action may be taken if necessary.

The company believes that the system is good, and the volume of information used is adequate. The main problem is costs involved in production control because a lot of people are needed to perform it.

Some computer based procedures are used, especially for handling data as, for example, in productivity calculations (which are treated statistically with data from several projects) and in the assessment of "economic positions".
PLANs
TAKEN
FROM
HERE
APPENDIX 2

PECI - A Computer Program for the Integrated Model.

A2.1 Introduction.

PECI comprises a set of programs written in the dBASE III PLUS programming language. It was designed to help the user in the management of construction projects. Specifically, PECI supports estimating, planning and the preparation of data for control. It was developed on the basis of the flow chart of section 8.4. An attempt was made to use computer support for most of the operations depicted therein.

However, PECI is just a prototype computer system which will be used to test the adequacy of the approach suggested in chapter 4 for integration of management functions. Therefore, most of its facilities are not so powerful as they usually are in current commercial systems. Moreover, the author is aware that the abilities of PECI could probably be better than they are. There are two main reasons for this:

lack of time and computer expertise of the author;

lack of more powerful hardware and software tools.

Most of the work with PECI does not require any knowledge of dBASE III PLUS command syntax. However, some operations like entering data in basic files or printing reports are still performed at the command level in this version of PECI. Moreover, the keyboard commands to enter and edit data on the screen will be used throughout the system.

Each field or item of data to be filled in by the user has a maximum allowable length indicated on the screen by a shaded area. Data types should also be respected. Sometimes data entry has to be confirmed by the user. PECI waits for a (Y/N) answer. Other times the system will recognize a valid entry and display a message if an error is detected. In this case, the user is requested to make
another attempt.

Next section describes the database and program files which comprise PECI. A sample project is presented afterwards. The way the system handled it is fully described.

A2.2 File and field name conventions.

File and field names have deserved some consideration in order to improve the readability and consistency of the system. Names have been selected so that they suggest their contents.

Standard dBase III PLUS names and extensions have been used for files. File names are not longer than eight characters. The prefix JT has been chosen for all database and index files and for most program files. This makes some operations concerning all files easier to perform. The following file extensions are used: .dbf for databases, .ndx for index files and .prg for programs. Names for index files have been selected by combining the names of the database and the field(s) upon which the index is based. Program names suggest the database names or the field names to which they are related. Some times PECI uses temporary databases or auxiliary databases. Their names always begin with JTTMP or JTAUX prefixes as the case may be.

Field names also follow the conventions of dBase III PLUS. They are all seven characters long and they approximate English words. Fields are attributes of the entities which have been discussed in chapter 6. Therefore, the following prefixes for field names have been chosen:

- RES for resources;
- TAS for tasks;
- WRK for works;
- ACT for activities;
- BQI for items of the bill of quantities;
- ISC for internal subcontracts;
- ESC for external subcontracts.
The following set of suffixes have been used in order to build up field names:

- **CODE** for code;
- **UNIT** for measuring unit;
- **DESC** for description;
- **QUAN** for measuring quantity;
- **COST** for cost;
- **UNCO** for unit cost;
- **DURA** for duration;
- **TEAM** for the size of the labour team involved.

Moreover, the following less self-explanatory field names have been chosen:

- **RESALLA** for **RES**ource **ALL**ocation to **A**ctivities;
- **RESALLI** for **RES**ource **ALL**ocation to the **I**tems of the **bq**;
- **KEY_RES** for **KEY** **RES**ources;
- **PALLRES** for **P**roject **A**llocation **RES**ources;
- **SCHTIUN** for **S**cheduling **T**ime **UN**it;
- **PROJNAM** for **PRO**ject **N**ame;
- **PR_DATE** for **PR**oject **DATE**.

### A2.3 The system of codes.

Codes are essential to identify the entities involved in the system. Five distinct codes are used throughout the system. Their main features are listed below:

**Resource codes (RESCODE): _ · _ · _ · _ · _ · _ · _**

Three sets of characters separated by periods (eight characters long). The first character corresponds to the resource type code. The following resource types are used:

- **L** for labour;
- **M** for materials;
P for plant;  
I for internal subcontracts;  
E for external subcontracts.

The next two characters refer to a possible chapter code and the last three characters to the element code.

Task codes (TASCODE): __ · ___

Two sets of characters separated by periods (six characters long). A similar organization to LNEC IC4 has been used: The first two characters correspond to the chapter and the last three characters correspond to the elementary construction task.

Work codes (WRKCODE): __ __ __ · __ · ___

Three sets of characters separated by periods (thirteen characters long). The first five characters correspond to a possible measurement coding system. The next two characters refer to the construction element and the last four characters to its location in the project.

Activity codes (ACTCODE): __ __ __ · __ · __

Three sets of characters separated by periods (ten characters long). The first five characters are used for the activity identification. The next two are used for activity location and the last one for the organization which performs the activity.

Items of the bq codes (BQICODE): __ · __ · __

Three sets of characters separated by periods (nine characters long). Character sets refer to the chapter code, the item code and the sub-item code of the bill of quantities.

Internal sub contracts codes (ISCCODE) and external sub contracts codes (ESCCODE) are resource codes (RESCODE) starting respectively with I or E.
A2.4 The system files.

PECI requires several files which have been grouped into the following file sets:

Basic Files contain general information about usual resources, tasks and internal subcontracts used in most construction projects. The prefix JTB has been selected for the Basic Files names. The Portuguese or English language may be selected for these basic data.

Source Files contain information about resources, tasks and internal subcontracts to be used in a specific project. The prefix JTS has been selected for the Source Files. Data is collected from general source files with the prefixes SR, ST and SI respectively.

Project Files contain information about a specific project. The prefix JTP has been selected for these files.

Work Files contain information about the construction works within a specific project. The prefix JTW has been selected for these files.

Due to their nature, auxiliary files and temporary files are not included in the above sets.

The structures of the system files are shown in next figures. Index files and the key resources upon which indexes are based are displayed as well.

A2.4.1 The basic files.

Three files have been created: The Basic Resources file JTBRES, the Basic Tasks file JTBTASK and the Basic Internal Subcontracts file JTBISC. Their structures are shown in figures A2.1 to A2.3. Files may use either Portuguese or English data. If Portuguese language is selected, data will be appended from BRESP.dbf, BTASP.dbf and BISCP.dbf whereas if English language is selected will be appended from BRESP.dbf, BTASP.dbf and BISCP.dbf files respectively.
### Structure for database: C:JTBRRES.dbf
- Number of data records: 0
- Date of last update: 24/08/91

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<td>Character</td>
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</table>

**Total**: 51

index file: C:JTBRRECO.ndx Key: RESCODE
index file: C:JTBRREDI.ndx Key: RESDESC

#### Figure A2.1: The Basic Resources File (JTBRRES)

### Structure for database: C:JTBTAS.dbf
- Number of data records: 0
- Date of last update: 24/08/91

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<td>TASDESC</td>
<td>Character</td>
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**Total**: 109

index file: C:JTBTTACO.ndx Key: TASCODE
index file: C:JTBTTADI.ndx Key: TASDESC

#### Figure A2.2: The Basic Tasks File (JTBTAS)

### Structure for database: C:JTBISC.dbf
- Number of data records: 0
- Date of last update: 24/08/91

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<td>ISCODESC</td>
<td>Character</td>
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</table>

**Total**: 51

index file: C:JTBIIISCO.ndx Key: RESCODE
index file: C:JTBIIISDI.ndx Key: RESDESC

#### Figure A2.3: The Basic Internal Subcontracts File (JTBISC)
A2.4.2 The source files.

Three files have been created: The Source Resources file (JTSRES) the Source Tasks file (JTSTAS) and the Source Internal Subcontracts file (JTSISC). The structure of source files is shown in figures A2.4 to A2.6. Data for this files is appended from Standard files with identical structures. The following prefixes are used in standard files: SR for resources, ST for tasks and SI for internal subcontracts. Generally, several standard files may exist for resources, tasks or internal subcontracts but only one of each file set may be selected for a particular project.

```
Structure for database: C:JTSRES.dbf
Number of data records: 0  
Date of last update : 24/08/91
Field Field Name Type With Dec Index
 1 RESCODE Character 8 Y
 2 RESCOST Numeric  6 2  N
 ** Total **          17
index file : C:JTSRRECOndx Key: RESCODE
```

Figure A2.4: The Source Resources Cost File (JTSRES)

```
Structure for database: C:JTSTAS.dbf
Number of data records: 0  
Date of last update : 24/08/91
Field Field Name Type With Dec Index
 1 TASCODE Character 6 Y
 2 RESCODE Character 8 N
 3 RESQUN Numeric 7 3  N
 ** Total **          22
index file : C:JTSTACOndx Key: TASCODE
```

Figure A2.5: The Standard Tasks File (JTSTAS)
A2.4.3 The project files.

Nine of these files have been created, which have been organized into four file sets as follows. The first set is composed of the Project Works file (JTPWRK) and the Project Relations file (JTPREL). Their structures are shown in figures A2.7 and A2.8.

Figure A2.6: The Standard Internal Subcontracts File (JTSISC)

Figure A2.7: The Project Works File (JTPWRK)
Figure A2.8: The Project Relations File (JTPREL)

In the second file set are included the Project Total Resource Requirements file (JTPTRR) and the Project Operations file (JTPOPS). These files relate to the works for which an operational estimating procedure has been selected. Their structures are shown in figures A2.9 and A2.10.

Figure A2.9: The Project Total Resource Requirements File (JTPTRR)
Structure for database: C:JTPOPS.dbf
Number of data records: 0
Date of last update: 24/12/91

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**Total:** 33

Index file: C:JTPOWRCO.ndx Key: WRKCODE
Index file: C:JTPOACCO.ndx Key: ACTCODE

Figure A2.10: The Project Operations File (JTPOPS)

The third file set includes the activities-related files viz, the Project Summary Activities file (JTPSAC), the Project Activities file (JTPACT) and the Project Duration file (JTPDUR). Their structures are shown in figures A2.11 to A2.13.

Structure for database: C:JTPSAC.dbf
Number of data records: 0
Date of last update: 24/12/91

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</table>

**Total:** 66

Index file: C:JTPSACCO.ndx Key: ACTCODE
Index file: C:JTPSACDI.ndx Key: ACTDESC

Figure A2.11: The Project Summary Activities File (JTPSAC)
The fourth file set comprises bill of quantities-related files viz, the Project Summary Bill of Quantities file (JTPSBQ) and the Project Bill of Quantities file (JTPBQI). Their structures are shown in figures A2.14 and A2.15.
A2.4.4 The work files

Six files have been created which have been organized into two file sets as follows.

