DATABASE APPROACH TO COST EFFECTIVE DESIGN OF A FRAME SYSTEM

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Abstract

In structural design, there are plenty of analysis software which handle individual building components, but there are only few programs that view the individual components as comprising a system needing a conceptual solution. The general trend in software development has been to concentrate on case dependent solutions incapable of general use or data transportation to other applications. This study has attempted to address these short comings.

The goal of the research was familiarization with modeling of computer application for structural design. The focus was the choice structure to be used during project planning phase of the frame systems in an office building. Part of the research project was to create new application software, which was used to test the presented models.

In this research the modeling of the frame systems was carried out using activity and conceptual models. The activity model was used to describe the actions and decisions made in the process of choosing of the frame system. The emphasis was in the search for the situations where choices are guided by economical factors.

The conceptual modeling was realized using the ER model. In it, the frame system was presented in three segments. Each segment formed its own independent part. The main idea was that frame systems are constructed of building components attached together, and each of those has it's own manufacturing, transportation and assembly costs, depending on the type of the component.

The application created in the research project was used in testing the models. The basic requirement for the demonstration of the software was the need for a graphical representation of the modeling of the frame systems. The interface of the application was a CAD system. A relational database system was used to store the information. Both graphical and alphanumeric libraries of the main building component types of the frame were made. The design of the frame systems was carried out by choosing the types of the component instances from the library. The equivalent instances in the graphical and the relation database were linked together. Thus the databases of the systems could be used as a whole, even though the information was located in different databases.

1 INTRODUCTION

1 .1 BACKGROUND OF THIS STUDY

In construction business, the first steps to a more customer oriented direction has been taken. This new attitude demands higher productivity and more flexible methods. It is the same when discussing quality. Customers are requiring better quality with lower costs.

Current computer technology offers some very efficient tools to improve several parts of the construction process, but utilization of computer technology requires a systematical approach. You have to present your problem area via standard forms and models. It is vital for successful modeling, that you can see and understand the entirety of the problem.

1 .2 THE GOALS AND IMPLEMENTATION OF THIS STUDY

The main goal of this study was familiarization with modeling of computer application for structural design. The focus was the economical choices concerning the frame system of the building during the project planning phase.

The secondary goal was to improve product data model based design

In this study the problem area has been modeled via activity and conceptual models. The activity model presents essential functions of the process and information flows between those processes. Conceptual models are based on information flows of the activity model. The presentation technique for activity models is SADT and for the conceptual models it is ER.

2 FRAME SYSTEMS

In Finland there are basically three different frame systems. The most common system is the column–beam –system. For example 90 % of concrete element frames are column–beam –systems [1]. Other systems are bearing walls –system and column–slab –system. This study concentrates on column–beam element frames.

2 .1 BUILDING COMPONENTS AND COST STRUCTURES

Column–beam element frames usually include three basic elements: columns, beams and slabs. It is possible to create several frame solutions by combining these elements in different ways.

The total costs of different building components are composed of direct and indirect costs. Direct costs of manufacturing are material and labour costs and indirect costs are e.g. quality control, storing and space costs. In this case we supposed that each building component type has its own unit cost that includes all manufacturing costs. Assembly costs are mainly composed of direct labour and equipment costs. Then there are transportation costs which are e.g. in the case of concrete elements 5 ... 15 % from the manufacturing costs [1].

The more interesting thing is, how the unit cost depends on different attributes of the building components and the frame system. When discussing computer models it is important to find out those attributes. The most significant factor is the length of the production serial of building component. When the length of the production serial increases from one to two, unit cost will be 21 ... 27 % lower. Also when the length of serial increases from two to fifteen, unit cost will decrease 23 ... 32 % [2]. Other important factors when discussing concrete components are the shape of the building component and the amount of steel. The effect of the amount of steel upon the cost can be 27 % and effect of concrete beam's shape can be almost 10 % [2].

