# ARE SCANNED DRAWINGS SUFFICIENT FOR FACILITY MANAGEMENT WORK?

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## Abstract

*In the construction industry today we see that the focus has changed from design and construction to facility management. To meet rising demands on efficiency and service in facility management, together with a larger and more complicated amount of information, there is a need for using information technology. Drawings are traditionally the most important source of information and this will probably remain so in the future. Almost all drawings are today kept as paper documents or as micro-films. The first step towards a computerised operation is to transform these drawings into a digital format.*

*This paper describes the numbers and various types of drawings involved in facility management and in what way they are used. The hypothesis "there is no need to vectorise huge volumes of old drawings - it is enough to scan them" is tested through a prototype system. This prototype seems to handle and use the graphical information in ways that are suitable for facility management. In the prototype system, drawings are linked together and combined with alpha-numerical documents and database facts in accordance with a building product model structure.*

*The recent progress of scanning techniques, including efficient compression of raster files and the raster-vector overlay technique for CAD and database applications, makes scanning a satisfactory way of digitising old drawings. A desirable development of the scanning technique would be automatic or semi-automatic recognition of building products in drawings of raster format. This will facilitate the use of building product-structured information that is created in the construction process. And this will further integrate design and construction with facility management.*

# BACKGROUND

A drawing is the most important format for exchanging information in the construction industry. A drawing includes a lot of information that can be hard to put into words. Many times drawings are also more versatile and comprehensive than text information - 'a picture tells more than a thousand words'. Drawings are traditionally the most important source of information in engineering and this will probably remain so in the future.

Facility managers use a lot of drawings in their daily work. To get a feeling of how many drawings are needed and how to use them in the facility management work we have collected some empirical information concerning drawing use. This provides a background for the later comparison of different techniques like raster/vector for filing and utilisation.

Many drawings that are produced in earlier phases of the building process are not used in the facility management phase. When a completed building is handed over to the owner, the contractor puts together a series of documents presenting the actual building (not how it was meant to be). Referring to Haugen: 40% of the total number of drawings that are needed to be able to build a building are not handed over - they are only used during the planning, designing and construction phases [Haugen, 1990]. The remaining 60% of the total number of drawings are updated corresponding to the actual building and are called *as built drawings.* Only 1/3 of the as built drawings is active that is they are often used and and/or modified, see figure 1.

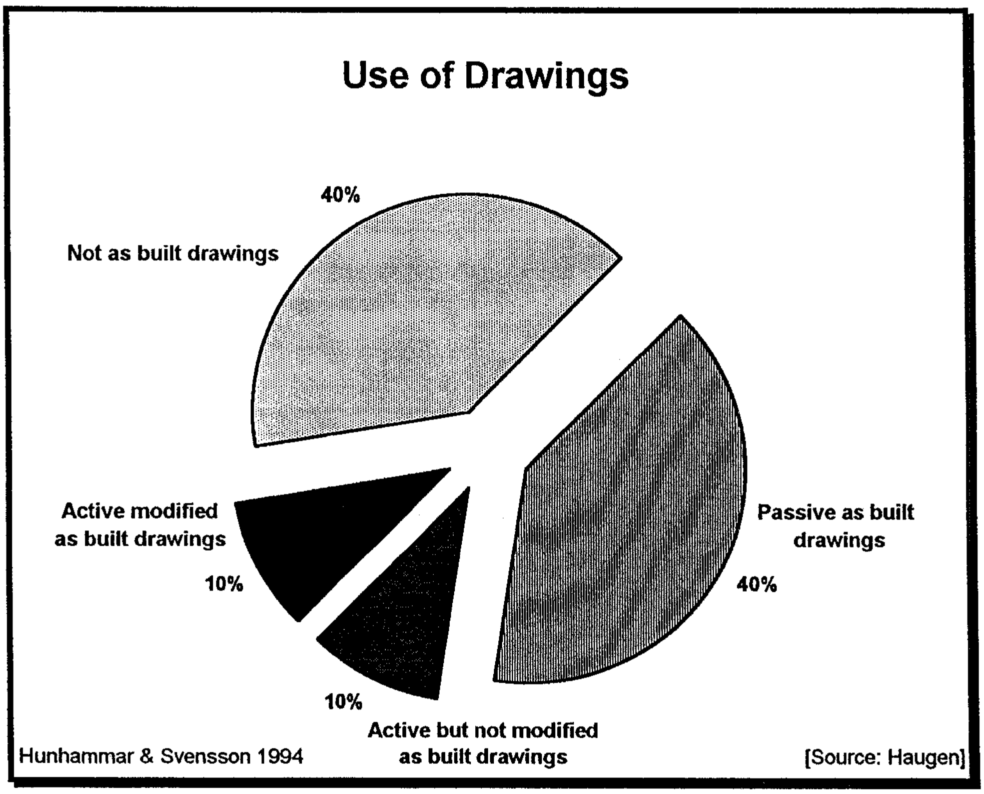


*Figure 1: Classification of drawings*

Modern buildings are increasingly complex and they include a growing number of different elements. In the beginning of the century one started to use water closets, and in the twenties one added elevators and heating systems. In the seventies we included HVAC systems in most of our buildings. This has of course increased the total number of drawings that are needed during the building process.