The first set is composed of the Work Tasks file (JTWWTAS) and the Work Cards file (JTWCAD). Their structures are shown in the following figures.
Structure for database: C:JTWTAS.dbf
Number of data records: 0
Date of last update : 24/12/91

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** Total **

Index file: C:JTWTTACO.ndx Key: TASCODE
Index file: C:JTWTTADI.ndx Key: TASDESC

Figure A2.16: The Work Tasks File (JTWTAS)

Structure for database: C:JTWCAD.dbf
Number of data records: 0
Date of last update : 24/12/91

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** Total **

Index file: C:JTWCTACO.ndx Key: TASCODE
Index file: C:JTWCRECO.ndx Key: RESCODE

Figure A2.17: The Work Cards File (JTWCAD)

The second file set includes all the resource-related files viz the Work Resources file (JTWRES), the Work Internal Sub-Contracts file (JTWISC), the Work Sub-Contracts Card file (JTWSCD) and the Work External Sub-Contracts file (JTWESC). Their structures are shown in next figures.
Structure for database: C:JTWRES.dbf
Number of data records: 0
Date of last update: 24/12/91

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</table>

** Total **: 59

Index file: C:JTWRRECOndx Key: RESCODE
Index file: C:JTWRREDIndx Key: RESDESC

Figure A2.18: The Work Resources File (JTWRES)

Structure for database: C:JTWISC.dbf
Number of data records: 0
Date of last update: 24/12/91

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** Total **: 59

Index file: C:JTWIISCOndx Key: ISCCODE
Index file: C:JTWIISDIndx Key: ISCDESC

Figure A2.19: The Internal Subcontracts File (JTWISC)
### Figure A2.20: The Work Sub-Contracts Cards File (JTWSCD)

Structure for database: C:JTWSCD.dbf  
Number of data records: 0  
Date of last update: 24/12/91  
Field | Field Name | Type | With Dec | Index  
-----|------------|------|----------|--------  
1    | ISCCODE    | Character | 8        | Y       
2    | RESCODE    | Character | 9        | Y       
3    | RESQUAN    | Numeric | 7        | N       
4    | RESCOST    | Numeric | 8        | 2      | N       
** Total ** |            |         | 32       |        
index file  | C:JTWSISCO.ndx | Key: ISCCODE  
index file  | C:JTWSRECO.ndx | Key: RESCODE

### Figure A2.21: The External Subcontracts File (JTWESC)

Structure for database: C:JTWESC.dbf  
Number of data records: 0  
Date of last update: 24/12/91  
Field | Field Name | Type | With Dec | Index  
-----|------------|------|----------|--------  
1    | ESCCODE    | Character | 6        | Y       
2    | ESCDESC    | Character | 40       | N       
3    | ESCCOST    | Numeric | 8        | 2      | N       
4    | ESCDURA    | Numeric | 5        | 2      | N       
4    | SCHTIUN    | Character | 4        | N       
** Total ** |            |         | 66       |        
index file  | C:JTWEESCO.ndx | Key: ESCCODE

### A2.4.5 Auxiliary files and Temporary files

These files are used to help in PECI data manipulation process. The difference between these two file sets is that while auxiliary files have been previously created for latter use in some program units, temporary files are automatically created within the program units.
Four auxiliary files have been created. Their structures are shown in the following figures.

**Structure for database: C:JTAUX1.dbf**
Number of data records: 0
Date of last update: 24/12/91

<table>
<thead>
<tr>
<th>Field</th>
<th>Field Name</th>
<th>Type</th>
<th>With</th>
<th>Dec</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ACTCODE</td>
<td>Character</td>
<td>10</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>RESCODE</td>
<td>Character</td>
<td>8</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>RESALLA</td>
<td>Numeric</td>
<td>7</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>ACTCOST</td>
<td>Numeric</td>
<td>8</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>ACTTEAM</td>
<td>Numeric</td>
<td>2</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

**Total**: 36

Index file: C:JTA1ACCO.ndx Key: ACTCODE
Index file: C:JTP1RECO.ndx Key: RESCODE

Figure A2.22: The first Auxiliary File (JTAUX1)

**Structure for database: C:JTAUX2.dbf**
Number of data records: 0
Date of last update: 24/12/91

<table>
<thead>
<tr>
<th>Field</th>
<th>Field Name</th>
<th>Type</th>
<th>With</th>
<th>Dec</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BQICODE</td>
<td>Character</td>
<td>9</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>RESCODE</td>
<td>Character</td>
<td>8</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>RESALLI</td>
<td>Numeric</td>
<td>7</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>BQICOST</td>
<td>Numeric</td>
<td>8</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

**Total**: 33

Index file: C:JTA2BQCO.ndx Key: BQICODE
Index file: C:JTA2RECO.ndx Key: RESCODE

Figure A2.23: The second Auxiliary File (JTAUX2)
The structures of temporary files are identical to the files from which they are generated. Three of these files are created when PECI is run and their structures follow from the following files:

- JTTMP1.dbf has an identical structure to JTAUX1.dbf;
- JTTMP2.dbf has an identical structure to JTAUX2.dbf;
- JTTMP3.dbf has an identical structure to JTWSCD.dbf;
- JTTMP4.dbf has an identical structure to JTPREL.dbf.
A2.4.6 The SFDATA file.

This file is used to store project names and the date of the last update. The structure of SFDATA is shown in figure A.3.26 below.

```
Structure for database: C:SFDATA.dbf
Number of data records: 0
Date of last update : 24/12/91
Field   Field Name  Type  With Dec  Index
  1   PROJNAM      Character  7   Y
  2   PR_DATE      Date     8   N
** Total **   16
index file    : C:SFDAPRRA.ndx  Key: PROJNAM
```

Figure A2.26: SFDATA File

A2.4.7 File sizes.

Once the file structures have been established, a rough calculation of the size of the databases is possible by multiplying their record lengths by the expected number of records.

In order to estimate the size of Basic files and Source files, the size of LNEC IC4 files will be considered. These include approximately 1000 distinct resources and 820 construction tasks. An average of five distinct resources per task will be considered. Moreover, 100 distinct internal sub-contracts will be added. Accordingly,

- JTBRES: 1000 resources x 51 bytes = 51 000
- JTBTAS: 820 tasks x 109 bytes = 89 380
- JTRISC: 100 sub-contracts x 51 bytes = 5 100
- JTSRES: 1000 resources x 17 bytes = 17 000

399
JTSTAS: 820 tasks x 5 resources x 22 bytes = 90 200
JTSISC: 100 sub-cont. x 5 res. x 24 bytes = 12 000
Sub-total = 264 680

PECI uses two languages for basic files. Disk space required may be calculated as follows:

\[ 2 \times (51 000 + 89 380 + 5 100) = 290 960 \text{ bytes.} \]

Source files to be used in each project are appended from general source files. Assume four distinct general source files for resources (sr*.dbf), tasks (st*.dbf) and internal sub-contracts (si*.dbf). Disk space required is

\[ 4 \times (17 000 + 90 200 + 12 000) = 476 800 \text{ bytes.} \]

Disk space to allocate data form 100 projects in SFDATA.dbf is

\[ \text{SFDATA:100 projects} \times \text{16 bytes} = \text{1 600} \]

\[ \text{Sub-total} = \text{769 360} \]

The size of project files (JTP*.dbf) and work files (JTW.dbf) depends on the project. For the aims of a rough size estimating, assume a rather large project with:

- 1 000 construction works;
- 200 activities;
- 400 items in the bill of quantities;
- 600 distinct resources;
- 40 internal sub-contracts;
- 20 distinct external sub-contracts.

Moreover, it is assumed that 70% of the construction works will be handled by using a unit rate approach involving 400 distinct construction tasks and that the remaining 30% will be handled by using an operational type analysis. Then, the
sizes of the above files would be the following:

<table>
<thead>
<tr>
<th>File</th>
<th>Description</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>JTPWRK</td>
<td>1 000 works × 116 bytes</td>
<td>116 000</td>
</tr>
<tr>
<td>JTPREL</td>
<td>1 000 works × 46 bytes</td>
<td>46 000</td>
</tr>
<tr>
<td>JTPTRR</td>
<td>300 works × 31 bytes</td>
<td>9 300</td>
</tr>
<tr>
<td>JTPOPS</td>
<td>300 works × 33 bytes</td>
<td>9 900</td>
</tr>
<tr>
<td>JTPSAC</td>
<td>200 activities × 66 bytes</td>
<td>13 200</td>
</tr>
<tr>
<td>JTPACT</td>
<td>200 activities × 38 bytes</td>
<td>7 600</td>
</tr>
<tr>
<td>JTPSBQ</td>
<td>400 items × 75 bytes</td>
<td>30 000</td>
</tr>
<tr>
<td>JTPBQI</td>
<td>400 items × 33 bytes</td>
<td>13 200</td>
</tr>
<tr>
<td>JTWAS</td>
<td>400 tasks × 109 bytes</td>
<td>43 600</td>
</tr>
<tr>
<td>JTWCAD</td>
<td>400 tasks × 5 resources × 30 bytes</td>
<td>60 000</td>
</tr>
<tr>
<td>JTWRES</td>
<td>600 resources × 59 bytes</td>
<td>35 400</td>
</tr>
<tr>
<td>JTWISC</td>
<td>40 sub-contracts × 59 bytes</td>
<td>2 360</td>
</tr>
<tr>
<td>JTWSAC</td>
<td>40 sub-cont. × 5 res. × 32 bytes</td>
<td>6 400</td>
</tr>
<tr>
<td>JTWSAC</td>
<td>20 sub-contracts × 66 bytes</td>
<td>1 320</td>
</tr>
</tbody>
</table>

Sub-total = 394 280
Total     = 1 328 320

Allowing 60 more Kbytes for the program files and 5 Kbytes for index files, the system would require roughly 1.4 Mbytes to run a project like the above. Allowing 3.6 more Mbytes to accommodate the files of dBASE III PLUS, a total disk space of 5 Mbytes would be required.

Historical data may be stored in floppy disks of 1.2 Mbytes capacity. Each of these is enough for 3 projects as large as the above one.