2 .2 QUANTITY SURVEYING AND COST ESTIMATING

Cost estimation of the frame system can be implemented in many ways. In this case we have used a cost estimation method that is based on building component types (figure 1).

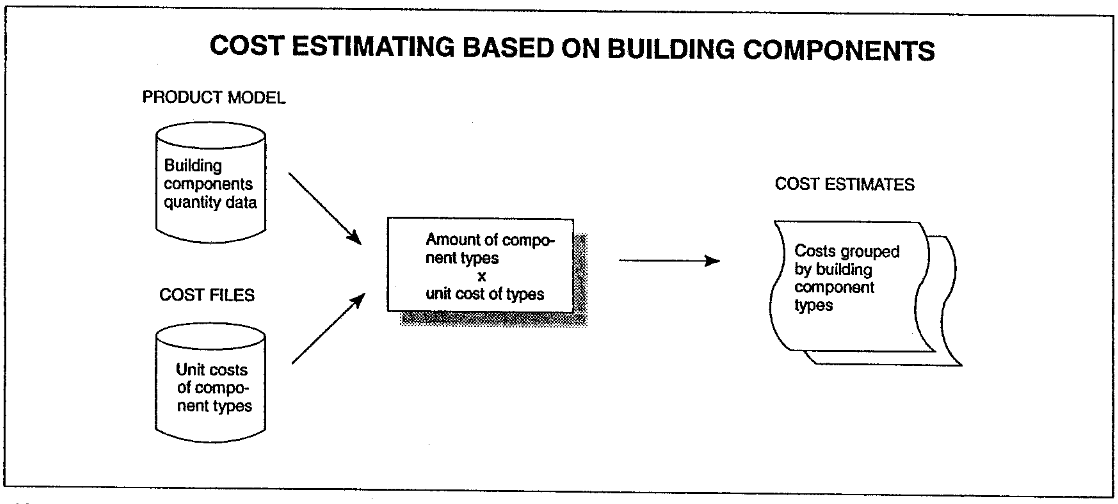

Figure 1 . Cost estimating based on building component types.

With the dimensioning method described above, all building components are classified to component types. Type files include all relevant data about component types e.g. unit costs. When calculating costs, we group all the element instances from the project's product model by type and survey quantities of every type. By combining the cost and quantity data, we can calculate a cost estimation of the frame system.

This kind of method is suitable when we have accuracy and reliable cost data. Usually this level of cost information during a project planning phase is accurate enough.

Another method, not discussed in this paper, is resource based cost estimation.

2 .3 COST EFFECTIVE DESIGN

Usually we design a building first and then we calculate how much it will cost. Cost effective design means that we have a cost frame that is set up by the customer and our design solutions should be within this frame. This presupposes that we have a good understanding of building costs in every phase of the design process.

2 .4 ACTIVITY MODEL OF THE DESIGN

The activity model (figure 2) presents the main activities of the designing process of the frame system in a logical order. It also presents inputs, outputs and information flows between these processes.