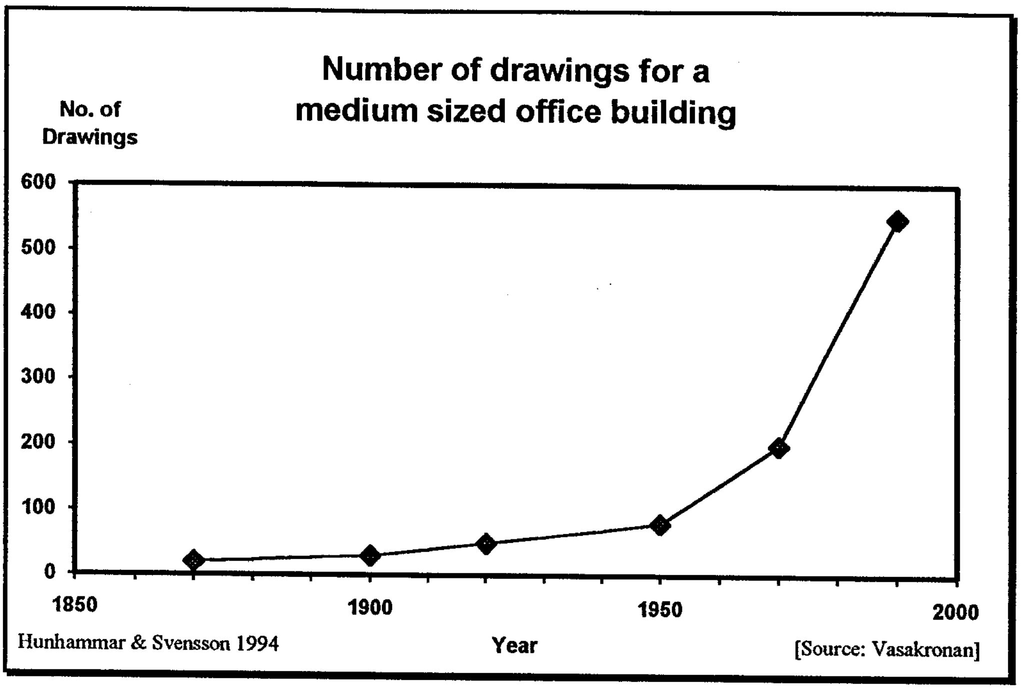


*Figure 2: The increasing number of required drawings since year 1870*

Based on our investigation at the archives of Vasakronan (a successor of Byggnads-styrelsen -The National Board of Public Building) some guide lines can be defined for how many filed drawings a medium sized (5.000 sqm) building requires, see figure 2. Vasakronan are facility managers of about 1.500 (the smallest are excluded) buildings, corresponding to about 85.000 drawings in their archives.

Today a medium sized office building requires roughly a total number of 500-600 drawings to be completed. The total number in proportion to different areas is shown in figure 3.

| Type of drawing | Total No. | No. To File |
|---|---|---|
| Architecture | 100 | 50 |
| Construction | 100 | 100 |
| HVAC | 150 | 60 |
| Electricity & Control Systems | 200 | 60 |

*Figure 3: Average number of drawings per discipline*

To these numbers we can add geographical maps and surveys. During the life time of a building smaller repairs or changes generate about 50 new drawings every 10th year. Every 50th year a major rebuild is required which adds another about 250 new drawings (and if the house lives long enough the second major rebuild often brings the house back to its origin). The further discussion deals only with *as built drawings*, so they will be referred to as just *drawings*.

The increasing number of drawings we want to file adds new demands on our archives. The importance of well kept records and the need for smooth access increases along with growing volumes of drawings. The accessibility of a document depends on how it is stored.

We can file drawings by many different methods, but we can identify two main categories - analogue and digital. The analogue method, i.e. paper & micro film, is by far the most common way to file documents today. Drawbacks with analogue filing, i.e. storage space, access time, update & inquire methods etc., have highlighted the benefits of digital filing methods. Many companies today are in the process of changing their archives into some kind of digital filing, i.e. raster, vector and hybrids. That raises the question - are scanned drawings sufficient for facility management work?