The above calculations show that a current personal computer (40 Mbytes hard DESC capacity) would be enough to run the above sample project. Moreover, data from several projects can easily be stored in the hard disk before transferring it to floppy disks as suggested above.
A2.5 Using PECI.

A2.5.1 Introduction.

PECI comprises a set of elementary programs. The program files (JT*.prg) are listed at the end of this Appendix. Programs are used for data entry and data manipulation procedures and to manage the system at the user's choice. In order to make communication easier between PECI and the user, a set of menus of options has been created.

The following sections describe the capabilities of PECI and how it can be used to perform estimating, planning and the preparation of control for construction projects. However, the best way to show how it can be used in real life projects is to follow an example. A sample project has been specially designed to test the ability of PECI in most of its features. Next sections describe data entry procedures for that project.

A2.5.2 Starting PECI.

The mask of figure A2.27 was created for all the screens used by PECI. This is displayed by JTMASK.prg.

Enter a dBASE III PLUS command.

Figure A2.27: PECI mask
In order to activate PECI, the following command should be entered by the user at the dot prompt level of dBASE III PLUS:

```plaintext
do PECI
```

Command will pass to PECI.prg which displays the following "Welcome Screen":

```
PECI by: Jose M. Cardoso Teixeira, 1991.

PLANNING ESTIMATING AND CONTROL INTEGRATED
Loughborough University of Technology (UK)
Universidade do Minho (Portugal)

October 1991

press any key to continue

Do you want to modify language for Basic Files (y/n) ?
```

Figure A2.28: The Welcome Screen

The welcome screen includes the question about the language to be used in basic files. If the user wants to change it, the system will delete the contents of current basic files JTB*.dbf and will append Portuguese or English data according to the selection.
A2.5.3 Using the Main Menu

Pressing any key makes PECI.prg display the "Main Menu" as shown in figure A2.29.

Selecting option (1) - Create new source files makes the system display the message:

Please use dBase III PLUS command level.

This means that creating new source files like sr*.dbf, st*.dbf or si*.dbf has to be made at the command level in this prototype version. Therefore, the user should next select option (8) - Exit to dBASE III PLUS Command Level if new source files have to be created.

Option (4) - Save your work will make the system store the files generated for a particular project into the PECI directory of the root (c:\). Firstly a name for the

Figure A2.29: The Main Menu
project is demanded. A suitable name can be any string of five characters allowed by MS-DOS for directory name and not before as a project name. Then PECI.prg automatically creates a subdirectory of c:\PECI with the project name and will copy all JT*.dbf and JT*.ndx files to it. For example, if TEST1 would be the project name, all JT*.dbf and JT*.ndx files generated by PECI would be copied to c:\PECI\TEST1 directory. Moreover, the project name will be stored into SFDATA.dbf for later use. Finally, unless the user tells PECI otherwise, the system will delete data from current files (by running ZAPPACK.prg) so that they can be ready for future use.

Option (9) - Exit to MS-DOS Operating System will activate the "Quit" command of dBASE III PLUS.

Options (2) and (3) will make the system follow a set of procedures as described in next sections. The effect of option (3) will be discussed in first place.

**A2.5.4 Working with a new project.**

Selecting option (3) in "Main Menu" will make the system run SETPACK.prg which has the effect of "packing" files to be used. Then command is transferred to JTPNEW.prg. The "Project Menu" as shown in figure A2.30 is displayed.

The four first options in this menu will make the system use data entry programs:

Option (1) - *Enter project measurements* will activate JTPWRK.prg which guides the user in data entry for JTPWRK.dbf. Data for all fields has to be entered by the user.

Option (2) - *Set relations among construction entities* will activate JTPREL.prg which helps in data entry for JTPREL.dbf. Work codes which would have been previously entered in JTPWRK.dbf are automatically transferred to the WRKCODE field of JTPREL.dbf; the user will enter data for the other fields. If no task code is assigned to a construction work, the system understands that that work will be handled using an operational approach. PECI automatically stores the word "NOUGHT" in the field.
PECI
Project Menu
(1) Enter project measurements
(2) Set relations among construction entities
(3) Select source files for the project
(4) Settle tasks and resources
(5) Work with the construction activities module
(6) Work with the bg items module
(7) Return to the Main Menu

Please enter your selection 0

Figure A2.30: The Project Menu for new projects

Option (3) - Select source files for the project will activate JTSFIL.prg which displays all the existing sr*.dbf, st*.dbf and si*.dbf files and asks the user for selection. Default selections exist viz,

SR000RES.dbf for resources source file;
STJCTTAS.dbf for tasks source file;
SIIC4ISC.dbf for internal sub-contracts file.

JTSFIL.prg will then append data to the corresponding Basic Files JTBRES.dbf, JTB TAS.dbf and JTBISC.dbf.

Option (4)- Settle tasks and resources will make JTPNEW.prg develop the following set of sequential procedures:

1 Pass the command to JTWTAS.prg in order to enter data for JTWTAS.dbf. The tasks codes are automatically transferred from JTPREL
unless they are "NOUGHT". The program checks each task code in JTBTAS.dbf and if the task code exists there, data will be automatically transferred to JTWTAS.dbf. Otherwise, the user will be asked to enter corresponding data. Return command to JTPNEW.prg.

2 Pass the command to JTWCAD.prg in order to enter data for JTWCAD.dbf. Data for the construction tasks which correspond to the task codes in JTWTAS.dbf is automatically transferred from JTSTAS.dbf for the existing codes. Otherwise the user will be asked for data. Command returns to JTPNEW.prg.

3 Enter data for the resources declared in JTWCAD.dbf. After this file has been selected, command passes to JTWRES.prg which manages the following operations:

3.1 Enter data for JTWISC.dbf. This is achieved by JTWISC.prg which operates similarly to JTWTAS.prg and by JTWSCD.prg which operates as JTWCAD.prg. Data about L, M and P resources used within internal subcontracts will be automatically passed to JTWRES.dbf by those programs.

3.2 Enter data for JTWESC.dbf. This is achieved by JTWESC.prg which is similar to JTWISC.prg.

3.3 Enter data for L, M and P resources the codes of which do not exist in JTBRES.dbf and which were not previously dealt with. This is achieved by JTWLMP.prg.

3.4 Return command to JTPNEW.prg.

4 Pass command to JTCOIN.prg which passes cost information (in RESCOST field) JTWRES.dbf to JTWCAD.dbf. Return command to JTPNEW.prg afterwards.

5 Enter data for the resources which had been declared in JTPTRR.dbf. After this file has been selected, command will be passed to
JTWRES.prg which manages the operations described under 3.1 to 3.4.

Option (5) - Work with the construction activities module or option (6) - Work with the bq items module will make the system use other "Menus" as described later.

A2.5.5 Working with an old project.

Selecting option (2) in "Main Menu" will make PECI.prg ask the user for the name of the project to be handled. The contents of SFDATA.dbf are displayed on the screen. The system will accept any name from that list. Then PECI.prg will automatically copy all JT*.dbf and JT*.ndx files from the corresponding subdirectory of c:\PECI to the directory of dBASE III PLUS. For example, if TEST1 were the name of the project to be recalled, all files in c:\PECI\TEST1 would be copied. Then PECI.prg will pass the command to JTPOLD.prg and the "Project Menu" as shown in figure A2.31 is displayed.

---

PECI
by: Jose M. Cardoso;Teixeira, 1991.

JTPOLD

PECI
Project Menu
(1) Enter new project measurements
(2) Set relations among construction entities
(3) Select other source files for the project
(4) Settle tasks and resources
(5) Work with the construction activities module
(6) Work with the bq items module
(7) Return to the Main Menu

Please enter your selection 0

Figure A2.31: The Project Menu for old projects
The way JTPOLD.prg operates is similar to JTPNEW.prg. Main differences are referred to below:

If option (1) is selected, new construction works may be added to the project but only new work codes will be accepted by JTPWRK.prg.

Selecting option (2) will make the system list one at a time the relations which had been established in the last update of JTPREL.dbf. The user will be asked if those relations are to be kept or if they shoud be modified.

Option (3) should be selected only if the user wishes to alter source files for the project.

Option (4) will make JTPOLD.prg delete the contents of work files (JTW*.dbf) JTPTRR.dbf and JTPOPS.dbf if new source files have been selected for the project in option (3). Otherwise only fresh data will be handled.

Options (5) and (6) will be discussed later.

**A2.5.6 Using the activities module.**

Option (5) of the "Project Menu" will make the system use the activities module. When working on a new project, the system will immediately pass control to JTPACM.prg. Otherwise the user will be asked if new measurements have been added to the last version of the project being handled. A positive answer will make JTPOLD.prg delete JTPACT.dbf and JTPK_R.dbf before passing control.

As control is passed to JTPACM.prg, the "Activities Menu" as shown in figure A2.32 will be displayed on the screen.

Option (1) - *Enter activities descriptions* will activate JTPSAC.prg. The user is asked to enter activities descriptions and units (if any) for all the activity codes in ACTCODE field of JTPREL which were not previously handled. Moreover, JTPSAC.prg automatically transfers from JTPOPS.dbf activities durations form
Activities Menu

(1) Enter activities descriptions
(2) Transfer resources data to activities
(3) Select key resources
(4) Select activities durations
(5) Select resources to allocate in the scheduling module
(6) Return to the Project Menu

Please enter your selection 0

Figure A2.32: The Activities Menu

JTPTRR.prg. Command returns to JTPACM.prg.

Selecting option (2) will make JTPACM.prg transfer command to JTPACT.prg which automatically enters data for the ACTCODE, RESCODE, RESALLA and ACTCOST fields of JTPACT.dbf. Activity costs is passed back to JTPSAC.dbf. Command returns to JTPACM.prg.

Option (3) will make JTPACM.prg pass command to JTPK_R.prg. The user is asked to select which key-resources should be considered in the activities duration procedure as discussed below. Each construction activity is dealt with at a time. Command will return to JTPACM.prg.

Option (4) will make the system help the user to assign durations to the project activities. Command passes to JPDUR.prg which manages all the process. Firstly, the scheduling unit is selected and relevant data for each activity is collected. Then data is passed to JTPADU.prg which runs for each activity.
Activities durations are computed from the quantities of key-resources required and the number of resources the user decides to allocate. This is an interactive procedure which is successively repeated until the user wishes to stop. Command finally returns to JTPACM.prg after all activities have been handled.