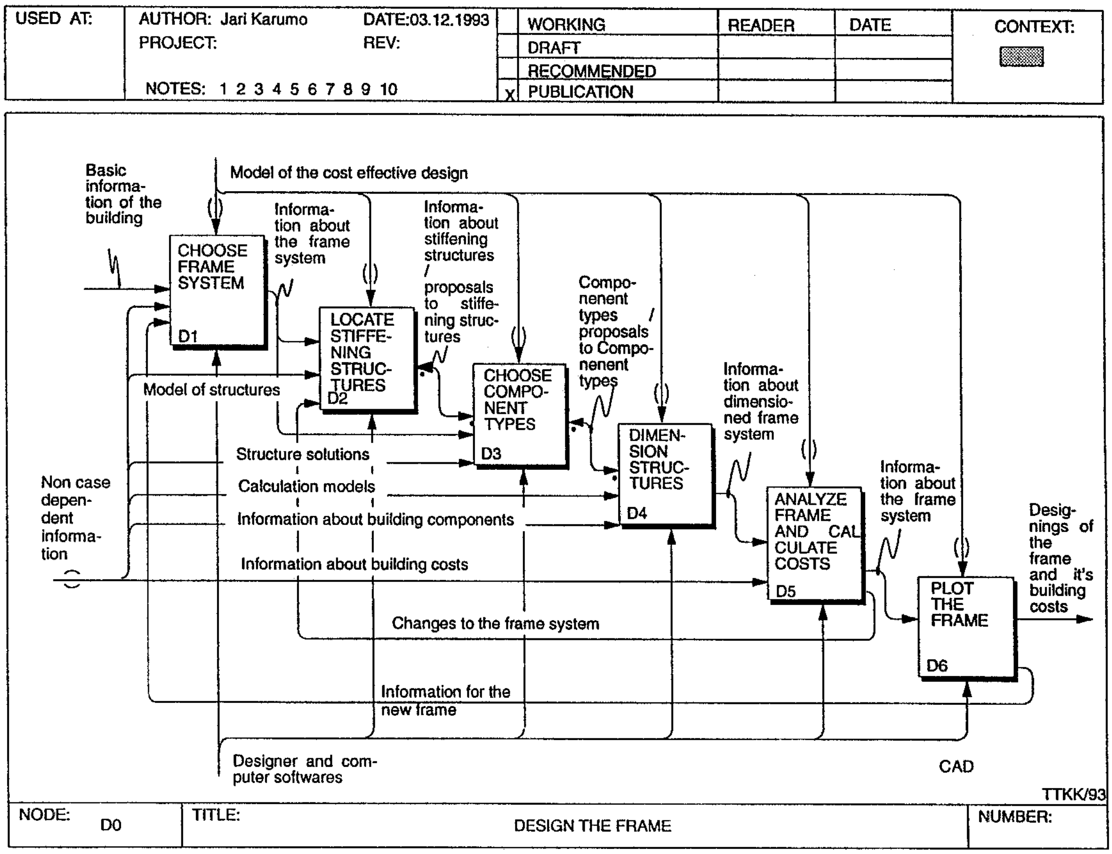

Figure 2 . The first level of the activity model.

Activities in the model are basically equal to the traditional designing process, but in this model there is some kind of economical examination in every activity except the last. Usually the examination is based on economical choice, which means that first you pick out structurally acceptable solutions and then evaluate their values and costs and finally choose the most beneficially solution. It is possible to apply this method to different levels of designing.

This kind of evaluation presupposes a good knowledge regarding the economy of the frame system, it's subsystems and it's components.

2 .5 CONCEPTUAL MODEL

The conceptual model is based on information flows of the activity model. The information is processed and converted into individual concepts and the most essential concepts are classified and sorted for the model. After the classification we have to define relationships between these concepts. This is a very important phase, especially when discussing economical concepts. In this study the main idea was that the frame systems are constructed of building components attached together and each of those has it's own cost structures depending on the type of component. This also offers a very flexible interface for the special applications, e.g. FEM software.

The model is presented in three segments. Each segment is its own independent part and together they form one entirety. The highest segment consists concepts which describe the frame system and its economical factors. These factors are dependant upon construction time and place. Typically they are different kinds of indexes.

The central segment consists concepts of a building component. The economical concepts in this segment describe cost structure of the building components. All factors are dependant upon the type of the component. There is also a concept that consists data about material of the building component. Concept *joints* includes equipment that are needed when components are attached together. Joint types also have an influence on the assembly costs.

In the lowest segment there are described hierarchical concepts of the building component and relationships between them. This segment shows how different components can be attached together.