Facility management includes a variety of different drawing activities, see figure 4.

| Drawing Activities | | |
|---|---|---|
| • search | • text remark | • adjust |
| • order | • redline (graphic remark) | • redraw |
| • view | • combine with other document | • sketch |
| • file | | • measure |
| • send | | • survey |
| • delete | | |

*Figure 4: Different drawing activities*

Drawings are used differently depending on users and purpose. The most used type of drawings is traditionally the plan view, see figure 5.

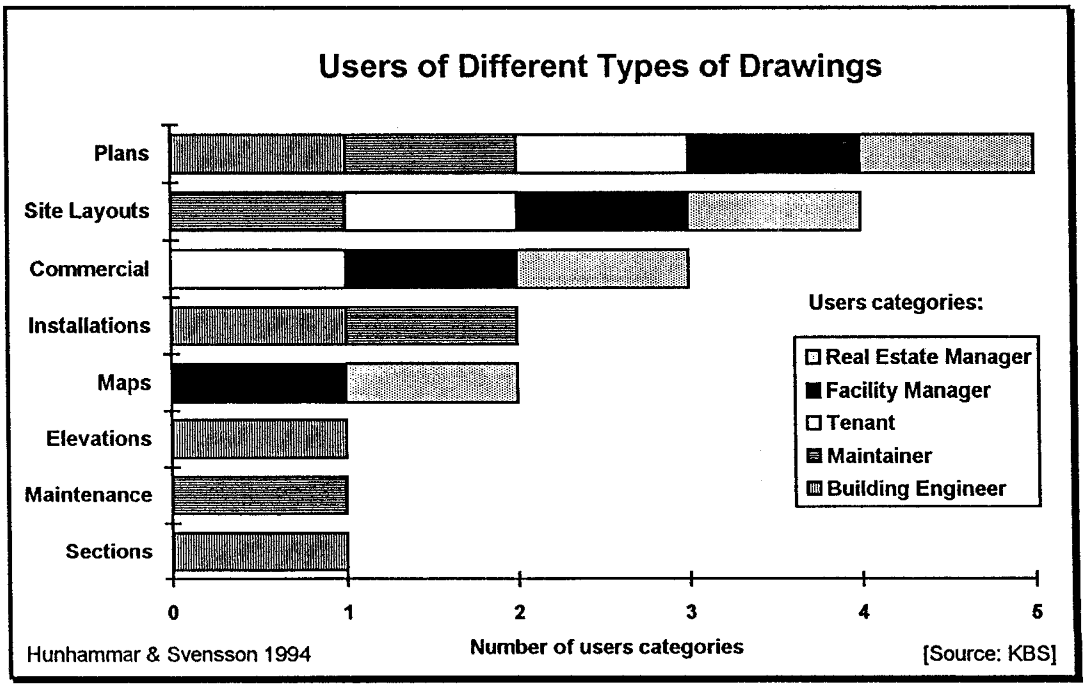


*Figure 5: Different types of drawings and their users*

## COMPUTERISED HANDLING OF DRAWINGS

To be able to use modern information technology (IT) efficiently, the paper based information needs to be transferred into digital format. The classification of available methods changes constantly as a result of technology development both on the hardware and software side. The following techniques are worth mentioning:

### REDRAFTING

Computerised redrafting is done using a CAD system and usually requires an experienced operator preferably with some design experience from the field represented by the original paper drawing. As a result we get a clean CAD file made according to the nominal dimensions, if they are available, but not necessarily corresponding exactly to the original due to unavoidable human errors.

### DIGITISING

Digitising is done, similarly to redrafting, using a CAD system but this time equipped with a full size digitising table. The operator still needs to digitise all drawing entities, but he can retrieve their coordinates from the paper drawing providing that it is to the scale. The digitising table is helpful, especially for as built drawings that often do not show dimensions. The process is, nevertheless, equally prone to human error.

### SCANNING

Scanning delivers a fine resolution digital image of the paper original and it is best seen as a way of getting an electronic photocopy. This photocopy may be improved by a filtering process that improves contrast, removes speckles, clears dark background. Digital image enhancement techniques, like two-dimensional dynamic tresholding, are being included into the scanning process itself, very often with excellent results.

### CALIBRATION

Calibration is a raster editing process that uses information about coordinates of selected points on the drawing in order to rectify the entire image geometrically. When properly used, the calibration may compensate both the imperfections of the original and image distortions introduced by the scanning process itself. Calibrating tools that have been introduced recently make it possible to perform multi-point calibration of full size scanned drawings on a standard PC equipment. As a result of the process we get a document that is often called *engineering image*: an improved copy of the original with proper size and proportions and with a coordinate system established.