Option (5) will make the system pass command to JTPRAL.prg. The user is asked which resources from JTWRES.dbf should be handled by the scheduling program. Information is stored in the PALLRES field of JTPACT.dbf. Command returns to JTPACM.prg.

A2.5.7 Using the bq items module.

Option (6) of the "Project Menu" will make the system use the bq items module. When working on a new project, the system immediately passes control to JTPBQM.prg. Otherwise the user is asked if new measurements had been added to the last version of the project being handled. A positive answer makes JTPOLD.prg delete JTPBQI.dbf before passing control.

As control is passed to JTPBQM.prg, the "Bill of Quantities Menu" as shown in figure A2.33 will be displayed on the screen.

Option (1) - Enter items descriptions, will activate JTPSBQ.prg. The user is asked to enter descriptions and units for all the bq items codes in BQICODE field of JTPREL which were not previously handled. Command will return to JTPBQM.prg.

Selecting option (2) will make JTPBQM.prg transfer command to JTPBQI.prg which automatically enters data for the BQICODE, RESCODE, RESALL and BQICOST fields of JTPBQI.dbf. Item costs are passed back to JTPSBQ.dbf. Then command passes to JTPQUA.prg which is used to compute item quantities and unit costs. Information is stored in BQIQUAN and BQIUNCO fields of JTPSBQ.dbf.
A2.5.8 Testing the system with sample data.

In this section, a sample project will be used to test PECI. The sample project is an ordinary three storey building. The production problem is the management of brickwork construction in internal walls. PECI was used to tackle the problem as shown herein after.

English language was selected for this project. The contents of basic files to be used for this project are shown in figures A2.34 to A2.36 below.
Figure A2.34: The contents of JTBTAS.dbf file.

<table>
<thead>
<tr>
<th>Record#</th>
<th>RESCODE</th>
<th>RESUNIT</th>
<th>RESDESC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M.00.012</td>
<td>Kg</td>
<td>Portland cement</td>
</tr>
<tr>
<td>2</td>
<td>M.00.002</td>
<td>m3</td>
<td>sand</td>
</tr>
<tr>
<td>3</td>
<td>M.00.039</td>
<td>m3</td>
<td>water</td>
</tr>
<tr>
<td>4</td>
<td>M.00.043</td>
<td>Un</td>
<td>bricks 0.30x0.20x0.11</td>
</tr>
<tr>
<td>5</td>
<td>M.00.042</td>
<td>Un</td>
<td>bricks 0.30x0.20x0.15</td>
</tr>
<tr>
<td>6</td>
<td>M.00.044</td>
<td>Un</td>
<td>bricks 0.30x0.20x0.15</td>
</tr>
<tr>
<td>7</td>
<td>L.00.001</td>
<td>Jr</td>
<td>bricklayer</td>
</tr>
<tr>
<td>8</td>
<td>L.00.018</td>
<td>Jr</td>
<td>worker</td>
</tr>
</tbody>
</table>

Firstly, construction works were recognized and measurements were made. This led to seven distinct construction works. A code was assigned to each construction work. The user is free to select which code convention to use. For this project the Masterformat of The Construction Specifications Institute of the...
USA was used. For example, the second construction work,

common brickwork 0.11 thick in internal walls of the second floor,

was assigned to the work code 04210.IW.0202 which means:

04210 - clay unit masonry;

.IW. - internal walls;

0202 - type 2 (ie 0.11 thick) of the 2nd floor.

Data about construction works is entered in JTPWRK.dbf. In order to activate the entering screen, the user selected option (1) - Enter project measurements in the "Project Menu" of figure A2.30. This screen is shown in figure A2.37. Figure A2.38 shows the contents of JTPWRK after data for all construction works had been entered.

---

PEel by: Jose M. Cardoso Teixeira, 1991.

Please enter project data for JTPWRK.

work code (WRKCODE): 04210.IW.0202
measuring unit (WRKUNIT): m2
work description (WRKDESC): Common brickwork 0.11 thick in internal walls of the second floor.

Confirm (y/n)

Figure A2.37: The data entry screen for JTPWRK.dbf
Work measurements for all construction works and their relations to tasks, activities and items of the bill of quantities are entered in JTPREL.dbf. Each construction work is handled at a time. The entering screen is activated by selecting option (2) - *Set relations among construction entities of the "Project*
Menu" of figure A2.30. This screen is shown in figure A2.39. A taskcode (TASCODE) is selected if a unit rate approach is used for the construction work. Otherwise, the field should be left blank and PECI automatically writes "NOUGHT" in it (figure A.40). Task codes either existed in JTSTAS (ie, they had been previously defined) or they were defined later by the user for this particular project. The activities where construction works should be included are selected by their codes (ACTCODE). Code convention used for this project divides the project by floors. For example, work code 04210.IW.0202 takes place on the second floor.

Please enter project data for JTPREL.

WRKCODE: 10300.IW.0100
Manufactured fireplaces.

work quantity (WRKQUN): 3.00
Corresponding task code (TASCODE): 00004.00.R
Activity code to be included in (ACTCODE): 00004.00.R

No task code has been declared for this construction work.
An operational approach will be used later. Confirm (y/n)

Figure A2.40: The data entry screen for JTPREL.dbf
Therefore, the corresponding activity code 00002.02.E means:

00002 - construction activity number 2;

.02. - 2nd floor;

E - "E" performing organization.

Similarly, the item of the bill of quantities comprising each construction work is selected by its code (BQICODE). In the above example, the work code 04210.IW.0202 was included in chapter 02, item 001, sub-item 02 of the bill of quantities thus yielding BQICODE 02.001.02. Figure A2.41 shows the contents of JTPREL after data for all construction works had been entered.

<table>
<thead>
<tr>
<th>Record#</th>
<th>WRKCODE</th>
<th>WRKQUAN</th>
<th>TASCODE</th>
<th>ACTCODE</th>
<th>BQICODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>04210.IW.0101</td>
<td>80.00</td>
<td>02.015</td>
<td>00001.01.E</td>
<td>02.001.01</td>
</tr>
<tr>
<td>2</td>
<td>04210.IW.0102</td>
<td>45.00</td>
<td>02.015</td>
<td>00002.02.E</td>
<td>02.001.01</td>
</tr>
<tr>
<td>3</td>
<td>04210.IW.0201</td>
<td>34.00</td>
<td>02.016</td>
<td>00001.01.E</td>
<td>02.001.02</td>
</tr>
<tr>
<td>4</td>
<td>04210.IW.0202</td>
<td>67.00</td>
<td>02.016</td>
<td>00002.02.E</td>
<td>02.001.02</td>
</tr>
<tr>
<td>5</td>
<td>04210.IW.0303</td>
<td>32.00</td>
<td>02.017</td>
<td>00003.03.E</td>
<td>02.001.03</td>
</tr>
<tr>
<td>6</td>
<td>04211.IW.0102</td>
<td>52.00</td>
<td>02.100</td>
<td>00002.02.E</td>
<td>02.001.04</td>
</tr>
<tr>
<td>7</td>
<td>10300.IW.0100</td>
<td>3.00</td>
<td>0000</td>
<td>00004.00.R</td>
<td>02.001.05</td>
</tr>
</tbody>
</table>

Figure A2.41: JTPREL.dbf file for the sample project

Returning to the "Project Menu", the user should select option (3) - Select source files for the project in order to select which source files to use. PECI displays all source files for resources tasks and internal sub-contracts. The screen which enables the user to select the Source Tasks file to use for the sample project is shown in figure A2.42. A summary of the user selections for this project is shown in figure A2.43. Figures A2.44 to A2.46 show the contents of those files.
Please select the tasks file.

STIC4TAS.DBF        STJCTTAS.DBF
1206 bytes in       2 files.
1908736 bytes remaining on drive.

Please enter your selection

Figure A2.42: The screen for the selection of the Source Tasks file.

your selections were:

source file for resources: SRO00RES
source file for tasks: STJCTTAS
source file for internal subcontracts: SIIC4ISC

Please confirm (y/n)

Figure A2.43: The user selections for source files.
Figure A2.44: The contents of JTSTAS.dbf file.

<table>
<thead>
<tr>
<th>Record#</th>
<th>TASCODE</th>
<th>RESCODE</th>
<th>RESQUAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>02.012</td>
<td>1.00.001</td>
<td>0.032</td>
<td></td>
</tr>
<tr>
<td>02.012</td>
<td>M.00.043</td>
<td>32.000</td>
<td></td>
</tr>
<tr>
<td>02.012</td>
<td>L.00.001</td>
<td>1.560</td>
<td></td>
</tr>
<tr>
<td>02.012</td>
<td>L.00.018</td>
<td>0.720</td>
<td></td>
</tr>
<tr>
<td>02.015</td>
<td>I.00.001</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>02.015</td>
<td>M.00.044</td>
<td>16.000</td>
<td></td>
</tr>
<tr>
<td>02.015</td>
<td>L.00.001</td>
<td>0.600</td>
<td></td>
</tr>
<tr>
<td>02.015</td>
<td>L.00.018</td>
<td>0.300</td>
<td></td>
</tr>
<tr>
<td>02.016</td>
<td>I.00.001</td>
<td>0.016</td>
<td></td>
</tr>
<tr>
<td>02.016</td>
<td>M.00.043</td>
<td>16.000</td>
<td></td>
</tr>
<tr>
<td>02.016</td>
<td>L.00.001</td>
<td>0.670</td>
<td></td>
</tr>
<tr>
<td>02.016</td>
<td>L.00.018</td>
<td>0.340</td>
<td></td>
</tr>
<tr>
<td>02.017</td>
<td>I.00.001</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td>02.017</td>
<td>M.00.044</td>
<td>16.000</td>
<td></td>
</tr>
<tr>
<td>02.017</td>
<td>L.00.001</td>
<td>0.750</td>
<td></td>
</tr>
<tr>
<td>02.017</td>
<td>L.00.018</td>
<td>0.300</td>
<td></td>
</tr>
<tr>
<td>07.425</td>
<td>I.00.002</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>07.425</td>
<td>L.00.001</td>
<td>0.630</td>
<td></td>
</tr>
<tr>
<td>07.425</td>
<td>L.00.018</td>
<td>0.270</td>
<td></td>
</tr>
</tbody>
</table>

Figure A2.45: The contents of JTSRES.dbf file.