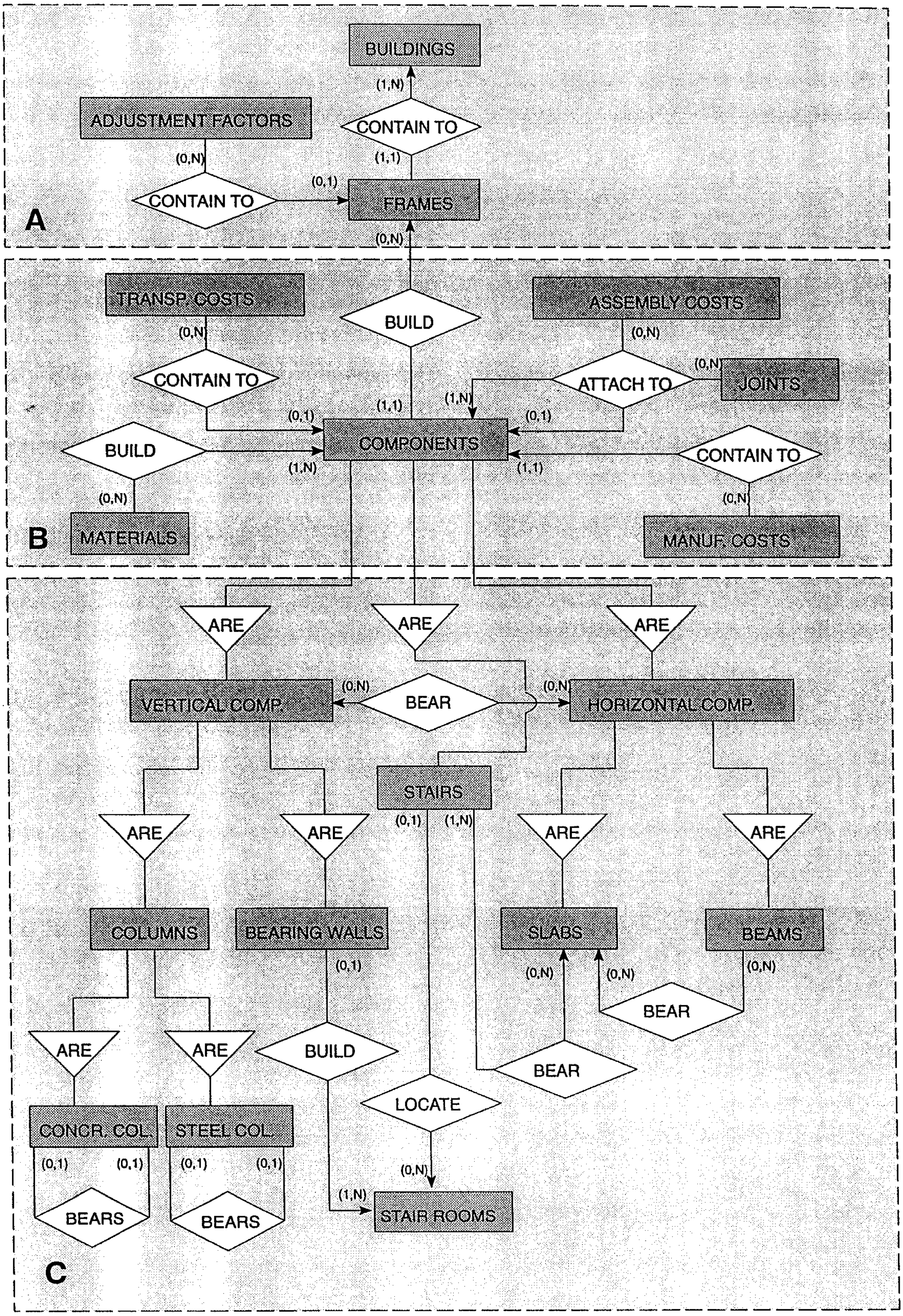

Figure 3 . Conceptual model of the frame system and it's cost types.

3 DATA MODEL

In the conceptual model you describe your abstract concepts and relationships between them. The data model presents the same concepts but with more detailed and applied to selected database solution.