### HYBRID EDITING

Calibrated scanned drawings represent such a high quality of the image and geometrical dimensions that it is quite tempting to use them for various applications without any further conversions. A number of hybrid viewing and editing tools that have been developed recently let us do exactly this: combining calibrated scanned data with overlaid vector entities and links to database records. The scanned data itself can be fully edited using tools that work either in picture editing style (painting, brushing) or in CAD style (geometrically oriented tools, raster block operations).

## VECTORISATION

A number of quite different processes are hidden behind this term. Heads-up digitalisation that employs hybrid editing tools for operator-controlled tracing of the drawing's image on the screen. Automatic tracing of lines mostly used in mapping. Automatic vectorisation of general type of drawings. Object-recognising vectorisation available only for special fields, like cadastral maps or printed circuit boards. One can expect good results only from operator-assisted methods or from object-recognising specialised systems. Generic type of automatic vectorisation often produces unstructured vector data of questionable accuracy.

## EVALUATION OF DRAWING CONVERSION METHODS

One would like to compare different methods of paper drawing conversion in terms of time and cost involved, accuracy and usability of results. The problem with this kind of comparisons is that they depend heavily on many factors like the type and quality of paper drawings. One possible result is shown in figure 6. The time needed to perform the operation is longest for redrafting, smallest for scanning. The relative accuracy measure, subjectively evaluated for as built drawings with some dimensioning data, is highest for digitising and calibration, and smallest for scanning. This results from the relatively high rate of human errors involved in redrafting incompletely dimensioned drawings on one side, and from the low accuracy of uncalibrated scanned data, on the other side. Calibration offers a very good ratio of time versus accuracy, that is comparable to redrafting and digitising, and usability, that is equally good when hybrid raster-vector systems are available.

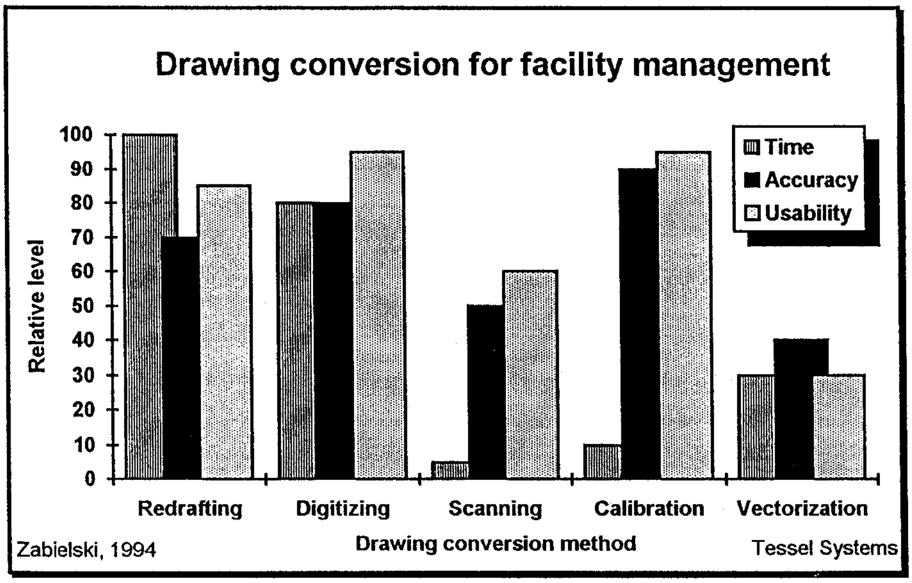


*Figure 6: A comparison of different methods for digital conversion*

Vectorisation, understood here as automatic vectorisation without object recognition, only adds time while resulting in a lower accuracy, due to image interpretation errors, and a lower usability, due to unstructured vector data that is often referred to as vector facsimile [Teicholtz, 1992].

This leads to the conclusion, that the most cost effective way of computerising paper drawings is to scan and calibrate them. The facility management field could be served best by computerised systems that can accept both calibrated scanned drawings and original CAD drawings from new designs or from redesign of old facilities, and can handle both categories in an integrated fashion.

Let's analyse the scanning process from this perspective.