<table>
<thead>
<tr>
<th>Record#</th>
<th>RESCODE</th>
<th>RESCOST</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.00.012</td>
<td>12.00</td>
<td></td>
</tr>
<tr>
<td>M.00.002</td>
<td>1800.00</td>
<td></td>
</tr>
<tr>
<td>M.00.039</td>
<td>70.00</td>
<td></td>
</tr>
<tr>
<td>M.00.043</td>
<td>42.00</td>
<td></td>
</tr>
<tr>
<td>M.00.042</td>
<td>35.00</td>
<td></td>
</tr>
<tr>
<td>M.00.044</td>
<td>56.00</td>
<td></td>
</tr>
<tr>
<td>L.00.001</td>
<td>600.00</td>
<td></td>
</tr>
<tr>
<td>L.00.002</td>
<td>450.00</td>
<td></td>
</tr>
<tr>
<td>N.00.001</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>N.00.002</td>
<td>200.00</td>
<td></td>
</tr>
</tbody>
</table>

Figure A2.46: The contents of JTSISC.dbf file.

<table>
<thead>
<tr>
<th>Record#</th>
<th>TASCODE</th>
<th>RESCODE</th>
<th>RESQUAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.00.001</td>
<td>M.00.012</td>
<td>300.000</td>
<td></td>
</tr>
<tr>
<td>I.00.001</td>
<td>M.00.002</td>
<td>1.097</td>
<td></td>
</tr>
<tr>
<td>I.00.001</td>
<td>M.00.039</td>
<td>0.322</td>
<td></td>
</tr>
</tbody>
</table>

Figure A2.46: The contents of JTSISC.dbf file.

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Next, tasks and resources should be handled. Option (4) - Settle tasks and resources, of the "Project Menu" was selected for this purpose. This made PECI perform a set of sequential procedures involving the project tasks and resources as referred in section A2.5.3.

While running the sample project, PECI could not find in JTB/TAS the task code 02.100 which was declared in JTPREL. Therefore, PECI displayed the screen of figure A2.47 and the user was asked to enter data.

Obviously, PECI could neither find in JST/TAS any task card for that task code. The screen of figure A2.48 was displayed for data entry.

<table>
<thead>
<tr>
<th>PECI</th>
<th>JT/TAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>by: Jose M. Cardoso Teixeira, 1991.</td>
<td>date 11/25/92</td>
</tr>
<tr>
<td>JTWTAS</td>
<td>time 20:10:30</td>
</tr>
</tbody>
</table>

Please enter data for the following construction task.

TASCODE: 02.100 has not been found in JTB/TAS.

measuring unit (TASUNIT: ) m2

task description (TASDESC: ) Internal common brickwork 0.30x0.20x0.07 including mortar in curved walls.

Figure A2.47: The screen for a missing TASCODE in JTB/TAS.
Please enter resource codes (RESCODE) and corresponding quantities (RESQUAN) for the following construction task.

**TASCODE**: 02.100

**Please enter number of distinct resource types**: 4

<table>
<thead>
<tr>
<th>RESCODE</th>
<th>RESQUAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.00.001</td>
<td>0.016</td>
</tr>
<tr>
<td>M.00.042</td>
<td>17.000</td>
</tr>
<tr>
<td>L.00.001</td>
<td>1.400</td>
</tr>
<tr>
<td>L.00.018</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Figure A2.48: The screen for a missing TASCODE in JTSTAS

Next, PECI found that no task code was declared for the work code 10300.IW.0100 (see figure A2.40), thus an operational approach would be used. Data collection was achieved by means of the following three data entry screens (figures A2.49 to A2.51).
Figure A2.49: Data entry screen for JTPTRR.dbf. Scheduling data.

Figure A2.50: Data entry screen for JTPTRR.dbf. Time dependent resources.
Please enter data for the following work code.

WRKCODE: 10300.IW.0100
WRKQUAN: 3.00
WRKDESC: Manufactured fireplaces.

Please enter number of other resource types: 2
Please enter resource codes (RESCODE), and resource quantities (RESQUAN) required.

<table>
<thead>
<tr>
<th>RESCODE</th>
<th>RESQUAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00.002</td>
<td>0.670</td>
</tr>
<tr>
<td>M.00.912</td>
<td>230</td>
</tr>
</tbody>
</table>

WRKDURA: 2.Wk
date 11/25/92
time 20:21:44

Figure A2.51: Data entry screen for JTPTRR.dbf. Time independent resources.

An internal sub-contract code (1.00.002) was declared in the last screen (figure A2.51) and PECI could not find it in JTBISC. Therefore, the screen of figure A2.52 was displayed and the user was asked to enter data. Similarly, a material code (M.00.912) was also declared and PECI could not find it in JTSRES. The entry screen on figure A2.53 was displayed.
Please enter data for the following internal subcontract.

ISCCODE: I.00.002 has not been found in JTBISC.
measuring unit (ISCUNIT): m³
subcontract description (ISCDESC): refractory mortar.

Confirm (y/n):

Figure A2.52: The screen for missing ISCCODE in JTBISC.

Please enter data for the following resource.

RESCODE M.00.912 has not been found in JTSRES.
measuring unit (RESUNIT) Un
resource description (RESDESC) refractory bricks.
resource cost (RESCOST) 78

Confirm (y/n):

Figure A2.53: The screen for missing RESCODE in JTSRES.
Because the ISCCODE 1.00.002 could not be found in JTBISC, it could not be found in JTSISC either. Therefore PECI displayed the data entry screen of figure A2.54.

One of the resource types (M.00.902) which was declared for 1.00.002 could not be found in JTSRES. Therefore PECI displayed the data entry screen of figure A2.55.

PECI by: Jose M. Cardoso Teixeira, 1991. JTWSCD date 11/26/92 time 10:19:21

Please enter resource codes (RESCODE) and corresponding quantities (RESQUAN) for the following internal subcontract.

ISCCODE: 1.00.002

Please enter number of distinct resource types 2

RESCODE: M.00.902 RESQUAN: 8.000
RESCODE: M.00.039 RESQUAN: 0.46

Figure A2.54: The data entry screen for ISCCODE.
Please enter data for the following resource.

RESCODE M.00.902 has not been found in JTSRES.

measuring unit (RESUNIT): Kg
resource description (RESDESC): refractory cement.
resource cost (RESCOST): 35

Figure A2.55: The screen for missing RESCODE in JTSRES.

Figures A2.56 to A2.61 show the contents of work files for resources and tasks.

Record#   TASKCODE TASKUNIT TASKDESC
1  02.015  w2  Internal common brickwork 0.30x0.20x0.07 including mortar 1:5.
2  02.016  w2  Internal common brickwork 0.30x0.20x0.11 including mortar 1:5
3  02.017  w2  Internal common brickwork 0.30x0.20x0.15 including mortar 1:5.
4  02.100  w2  Internal common brickwork 0.30x0.20x0.07 including mortar in curved walls.

Figure A2.56: JTWTAS.dbf file for the sample project
<table>
<thead>
<tr>
<th>Record#</th>
<th>RESCODE</th>
<th>RESUNIT</th>
<th>RESDESC</th>
<th>RESESCOST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I.00.001</td>
<td>m³</td>
<td>mortar for bricklaying.</td>
<td>5597.14</td>
</tr>
<tr>
<td>2</td>
<td>M.00.002</td>
<td>m³</td>
<td>sand.</td>
<td>1800.00</td>
</tr>
<tr>
<td>3</td>
<td>M.00.012</td>
<td>Kg</td>
<td>Portland cement.</td>
<td>12.00</td>
</tr>
<tr>
<td>4</td>
<td>M.00.039</td>
<td>m³</td>
<td>water.</td>
<td>70.00</td>
</tr>
<tr>
<td>5</td>
<td>L.00.001</td>
<td>Hr</td>
<td>bricklayer.</td>
<td>600.00</td>
</tr>
<tr>
<td>6</td>
<td>L.00.018</td>
<td>Hr</td>
<td>worker.</td>
<td>450.00</td>
</tr>
<tr>
<td>7</td>
<td>M.00.042</td>
<td>Un</td>
<td>bricks 0.30x0.20x0.07.</td>
<td>35.00</td>
</tr>
<tr>
<td>8</td>
<td>M.00.043</td>
<td>Un</td>
<td>bricks 0.30x0.20x0.11.</td>
<td>42.00</td>
</tr>
<tr>
<td>9</td>
<td>M.00.044</td>
<td>Un</td>
<td>bricks 0.30x0.20x0.15.</td>
<td>56.00</td>
</tr>
<tr>
<td>10</td>
<td>I.00.002</td>
<td>m³</td>
<td>refractory mortar.</td>
<td>28032.20</td>
</tr>
<tr>
<td>11</td>
<td>M.00.912</td>
<td>Un</td>
<td>refractory bricks.</td>
<td>78.00</td>
</tr>
<tr>
<td>12</td>
<td>M.00.902</td>
<td>Kg</td>
<td>refractory cement.</td>
<td>35.00</td>
</tr>
</tbody>
</table>

Figure A2.57: JTWCAD.dbf file for the sample project

Figure A2.58: JTWRES.dbf file for the sample project
<table>
<thead>
<tr>
<th>Record#</th>
<th>ISCCODE</th>
<th>ISCUNIT</th>
<th>ISCDESC</th>
<th>ISCCOST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00.001</td>
<td>m³</td>
<td>mortar for bricklaying.</td>
<td>5597.14</td>
</tr>
<tr>
<td>2</td>
<td>1.00.002</td>
<td>m³</td>
<td>refractory mortar.</td>
<td>28032.20</td>
</tr>
</tbody>
</table>

Figure A2.59: JTWISC.dbf file for the sample project

<table>
<thead>
<tr>
<th>Record#</th>
<th>ISCCODE</th>
<th>RESCODE</th>
<th>RESQUAN</th>
<th>ISCCOST</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00.001</td>
<td>M.00.012</td>
<td>300.000</td>
<td>3600.00</td>
</tr>
<tr>
<td>2</td>
<td>1.00.001</td>
<td>M.00.002</td>
<td>1.097</td>
<td>1794.60</td>
</tr>
<tr>
<td>3</td>
<td>1.00.001</td>
<td>M.00.039</td>
<td>0.322</td>
<td>22.24</td>
</tr>
<tr>
<td>4</td>
<td>1.00.002</td>
<td>M.00.902</td>
<td>800.000</td>
<td>28000.00</td>
</tr>
<tr>
<td>5</td>
<td>1.00.002</td>
<td>M.00.039</td>
<td>0.460</td>
<td>32.20</td>
</tr>
</tbody>
</table>

Figure A2.60: JTWSCD.dbf file for the sample project

<table>
<thead>
<tr>
<th>Record#</th>
<th>WRKCODE</th>
<th>RESCODE</th>
<th>RESQUAN</th>
<th>WRKTEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10300.IW.0100</td>
<td>L.00.001</td>
<td>90.000</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>10300.IW.0100</td>
<td>L.00.018</td>
<td>90.000</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>10300.IW.0100</td>
<td>L.00.002</td>
<td>0.670</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>10300.IW.0100</td>
<td>M.00.912</td>
<td>230.000</td>
<td></td>
</tr>
</tbody>
</table>

Figure A2.61: JTPTRR.dbf file for the sample project
Returning to the "Project Menu", the user selected option (5) - *Work with the construction activities module*. However, items of the bill of quantities could have been handled before activities as well.