In this study we have used relational data model, although it has many limitations. On the other hand it is the most common data model today and there is plenty of commercial software which support it. In addition it offers quite a good possibility to transfer data to other systems.

The data model (figure 4)presents tables of the database and their primary and foreign keys. The model is divided into three segments according to the type of database table. These segments are instances, building component type and cost libraries. Instance tables include all instances of the frame model. Data which is more permanent are stored to libraries.

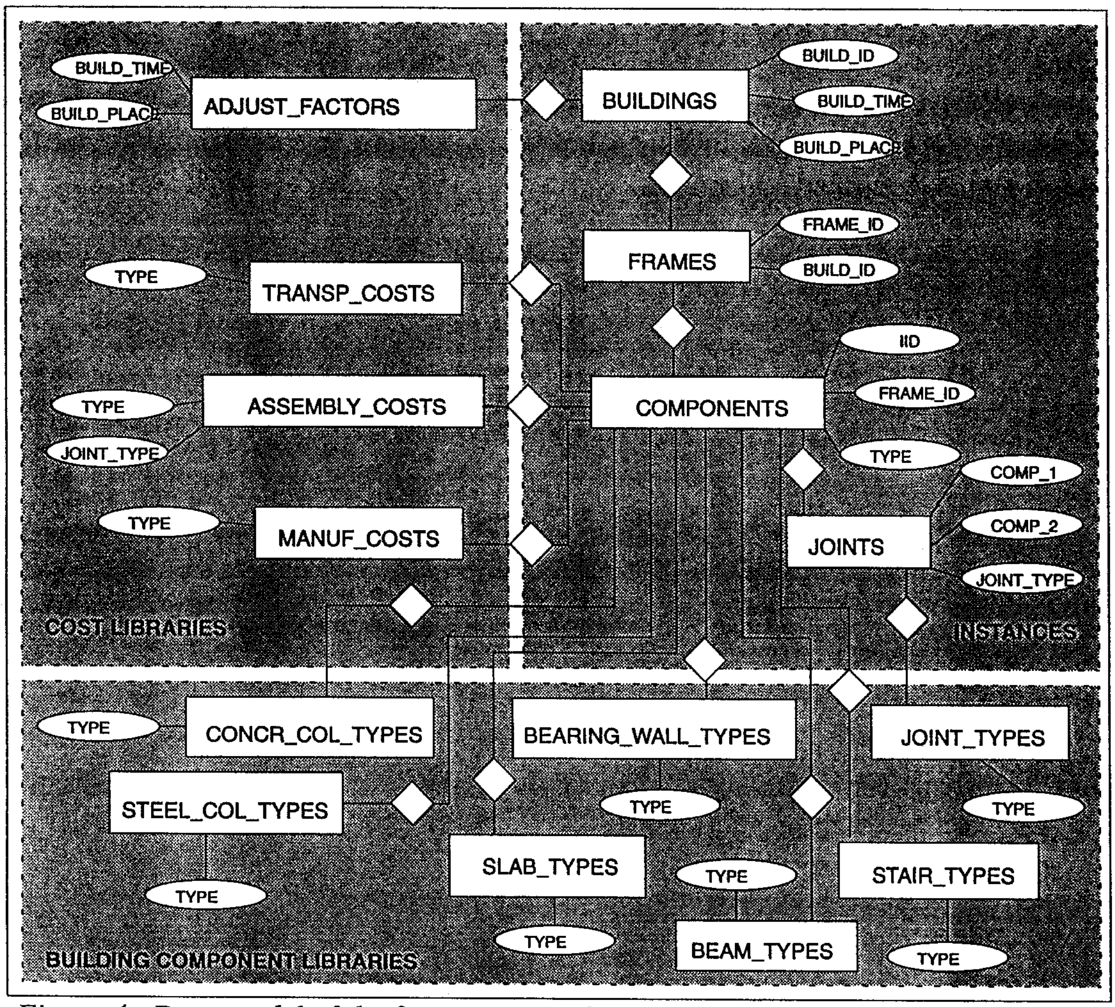

Figure 4 . Data model of the frame system [3].