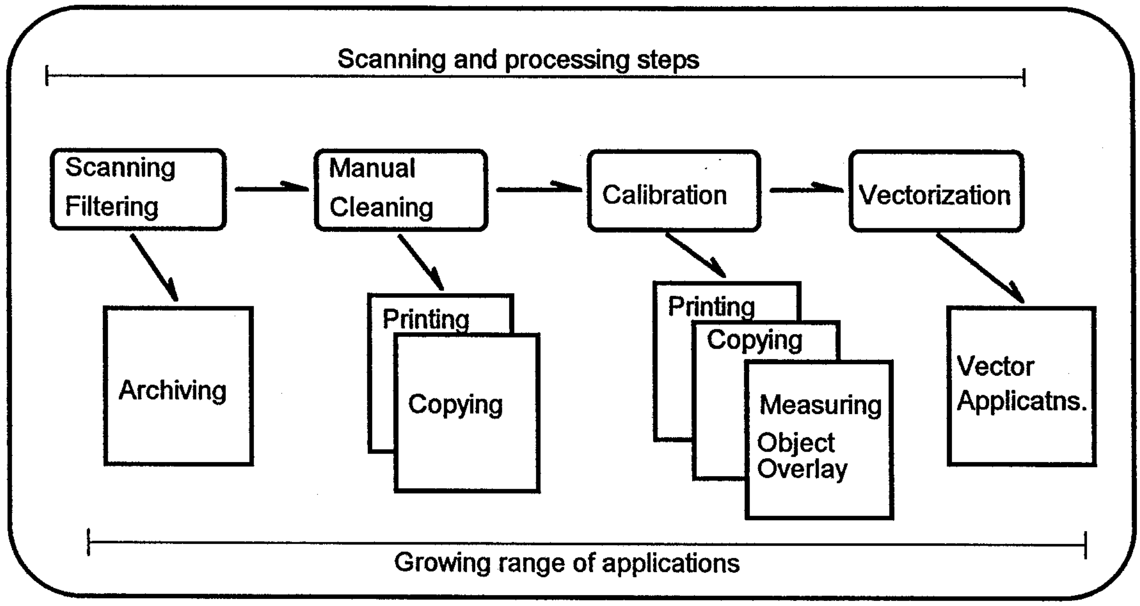


*Figure 7: The scanning process*

First, the drawing is scanned. Normally you start with a quick overview scan to optimise the settings of contrast and resolution of the scanner. Some additional scanning options, like dynamic tresholding, may be also selected at this time. By doing this the scanning machine can automatically filter away quite a lot of the "dirt"on the drawing which does not belong to the drawing information. The scanned data is usually produced directly in a highly compressed format - for full size black & white drawings the international standard compression is known as CCITT Group 4. Scanned files are archived for storage and further processing.

Further processing steps, marked in figure 7 as Manual Cleaning and Calibration, add quality to the scanned image and improve its geometrical correctness. The number of possible applications grows with the quality of data, so that e.g. calibrated raster images may be used for measuring and object overlay applications without conversion to vector format.

## RASTER CONTRA VECTOR FORMAT

There are a lot of opinions about raster versus vector format, some of them not necessarily true anymore in consequence of the continuing development of new tools and methods. Let's challenge some of those:

*The size of the vector format file is much smaller than the raster format file.*

This is true only in the case of very simple drawings. It's not unusual today to have a 2MB AutoCAD file (DWG) with a CAD design that is printed as e.g. A1 drawing. The same drawing scanned at a resolution of 300 dots per inch (DPI) would typically produce only a 400KB TIFF file (using CCITT Group 4 compression).

*The vector format drawing is more precise than the raster format drawing.*

This is true only if the vector format drawing is an original CAD drawing. The results of vectorisation may be only as good (at best) as the paper original. The calibrated raster images very often give a better precision that is in the range of 1-5 cm in the building coordinate system (0.1-0.5 mm on paper).

*The drawing must be in vector format if one should be able to edit it.*

This is one of the most common misunderstandings. A complete set of tools for editing scanned images directly in the compressed raster format is available both for CAD environments and as independent applications. In contrast, the results of automatic vectorisation are often very difficult to edit since they are not sufficiently structured.

*To use the information in the drawing in an intelligent process, for instance to identify different objects or to measure in the drawing, one needs to have a vector drawing.*

This is also just partly true. Measurements can be easily done on the background of scanned drawings directly in the world coordinate system. If the scanned data is calibrated, we may achieve a very good precision. Information linking may be implemented using the Object Overlay technique that represents the necessary objects on the background of scanned drawings.

On the other hand there are some typical advantages with the raster format drawing compared with the vector format drawing. As already seen it takes less time to produce a raster format drawing compared with a vector format drawing and as a result of this the cost is lower for creating the raster format drawing. It is also easier to handle the standardised raster files compared to vector files because the raster format is simpler and standardised.

## THE AIMS WITH COMPUTERISED HANDLING OF DRAWINGS

Now, why is it interesting to use computers together with drawings and the graphical information on the drawings? There must be some strong reasons for trying to transform paper based information into digital form. The purposes of computer aided drawing management could, in our opinion, be described as follows.