PECI automatically displayed the "Activities Menu" of figure A2.32. Option (1) - *Enter activities discriptions* should be selected in the first place. This activated the entering screen of JTPSAC.dbf as shown in figure A2.62.

```
PECI by: Jose M. Cardoso Teixeira, 1991. JTPSAC

Please enter data for the following construction activity.

ACTCODE: 00002.02.E

measuring unit (ACTUNIT): m²

activity description (ACTDESC): Internal walls of the second floor.

Confirm (y/n):
```

Figure A2.62: The data entry screen for JTPSAC.

After all activities discriptions and measuring units (if any) had been entered, PECI returned to the "Activity Menu". Option (2) - *Transfer resources data to activities* should be selected to make PECI enter data into JTPACT.dbf. This was performed with no interference from the user. When it was finished, the "Activities Menu" was displayed again on the screen.

The user should select option (3) - *Select key resources* in order to settle the relevant resources for the calculation of activities durations. PECI displayed
resources and corresponding quantities for each construction activity and the user entered "Y" to mark the resources to be considered. Figure A2.63 shows this entering screen.

![Figure A2.63: The data entry screen for the selection of key resources.](image)

Figure A2.63: The data entry screen for the selection of key resources.

Option (4) - Select activity durations makes PECI start the calculation of activity durations. Firstly, the user should select which scheduling unit will be used and the number of daily working hours. The screen PECI displayed for this purpose is shown in figure A2.64.

Then the duration of each activity was calculated at a time. The screen for activity code 00002.02.E is shown on figure A2.65. Key resources and corresponding quantities were displayed on the screen. The user entered the number of resources of each type to allocate to the activity (WRKTEAM); PECI computed the time required by those resources to perform the activity (ACTDURA). Finally the user was asked if WRKTEAM should be confirmed.
Please enter scheduling unit (Week/Day). SCHUN: W
Please enter number of daily working hours. DYWKH: 9.0

Figure A2.64: The screen for the selection of the scheduling unit and the number of daily working hours.

Please enter data for the calculation of the following activity duration.
ACTCODE: 00002.02.E
ACTDESC: Internal walls of the second floor.
Please enter the work (WRKTEAM) required to perform the upper construction activity.
RESCODE RESALLA Un WRKTEAM ACTDURA
L.00.001 144.690 Hr 4 0.80
L.00.018 83.080 Hr 1 1.65

Confirm (Y/N) N

Figure A2.65: The screen used to compute activity durations.
The user answered "N" and PECI displayed data for the same activity again and waited for new WRKTEAM data. New activity durations were computed. This time the user felt the results more satisfactory and confirmed resource allocation. Finally PECI asked for the final decision about the activity duration. This screen is shown on figure A2.66.

Figure A2.66: The screen used to compute activity durations.

The screen shown on figure A2.67, was displayed for activity code 00004.00.R because the duration of this activity had already been assigned by JTPTRR.prg (see figure A2.41). Actually, construction work 10300.IW.0100 which corresponds to that activity code had been previously handled by an operational approach. PECI allows for the revision of the activity duration but no review was decided in this case.
Please enter data for the calculation of the following activity duration.
ACTCODE: 00004.00.R
ACTDESC: Fireplaces.

Activity duration has already been assigned.
Please enter N to handle next activity or press any key to review.

Figure A2.67: The screen of assigned duration.

After all activities had been handled, PECI automatically returned to the "Activities Menu". Option (5) - *Select resources to allocate to the scheduling module*, should be selected in order to decide which resources to deal with on the schedule. PECI displayed a screen like the one shown in figure A2.68 for each project resource and the user was asked for a Y/N answer.

Figures A2.69 and A2.70 show the contents of project activities files.
Please select (Y/N) resources to allocate to the construction program.

RESCODE: L.00.001
RESDESC: bricklayer

Should this resource be handled?

Figure A2.68: The screen used for the selection of scheduling resources.

<table>
<thead>
<tr>
<th>Record#</th>
<th>ACTCODE</th>
<th>ACTDESC</th>
<th>ACTUNIT</th>
<th>ACTCOST</th>
<th>ACTDURA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>00001.01.E</td>
<td>Internal walls of the first floor.</td>
<td>m²</td>
<td>133641</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>00002.02.E</td>
<td>Internal walls of the second floor.</td>
<td>m²</td>
<td>236540</td>
<td>1.00</td>
</tr>
<tr>
<td>3</td>
<td>00003.03.E</td>
<td>Internal walls of the third floor.</td>
<td>m²</td>
<td>51153</td>
<td>1.00</td>
</tr>
<tr>
<td>4</td>
<td>00004.00.R</td>
<td>Fireplaces.</td>
<td>Un</td>
<td>131222</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Figure A2.69: JTPSAC.dbf file for the sample project
<table>
<thead>
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<td>Y</td>
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<td></td>
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<td>512.000</td>
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<td>L.00.018</td>
<td>90.000</td>
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<td>M.00.912</td>
<td>230.000</td>
<td>17940.00</td>
<td>N</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Figure A2.70: JTPACT.dbf file for the sample project

PECI returned to the "Project Menu", the user selected option (6) - *Work with the bq items module* in order to finish the study of the project.

PECI automatically displayed the "Bill of Quantities Menu" of figure A2.33. Option (1) - *Enter item discriptions* works much like option (1) of the "Activities Menu". The entering screen shown in figure A2.71.

After all item descriptions and measuring units had been entered, PECI returned to the "Bill of Quantities Menu". Option (2) - *Transfer resources data to bq items* should be selected to make PECI enter data into JTPBQI.dbf. The user was asked to confirm work quantities for each item (BQIQUAN). The screen used for this purpose is shown on figure A2.72.
Please enter data for the following item of the bill of quantities.

BQICODE: 02.001.02

measuring unit (BQUNIT): m2

item description (BQIDESC): Internal walls 0.11 thick.

Confirm (y/n):

Figure A2.71: The data entry screen for JTPSBQ.

Please confirm (y/n) quantities for the following bq item.

BQICODE: 02.001.02  BQIQUAN: 101.000

BQIDESC: Internal walls 0.11 thick.

Confirm (y/n):

Figure A2.72: The screen used to confirm BQIQUAN.
Figures A2.73 and A2.74 show the contents of project bq items files.

This project was named TEST01E and files used above were stored in directory c:\peci\test01. This was carried out by PECI after option 4 - Save your work was
selected.

Project data was later looked over and it was decided it would be better to let fireplaces be made by a specialist subcontractor. Therefore, it was decided that TEST01E should be reviewd in order to take this into consideration.

TEST01E files were brought up through the selection of option (2) - *Work on an existing project* of the "Main Menu". made PECI bring up TEST01E files.

The "Project Menu" of figure A2.31 was used to update TEST01 files. Project measurements and relations among construction entities had no change from the first version. Therefore, there was no need to select options (1) or (2). However option (2) was selected just to see how PECI would handle a change on project relations. A screen like the one of figure A2.75 was displayed for each construction work.

```
PECI
by: Jose M. Cardoso Teixeira, 1991.

Please enter project data for JTPREL.

WRKCODE: 10300.IW.0100
Manufactured fireplaces.

An identical code already exists in JTPREL. Therefore, this work will not be handled again. Confirm (y/n):
```

Figure A2.75: The screen used in the revision of JTPREL.dbf file.

Answering "Y" to the confirm question on the bottom of the screen would make
PECI review the corresponding construction work. In the case of work code 10300.IW.0100, no changes were to be made to the previous record. PECI returned to the "Project Menu" after the last construction work had been passed by.

Option (4) - Settle tasks and resources was selected next. Afterwards, PECI started to look over task files and resource files.

Construction works for which the unit rate approach was selected were first reviewed. No modifications had been made for these works. Thus no help from the user was required. Obviously, the screens of figures A2.47 and A2.48 were not displayed because information about the task code 02.100 was already available in TEST01E files.

Then construction works for which the operational approach had been selected were reviewed. Work code 10300.IW.0100 should be updated. Therefore "Y" was entered on the screen as shown in figure A2.76.

---

The work code (WRKCODE) 10300.IW.0100 has been handled before.
Should it be updated? (y/n)

---

Figure A2.76: The screen used in the revision of JTPTRR.dbf file.
New data for this work code was entered in the screens as shown in figures A2.77 to A2.79.

Figure A2.77: Data entry screen for JTPTRR.dbf. Scheduling data.

Figure A2.78: Data entry screen for JTPTRR.dbf. Time dependent resources.
Please enter data for the following work code.
WRKCODE: 10300.IW.0100  WRKQUAN:  3.00
WRKDESC: Manufactured fireplaces.

Please enter number of other resource types: 1
Please enter resource codes (RESCODE), and resource quantities (RESQUAN) required.

RESCODE RESQUAN
E.00.001  1.

Figure A2.79: Data entry screen for JTPTRR.dbf. Time independent resources.

Code E.00.001 was assigned to the external sub-contract as declared in JTPTRR.dbf. This was a new code for PECI. Therefore, the screen of figure A2.80 was displayed and the user was asked to enter corresponding data.
Please enter data for the following external subcontract.

ESCCODE: E.00.001
subcontract description (ESCODEC): Making fireplaces.
subcontract duration (ESCDURA): 1.00
scheduling unit (week/day): W
subcontract total cost (ESCOST) 50000.00

Confirm (y/n):

Figure A2.80: The data entry screen for ESCCODE

When PECI returned to the "Project Menu", option (5) - *Work with the construction activities module* was selected. This worked as before. The new work code was not selected as a key resource as shown in figure A2.81.
Please select (Y/N) key resources (KEY_RES) for the following activity.