4 APPLICATION SOFTWARE

In this study the main idea of the prototype software was to test the created models. Another goal to investigate was is it possible to combine graphical and relational databases fluently so that they form conceptually as the one entire database.

The software was carried out in UNIX environment. The programming language was C and the database used in this study was INGRES with embedded SQL utilities. As a CAD software there was AES.

Software is a tool for the modeling of the frame system of an office building. The software is fully interactive and the modeling process is guided via a graphical user interface. It permits the user to test different construction solutions when modeling the frame. When the user has chosen all the building component types it is possible to check current cost situation and make changes if needed. The created model is three dimensional and by using CAD's raytracing utilities the software offers high class visualization opportunities.

4 .1 COMPOSED DATABASES

When we have graphical and alphanumerical data concerning the same data we have to link them together somehow. Prototype software, created during the study, uses the *pair* concept (figure 5) when linking data.

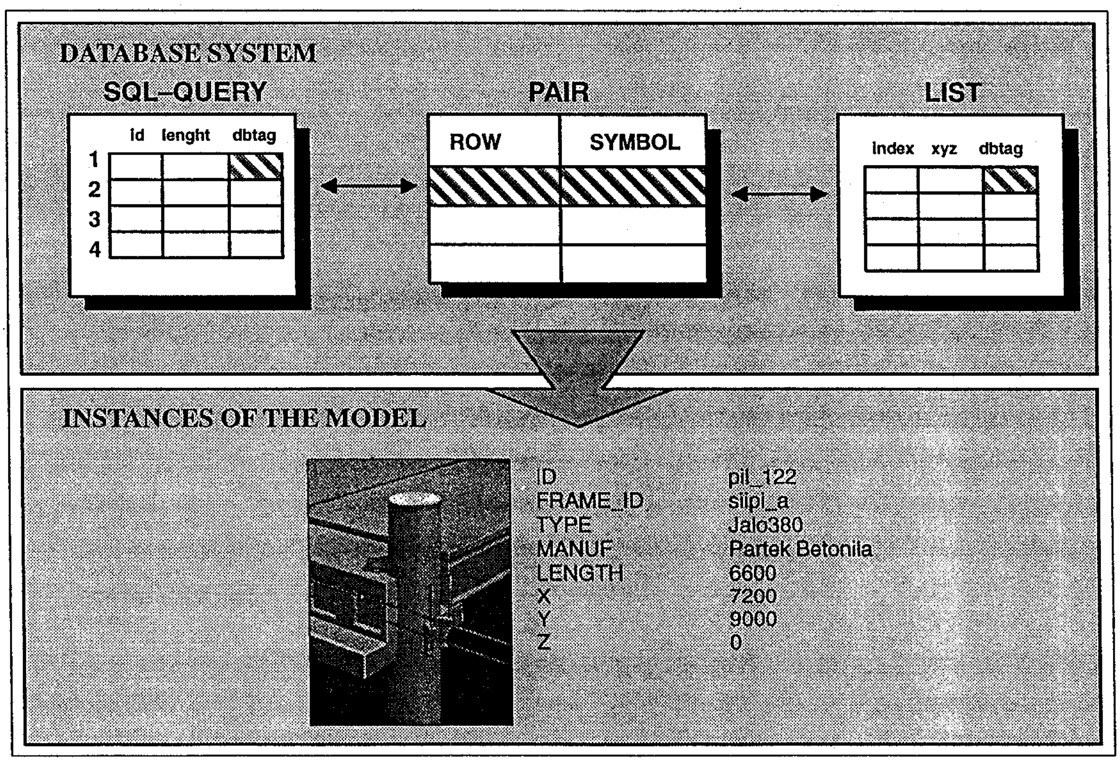

Figure 5 . Pairing data [3].