The system should facilitate:

- better quality of the drawings and their information
- smoother ways to keep the drawings up to date with reality
- better management of the drawings
- better access to and distribution of the drawings

Important requirements that the technique and the system must fulfil:

- the storage of the information must be secure
- the storage format should be standardised
- the system should be able to handle drawings produced

both by CAD system and scanned paper drawings

One of the main reasons for trying to transfer paper based drawings to a new media is to apply modern information processing techniques equally to all drawings. Therefore the system should allow one to combine graphical information with alfa-numerical information. Both information types should be possible to transfer to other computer systems. The graphical information should be possible to process in a database-centered system for administrative users and in a CAD environment for design and engineering users.

To be sure that the system is used by different kinds of potential users it must be complete and easy to use. The popularity of Windows and the wealth of compatible applications make it a platform of choice. The system should be accessible to everyone who needs the information on the drawings. And last but not least the system must be profitable. Is it really possible to create such a system? And mustn't that system use vector based drawings to fulfil all the demands on a system?

## THE PROTOTYPE SYSTEM

A prototype system is now described. This prototype system should hopefully give some answers to the two questions above. In order to test some of the hypothesis the prototype system has been developed in cooperation between Byggnadsstyrelsen and Tessel Systems. It consists of different parts illustrated in the figure 8 below.

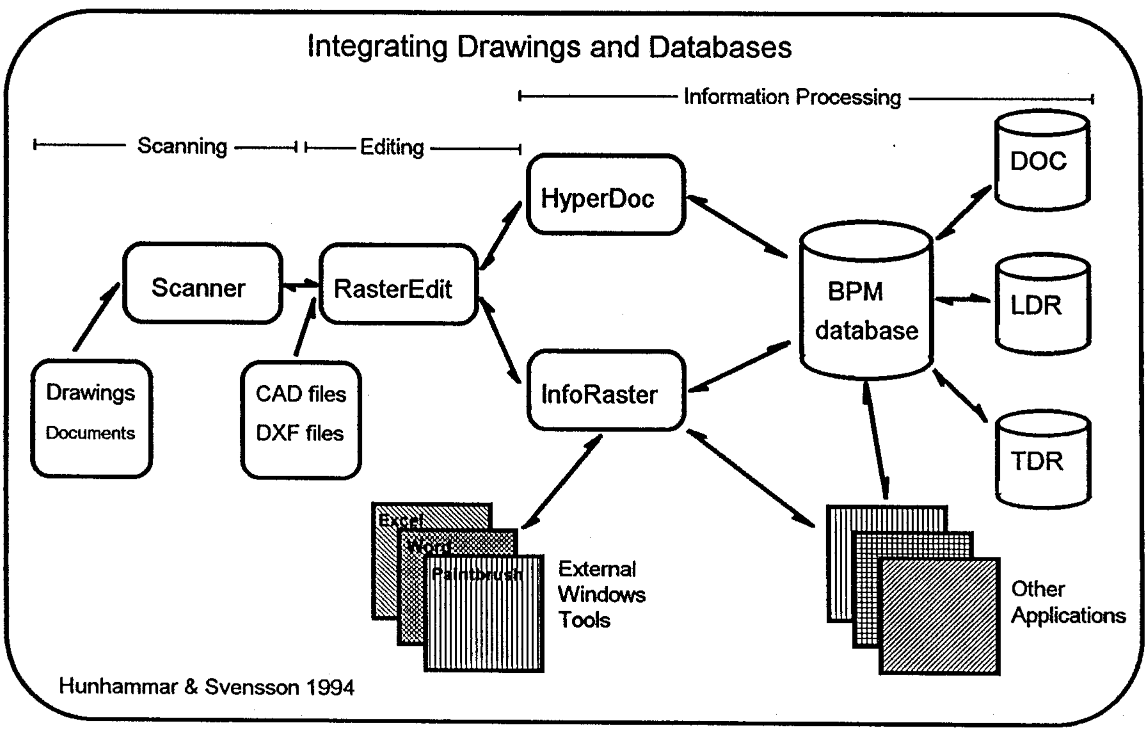


*Figure 8: Components and structure of the prototype system*

The three important program modules "RasterEdit", "InfoRaster" and "HyperDoc" are first of all briefly described as follows [Zabielski, 1993].

The RasterEdit module is a Windows based editor of raster and vector data. It performs enhancement of scanned data and adds some engineering quality to it.

The module performs the following important preparation of the scanned drawing: cropping, alignment, definition and verification of both resolution, scale and units of the drawing. It facilitates independent X&Y resizing, precise rotation around any angle, cleaning of unwanted spots and entire areas of any shape of the scanned drawing. It also contains multipoint calibration possibility which rectifies coordinates of multiple raster points.