ACTCODE: 00004.00.R
ACTDESC: Fireplaces.

RESOURCES QUANTITIES KEY_RES
E.00.001 1.000   N
L.00.018 98.000

Figure A2.81: The data entry screen for the selection of key resources of activity 00004.00.R.

Finally, option (6) - *Work with the bq items module* of the "Project Menu" was selected in order to complete the project revision.

Figures A2.82 to A2.92 show the contents of the files which had been modified by the revision of TEST01E.

Record# TASCODE TASUNIT TASDESC
1 02.016 m2 Internal common brickwork 0.30x0.20x0.07 including mortar 1:5.
2 02.016 m2 Internal common brickwork 0.30x0.20x0.11 including mortar 1:5
3 02.017 m2 Internal common brickwork 0.30x0.20x0.15 including mortar 1:5.
4 02.100 m2 Internal common brickwork 0.30x0.20x0.07 including mortar in curved walls.

Figure A2.82: JTWTA.dbf file for the sample project (after revision).
### Figure A2.83: JTWCAD.dbf file for the sample project (after revision).

<table>
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<th>RESQUAN</th>
<th>TASCOST</th>
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<td>I.00.001</td>
<td>0.010</td>
<td>55.97</td>
</tr>
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<td>02.015</td>
<td>M.00.042</td>
<td>15.000</td>
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<tr>
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<td>02.015</td>
<td>L.00.001</td>
<td>0.600</td>
<td>360.00</td>
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<tr>
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<td>02.015</td>
<td>L.00.018</td>
<td>0.300</td>
<td>135.00</td>
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<tr>
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<td>02.016</td>
<td>I.00.001</td>
<td>0.015</td>
<td>89.55</td>
</tr>
<tr>
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<td>02.016</td>
<td>M.00.043</td>
<td>16.000</td>
<td>672.00</td>
</tr>
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<td>L.00.001</td>
<td>0.670</td>
<td>402.00</td>
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<tr>
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<td>02.016</td>
<td>L.00.018</td>
<td>0.340</td>
<td>153.00</td>
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<tr>
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<td>I.00.001</td>
<td>0.021</td>
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<td>16.000</td>
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<td>0.750</td>
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<td>L.00.018</td>
<td>0.900</td>
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### Figure A2.84: JTWRES.dbf file for the sample project (after revision).

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<th>RESUNIT</th>
<th>RESDESC</th>
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<tbody>
<tr>
<td>1</td>
<td>I.00.001</td>
<td>m3</td>
<td>mortar for bricklaying.</td>
<td>5597.14</td>
</tr>
<tr>
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<td>m3</td>
<td>sand.</td>
<td>1800.00</td>
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<tr>
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<td>M.00.012</td>
<td>Kg</td>
<td>Portland cement.</td>
<td>12.00</td>
</tr>
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<td>4</td>
<td>M.00.039</td>
<td>m3</td>
<td>water.</td>
<td>70.00</td>
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<td>Hr</td>
<td>bricklayer.</td>
<td>600.00</td>
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<td>Hr</td>
<td>worker.</td>
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<td>refractory bricks</td>
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<td>refractory mortar.</td>
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Figure A2.85: JTWISC.dbf file for the sample project (after revision).

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<td>28000.00</td>
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Figure A2.86: JTWSCD.dbf file for the sample project (after revision).

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Figure A2.87: JTPTRR.dbf file for the sample project (after revision).
Making fireplaces.

Figure A2.88: JTWESC.dbf file for the sample project (after revision).

Internal walls of the first floor.

Figure A2.89: JTPSAC.dbf file for the sample project (after revision).

Fireplaces.

Figure A2.90: JTPACT.dbf file for the sample project (after revision).
<table>
<thead>
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<td>0.672</td>
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</table>

Figure A2.91: JTPSBQ.dbf file for the sample project (after revision).

Figure A2.92: JTPBQI.dbf file for the sample project (after revision).

A2.6 The program files.

Some PECI program files are listed in next pages.
set talk off
set bell off
set status off
set deleted on
set escape off
close databases

store space(1) to MOD

set procedure to JTMASK
do JTMASK
  @ 10,18 say "PLANNING ESTIMATING AND CONTROL INTEGRATED"
  @ 12,19 say "Loughborough University of Technology (UK)"
  @ 13,18 say "Universidade do Minho (Portugal)"
  @ 15,68 say "October 1991"
  wait "press any key to continue"

  @ 20,12 say "Do you want to modify language for Basic Files + (y/n) ?"
  @ 20,67 get MOD picture "@!"
  read

  if MOD = "Y"
    do JTLANG
      store space(1) to MOD
  endif

do while .T.

clear
do JTMASK
  @ 5,33 say "PECI"
  @ 6,30 say "Main Menu"
  @ 8,21 say "(1) Create new source files"
  @ 10,21 say "(2) Work on an existant project"
  @ 12,21 say "(3) Start a new project"
  @ 14,21 say "(4) Save your work"
  @ 17,13 say "(8) Exit to dBASE III PLUS Command Level"
  @ 19,13 say "(9) Exit to MS-DOS Operating System"
store 0 to MSL
@ 23,13 say "Please enter your selection" get MSL
+ picture "9"
read

store space(7) to PROJ
store space(1) to CONF

    do case

    case MSL = 1
    @ 23, 2 say "Please use dBASE III PLUS Command Level" wait

    case MSL = 2
    clear
do JTMASK
    use SFCDATA index SFDAPRNA
    display all
    @ 18, 2 say "Please enter the name of the project."
    @ 18,41 get PROJ read
    @ 19, 2 say "Confirm (y/n):" get CONF picture "@!"
read
    if CONF <> "N"
        goto top
    find &PROJ
    if found()
clear
      run copy c:\PECI\&PROJ\JT*.* c:\dbase\JT*.*
      run copy c:\PECI\&PROJ\JT*.* c:\JCT\JT*.*
clear
do JTMASK
      @ 23, 5 say "Please wait. Setting files for
+       use..."
do SETPACK
do JTPOLD
    else
      @ 20, 2 say "Project name not in list. Please"
      @ 20,35 say "press any key to try again."
      wait ""
endif
endif
store space(1) to CONF

    case MSL = 3
    clear
do JTMASK
    @ 23, 5 say "Please wait. Setting files for use..."
do SETPACK
do JTPNEW

449
case MSL = 4
  do JTMASK
  use SFDATA index SFDAPRNA

  do while .T.
    store space(7) to PROJ
    @ 5, 2 say "Please enter the name of the project."
    @ 6, 2 say "Project name (up to seven digits):"
    @ 6,37 get PROJ picture "@!"
    read
    find &PROJ
    if found()
      @ 8, 2 say "This project name already exists."
      @ 8,36 say "Please try again."
      wait
    else
      append blank
      replace PROJNAM with PROJ
      replace PR_DATE with date()
      pack
      exit
    endif
    @ 8, 2 say space(60)
  enddo
  clear

  ! mkdir c:\peci\&PROJ
  * ! copy c:\dbase\JT*.dbf c:\peci\&PROJ\jt*.dbf
  * ! copy c:\dbase\JT*.ndx c:\peci\&PROJ\jt*.ndx
  * ! copy c:\jc\JT*.dbf c:\peci\&PROJ\jt*.dbf
  * ! copy c:\jc\JT*.ndx c:\peci\&PROJ\jt*.ndx
  use
  do JTMASK
    @ 8, 2 say "Data in current files will be deleted.
    Confirm (Y/N)"
    @ 8,55 get CONF picture "@!"
    read
    if CONF = "Y"
      @ 23, 5 say "Please wait. Deleting data from
      files..."
      do ZAPPACK
        store space(1) to CONF
    endif
  case MSL = 8
    set talk on
    set bell on
    set status on
    set deleted off
    set escape on
    clear
    cancel
case MSL = 9
    clear
    quit

otherwise
    @ 23,10 say "Not a valid selection."
    @ 23,32 say "Please press any key to try again"
    wait ""
endcase

endo
case
* JTPNEW.prg
* This program commands the generation of JT*.dbf files for a new project. This will be achieved by running several JT*.prg.

*by Jose Teixeira 2 November 1991.

do while .T.
store space(1) to CONF
clear
do JTMASK
  @ 2,41 say "JTPNEW"
  @ 5,33 say "PECI"
  @ 6,30 say "Project Menu"
  @ 8,21 say "(1) Enter project measurements"
  @ 10,21 say "(2) Set relations among construction entities"
  @ 12,21 say "(3) Select source files for the project"
  @ 14,21 say "(4) Settle tasks and resources"
  @ 16,21 say "(5) Work with the construction activities module"
  @ 18,21 say "(6) Work with the bq items module"
  @ 20,21 say "(7) Return to the Main Menu"

store 0 to MSL
@ 23,13 say "Please enter your selection " get MSL
  picture "9"
read
  do case
    case MSL = 1
    * generate JTPWRK...
      do JTMASK
        @ 2,41 say "JTPNEW (JTPWRK)"
        do JTPWRK
clear
      case MSL = 2
      * generate JTPREL...
        do JTMASK
          @ 2,41 say "JTPNEW (JTPREL)"
          do JTPREL
clear
case MSL = 3
* generate source files JTS*...
    do JTMASK
      @ 2,41 say "JTPNEW (JTSFIL)"
do JTSFIL
clear

case MSL = 4
* generate the work files JTW*...
    @ 23,13 say space(60)
    @ 23,13 say "Have you selected source files for the
    + project ?"
    @ 23,62 get CONF picture "@!"
read
if CONF <> "Y"
   loop
endif
store space(1) to CONF

* generate the work tasks file JTWTAS...
    do JTMASK
      @ 2,41 say "JTPNEW (JTWTAS)"
    + @ 23, 5 say "Please do not interrupt. Generating
      + JTWTAS..."
    do JTWTAS
clear