By pairing the data we can reach several advantages. The main advantage is, that you are able to design interactively, because you have access to alphanumerical data direct from the graphics. This utility also enables cost effective designing.

As mentioned above, pairing composes conceptually one database. From the view point of computer technology, those databases can be distributed and accessed via a network.

After designing it is easy to create different kinds of reports and drawings from the created model (figure 6).

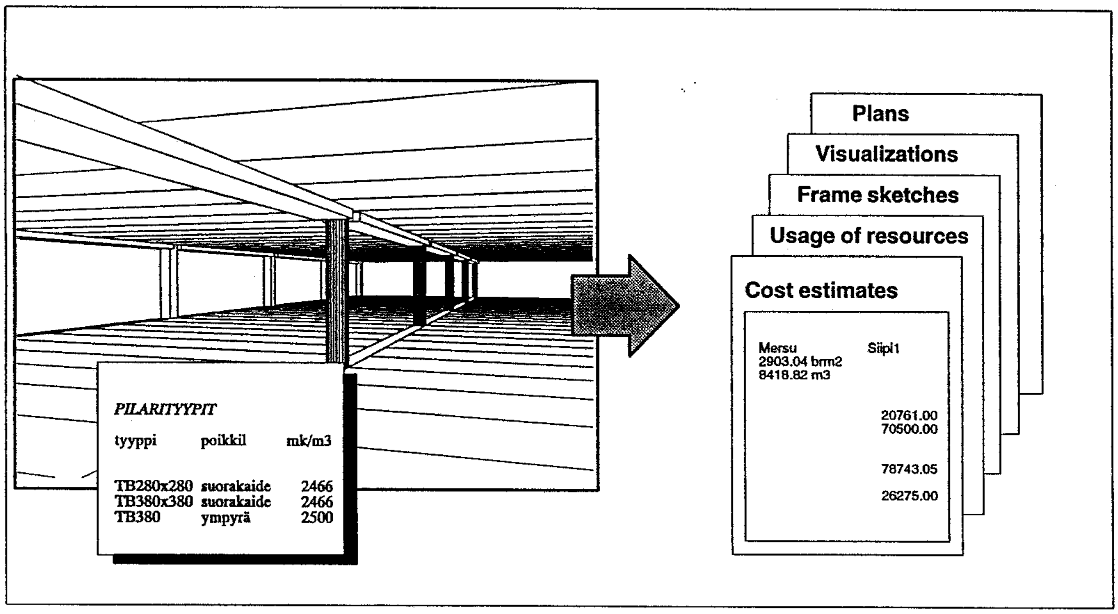

Figure 6 . Creating reports and drawings from the model [3].

4 .2 DATA TRANSFERRING

In the construction business it is typical that the same data will be created several times by different designers. Utilization of created data requires some kind of data transferring. The main problem is, how will you manage to transfer all essential data in a useful format. There are no instructions as to which data should be transferred and in which format. Even though the problem is difficult, it is always possible to create your own filters and transferring formats. In relational database environment it is quite an easy job to create programs which will convert the data to the required format, because there are no complicated data structures.

The graphical data can be transferred by using standard formats e.g. DXF. The problem is that those standard graphics formats do not support links to alpha numerical databases and the connections between databases will be lost. There are no common features in CAD software which support alpha numerical data.

5 CONCLUSIONS

As a result of this study we discovered out the importance of models. They offer remarkable benefits when considering the entirety of the problem area, especially when discussing computerized applications. From the viewpoint of software engineering it is important to construct a clear picture from the problem area. This makes it possible to design useful and efficient interfaces for users and other software. It also creates the basis for data transferring.

The created models were tested by using the prototype software. This prototype prowes that it is possible to design applications which are based directly on these models. The prototype software is able to model different kinds of frame systems with on–line cost information. This kind of software can improve design in every phase, because designers have opportunities to continually analyze their work, and that enables them to test many different variations of the structure, and so they have enough information to make decisions.

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