Finally it provides access to CAD-like drafting tools and supports insertion of raster and vector blocks. It is possible both to just mark requested modifications without changing the original drawing (redlining) and to actually change the original drawing (editing).

The InfoRaster module integrates the scanned drawing with relational databases and measuring tools.

User programmable objects are placed on the drawing. The objects are either graphical symbols or description forms that may contain any number of named fields. Figure 9 below gives some examples of objects on a drawing.

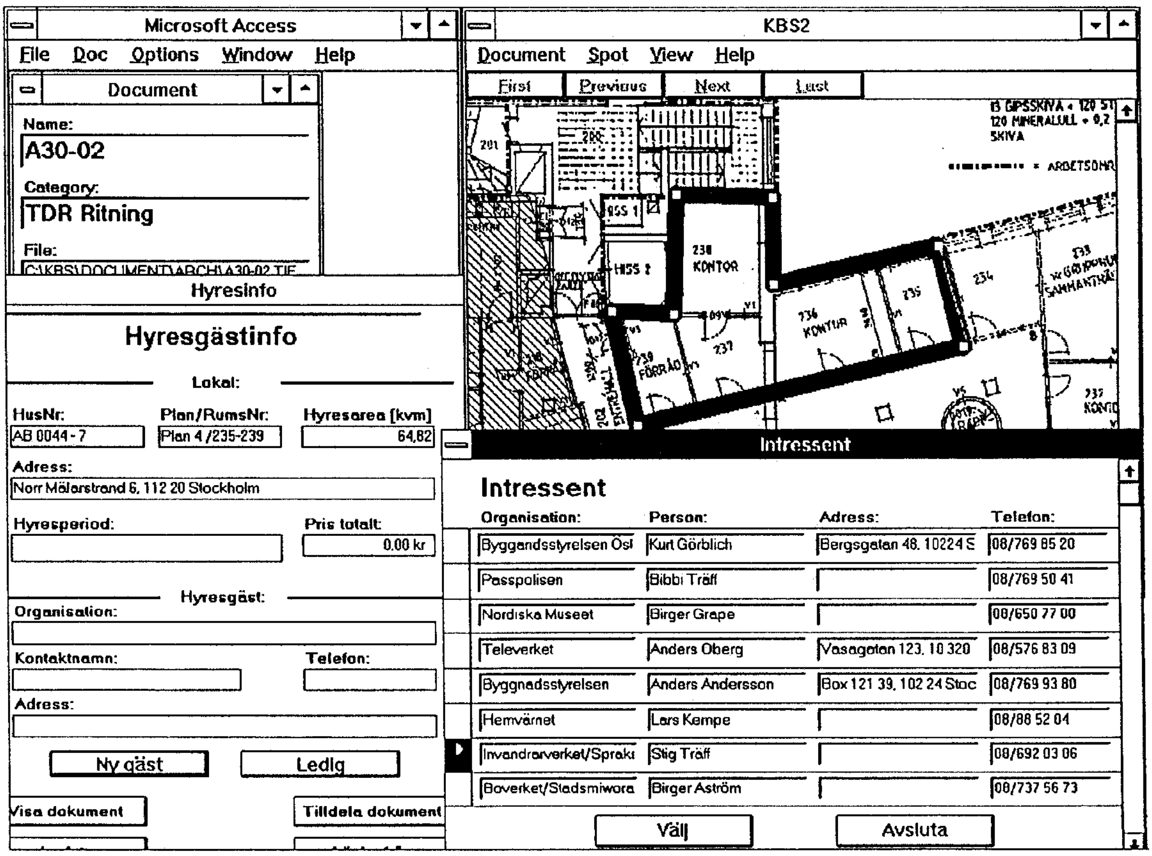


*Figure 9: Scanned drawing with InfoRaster objects*

An open interface to relational databases makes it possible to keep all data about the marked objects in external databases or database servers. Scanned or rasterised drawings may also be attached to the objects. All data modifications may be used to update the underlying databases.

The database also stores important parameters like scanning resolution and the scale and units of the drawing. This makes it possible to directly on the screen measure distances, angles, areas and volumes in the real world coordinates system.

The data in the databases may be dynamically linked with different applications using desktop tools like word processors, spreadsheets and graphical tools. The HyperDoc module provides a possibility to connect documents to each other and to connect documents with information in underlying relational databases.

The prototype system consists of four different databases or database servers. The main information source of the prototype system is the "BPM database". It provides an object oriented way of organising data. The database is structured according to the "KBS Model" [Svensson and Falk, 1994] which means it is structured according to a building product model. Figure 10 below shows the main structure of the BPM database.