* generate the work card file JTWCAD...
    do JTMASK
      @ 2,41 say "JTPNEW (JTWCAD)"
    + @ 23, 5 say "Please do not interrupt. Generating
      + JTWCAD..."
    do JTWCAD
clear
* generate the work resources file JTRES after JTWCAD

    do JM ASK
    @ 2,41 say "JTPNEW (JTRES)"
    @ 23, 5 say "Please do not interrupt. Generating JTRES
    +
    from JTWCAD"

    select 1
    use JTWCAD index JTWCRCO
    pack
    do JTRES
    do JM ASK
    @ 2,41 say "JTPNEW (JTRES)"
    @ 23, 5 say "Please do not interrupt. Generating JTRES
    +
    from JTWCAD..."
    do JTRES
    clear
    close databases

* generate the total resource requirements file JTPTRR

    do JM ASK
    @ 2,41 say "JTPNEW (JTPTRR)"
    @ 23, 5 say "Please do not interrupt. Generating
    +
    JTPTRR..."

    do JTPTRR
    clear

* generate the work resources file JTRES after JTPTRR

    do JM ASK
    @ 2,41 say "JTPNEW (JTRES)"
    @ 23, 5 say "Please do not interrupt. Generating JTRES
    +
    from JTPTRR..."

    select 1
    use JTPTRR index JTPTRCRO
    pack
    do JTRES
    clear
    close databases
case MSL = 5

* work with the construction activities module

@ 23,13 say space(60)
@ 23,13 say "Have you settled tasks and resources ?"
@ 23,52 get CONF picture "@!"
read
if CONF = "N"
    loop
endif
store space(1) to CONF

do JTMASK
@ 2,41 say "JTPNEW (JTPACM)"

do JTPACM
clear

case MSL = 6

* work with the bill of quantities module

@ 23,13 say space (60)
@ 23,13 say "Have you settled tasks and resources ?"
@ 23,52 get CONF picture "@!"
read
if CONF = "N"
    loop
endif
store space(1) to CONF

do JTMASK
@ 2,41 say "JTPNEW (JTPBQM)"

do JTPBQM
clear

case MSL = 7

return

otherwise

@ 23,10 say "Not a valid selection."
@ 23,32 say "Please press any key to try again."
wait ""
endcase

enddo

return 455
* JTPOLD.prg
* This program commands the re-generation of JT*.dbf files for an exixtant project. This will be achieved by running several JT*.prg.

*by Jose Teixeira 2 December 1991.

store space(1) to CONF

do while .T.
clear
do JTMASK
  @ 2,41 say "JTPOLD"
  @ 5,33 say "PECI"
  @ 6,30 say "Project Menu"
  @ 8,21 say "(1) Enter new project measurements"
  @ 10,21 say "(2) Set relations among construction entities"
  @ 12,21 say "(3) Select other source files for the project"
  @ 14,21 say "(4) Settle tasks and resources"
  @ 16,21 say "(5) Work with the construction activities module"
  @ 18,21 say "(6) Work with the bq items module"
  @ 20,21 say "(7) Return to the Main Menu"

store 0 to MSL
@ 23,13 say "Please enter your selection" get MSL picture "9"
read

  do case
    case MSL = 1

* generate JTPWRK

  do JTMASK
    @ 2,41 say "JTPOLD (JTPWRK)"
  do JTPWRK
  clear

    case MSL = 2

* generate JTPREL

  do JTMASK
    @ 2,41 say "JTPOLD (JTPREL)"
  do JTPREL
  clear

    case MSL = 3

* select new source files

456
do JTMASK
  @ 2,41 say "JTPOLD (JTSFIL)"
do JTSFIL
clear

case MSL = 4
  @ 23,13 say space(60)
  @ 23,13 say "Have you selected new source files for the project ?"
  @ 23,66 get CONF picture "@!"
  read
  if CONF = "Y"
    use JTWTAS
    delete all
    pack
    use JTWCAD
    delete all
    pack
    use JTWISC
    delete all
    pack
    use JTWSCD
    delete all
    pack
    use JTWLMP
    delete all
    pack
    use JTCOIN
    delete all
    pack
    use JTPTRR
    delete all
    pack
    use JTOPPS
    delete all
    pack
    use
  endif
  store space(1) to CONF

* generate the work tasks file

do JTMASK
  @ 2,41 say "JTPOLD (JTWTAS)"
  @ 23, 5 say "Please do not interrupt. Generating JTWTAS..."
  do JTWTAS
  clear

* generate the work card file
do JTMASK
go to 2,41 say "JTPOLD (JTWCAD)"
go to 23, 5 say "Please do not interrupt. Generating JTWCAD..."

do JTWCAD

clear

* generate the work resources file JTWRES after JTWCAD

do JTMASK
go to 2,41 say "JTPOLD (JTWRES)"
go to 23, 5 say "Please do not interrupt. Generating JTWRES from JTWCAD..."

do JTWRES
do JTMASK
go to 2,41 say "JTPOLD (JTCOIN)"
go to 23, 5 say "Please do not interrupt. Generating JTWRES from JTWCAD..."

do JTCOIN

clear
close databases

* generate the total resource requirements file JTPTRR

do JTMASK
go to 2,41 say "JTPOLD (JTPTRR)"
go to 23, 5 say "Please do not interrupt. Generating JTPTRR..."

do JTPTRR
clear

* generate the work resources file JTWRES after JTPTRR

do JTMASK
go to 2,41 say "JTPOLD (JTWRES)"
go to 23, 5 say "Please do not interrupt. Generating JTWRES from JTPTRR..."

select 1
use JTPTRR index JTPTRECO
pack
do JTWRES
clear
close databases

case MSL = 5

* work with the construction activities module
@ 23,13 say space(60)
@ 23,13 say "Have you modified relations among entities ?"
@ 23,58 get CONF picture "@!
read
if CONF = "Y"
   @ 23,13 say space(60)
   @ 23, 2 say "Remember to update all activities files."
   @ 23,43 say "Please press any key to continue."
   wait ""
endif
store space(1) to CONF

do JTMASK
   @ 2,41 say "JTPOLD (JTPACM)"

do JTPACM
clear

case MSL = 6
* work with the bill of quantities module
   @ 23,13 say space (60)
   @ 23,13 say "Have you modified relations among entities ?"
   @ 23,58 get CONF picture "@!
read
if CONF = "Y"
   @ 23,13 say space(60)
   @ 23, 2 say "Remember to update all bq items files."
   @ 23,43 say "Please press any key to continue."
   wait ""
endif
store space(1) to CONF

do JTMASK
   @ 2,41 say "JTPOLD (JTPBQM)"

do JTPBQM
clear

case MSL = 7
return
otherwise
   @ 23,10 say "Not a valid selection."
   @ 23,32 say "Please press any key to try again."
   wait ""

459
endcase
enddo
return

→
This program commands the generation of the construction activities files.

by Jose Teixeira 2 December 1991.

do while .T.
clear
do JTMASK
@ 2,41 say "JTPACM"
@ 5,33 say "PECI"
@ 6,30 say "Activities Menu"
@ 8,21 say "(1) Enter activities discriptions"
@ 10,21 say "(2) Transfer resources data to activities"
@ 12,21 say "(3) Select key resources"
@ 14,21 say "(4) Select activities durations"
@ 16,21 say "(5) Select resources to allocate in the scheduling module"
@ 20,21 say "(6) Return to the Project Menu"

store 0 to MSL
@ 23,13 say "Please enter your selection " get MSL
+ picture "9"
read

do case

case MSL = 1

* generate the project activity file JTPSAC

    do JTMASK
    @ 2,41 say "JTPACM (JTPSAC)"
    @ 23, 5 say "Please do not interrupt. Generating JTPSAC..."

    do JTPSAC
    clear

    case MSL = 2

* generate the project activity file JTPACT

    use JTPACT
delete all
pack
use JTPSAC
replace all ACTCOST with 0
replace all ACTDURA with 0
pack
use
do JTMASK
@ 2,41 say "JTPACM (JTPACT)"
@ 23, 5 say "Please do not interrupt. Generating JTPACT..."
  do JTPACT
  clear
  case MSL = 3
  * generate the project key resources file JTPK_R
  do JTMASK
  @ 2,41 say "JTPACM (JTPK_R)"
  @ 23, 5 say "Please do not interrupt. Generating JTPK_R"
  do JTPK_R
  clear
  case MSL = 4
  * generate the project duration file JTPDUR
  do JTMASK
  @ 2,41 say "JTPACM (JTPDUR)"
  @ 23, 5 say "Please do not interrupt. Generating JTPDUR..."
  do JTPDUR
  clear
  case MSL = 5
  * generate the project program resource allocation file JTPRAL
  do JTMASK
  @ 2,41 say "JTPACM (JTPRAL)"
  @ 23, 5 say "Please do not interrupt. Generating JTPRAL..."
  do JTPRAL
  clear
  case MSL = 6
  return
otherwise
  @ 23,10 say "Not a valid selection."
  @ 23,32 say "Please press any key to try again."
  wait ""
endcase
enddo
return
* JTPBQM.prg
* This program commands the generation of bq files.

*by Jose Teixeira 6 December 1991.

do while .T.
clear
do JTMASK
  @ 2,41 say "JTPBQM"
  @ 5,33 say "PECI"
  @ 6,25 say "Bill of Quantities Menu"
  @ 8,21 say "(1) Enter items discriptions"
  @ 10,21 say "(2) Transfer resources data to bq items"
  @ 20,21 say "(3) Return to Project Menu"

store 0 to MSL
@ 23,13 say "Please enter your selection " get MSL
+ picture "9"
read

do case
  case MSL = 1
    * generate the project bq items file JTPSBQ
    do JTMASK
      @ 2,41 say "JTPBQM (JTPSBQ)"
      @ 23, 5 say "Please do not interrupt. Generating JTPSBQ..."
    do JTPSBQ
    clear
  case MSL = 2
    * generate the project bill of quantities file JTPBQI
    use JTPBQI
    delete all
    pack
    use JTPSBQ
    replace all BQQUAN with 0
    replace all BQUNCO with 0
    replace all BQCOST with 0
    pack
    use
    do JTMASK
      @ 2,41 say "JTPBQM (JTPBQI)"
      @ 23, 5 say "Please do not interrupt. Generating JTPBQI..."
use JTPBQI
delete all pack
do JTPBQI
  @ 2,41 say "JTPNEW (JTPQUA)"
  @ 23, 5 say "Please do not interrupt. Generating JTPSBQ..."
do JTPQUA
clear

case MSL = 3
  return

otherwise
  @ 23,10 say "Not a valid selection."
  @ 23,32 say "Please press any key to try again."
  wait ""
endcase
enddo

return