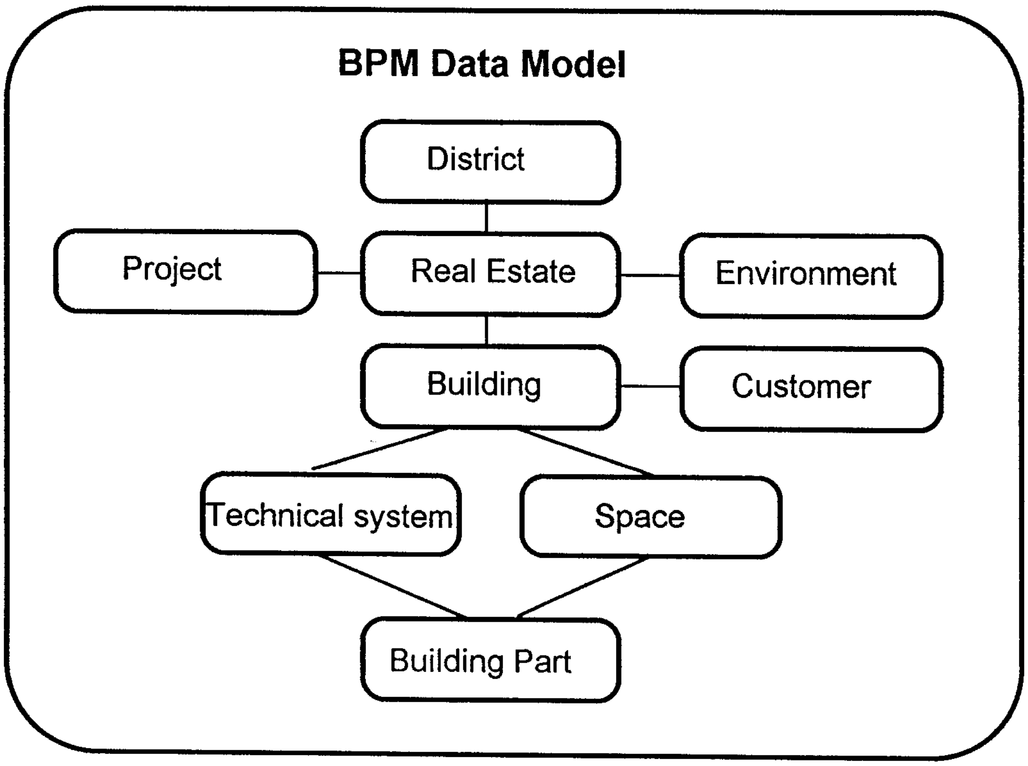


*Figure 10: Schematic information model of the BPM database*

Two existing (external) database servers are included into the prototype system: the Technical Document Register (TDR) and the Space Data Register (LDR). TDR contains information (meta data) about all drawings and written documents of the building of interest and LDR contains important information about the different spaces of the building of interest.

DOC is the storage of scanned and rasterised documents in the prototype system .

## CONCLUSION

The above described prototype system has been implemented in the MS Windows environment and loaded with data and drawings from Byggnadsstyrelsen archives. Further experiments show that it is possible to handle different sorts of drawing-related activities (figure 3) in the prototype system. The results of its evaluation are documented in a KBS report [Svensson and Zabielski, 1993]. The system also fulfils the above described purposes of computer aided drawing management. We therefore conclude that properly processed scanned drawings are sufficient for the facility management work.

A desirable future development could add selective object recognition capability, so that more building product-structured information may be retrieved automatically (or with reasonable help of the operator) from scanned drawings.

## REFERENCES

APM Multimedia AB [1989]
**Förstudie av scanningproject inom Byggnadsstyrelsen**

Forsberg, S. [1990]
**Lägesrapport: Datoriserad ritningshantering**
Bygg Sverige, 2•1990

Haugen, L. [1990]
**Bygningsforvaltning: Økonomisk drift og vedlikehald - organisasjon, information og system**
Norges Tekniska Høgskole, Trondheim

Svensson, K. [1991]
**Neutral Building Product Model - The KBS Model**
Technical Report T:123E, The National Board of Public Building

Svensson, K. and Zabielski, L. [1993]
**Fältdatabas med ritningar**
Byggnadsstyrelsen, Stockholm, Sweden

Svensson, K. and Falk, Ö. [1994]
**Prototyp av Neutral byggproduktmodell (KBS-modellen)**
Byggförskningsrådet

Teicholtz, E. [1992]
**Computer Aided Facility Management**
McGraw-Hill, Inc. ISBN 0-07-063405-X

Zabielski, L. [1993]
**Your Paper Drawings in the World of Organized Information**
Proceedings of the Fifth International Conference on Computing in Civil and Building Engineering, Anaheim, Calif. USA.