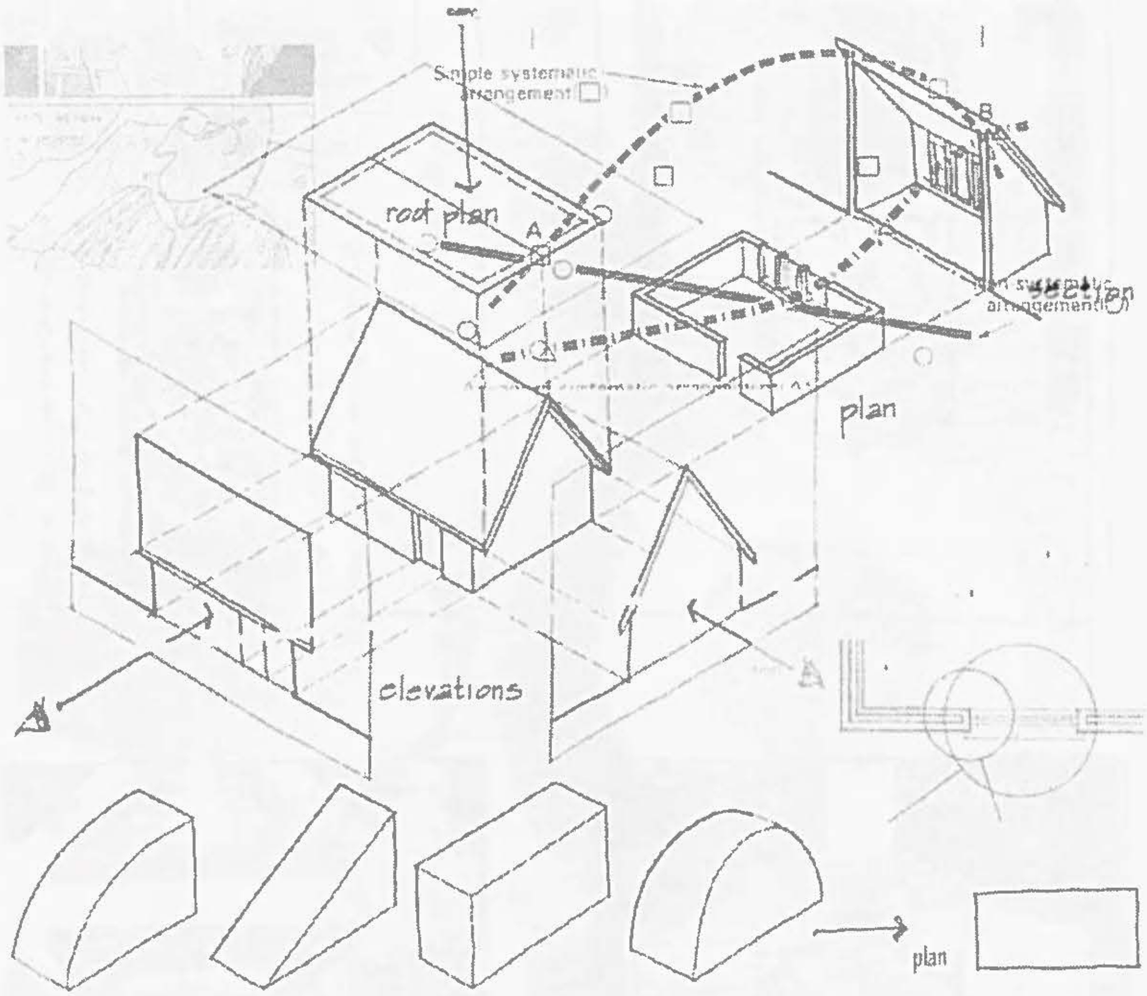
Utilising Information in Architectural Design Drawings- Problems and Solutions



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This work is concerned with how design information from architectural drawings is conveyed and transformed into built objects. Architectural drawings are identified as the primary source of the required information and their role is considered. In particular, how they came to be such a dominant means of communicating design information is considered. Previous studies identified potential sources of difficulty in their use and also proposed improvements in the presentation of the information as a potential solution. However, the construction industry has been reluctant to change its practices and the alternative viewpoint to drawing presentation that explores how individuals use the information is proposed

The design and construction of buildings

The design and construction of any building consists of a complex intellectual, administrative and logistical exercise that underlies the visible site activities. The latter, unfortunately, constitutes the typical image of the industry. Turner suggests that

> "Construction is undeniably an enterprise, an act of boldness even for the simplest of building. For modern, complex buildings it involves the commissioning, management, design and assembly of huge amounts of raw materials and the use of considerable labour resources over a long period of time."

Day extends this theme further by noting that it is misleading to consider that most of the activity on a building project occurs on the construction site. Most of the effort has to do with the processing of information in order to ensure that a design intention becomes physical reality. Information flows back and forth between the various members of the design team, manufacturers and finally the construction team. There is a steady build up in the flow of information until it reaches a peak during the construction phase where details must be finalised, materials and fittings ordered and any ambiguities in the information resolved. The site operative assembling and fixing a component in a specific part of the building is the final, but most obvious, part of a complex information processing chain. Almost like a complex variation of a child's game of "chinese whispers". This is confirmed by Osbourn and Greeno when they suggest that all operational and management activities associated with the design, construction and subsequent performance of a building rely on quite complex information being transferred between the various participants of the building team.

Communicating the design intention

Styles notes there are three classes of information about the elements of the building that may be required to understand the design intention:

- What it is that has to be installed or erected. Information such as the nature and amount of the material or components and its physical dimensions.
- Where it is to be placed. This demands graphical and dimensional information regarding its location and its relationship to the entire building.
- How it is to be placed or fixed in place, particularly in association with any neighbouring elements.

Despite alternative methods that have been devised for particular situations, the tri-partite concept of drawings, specifications and bills of quantities together form the complete information package that conveys the design intention. This is also long enshrined in building contract procedure. The differentiation of function of these three forms of information and the resulting hierarchy is also noted.

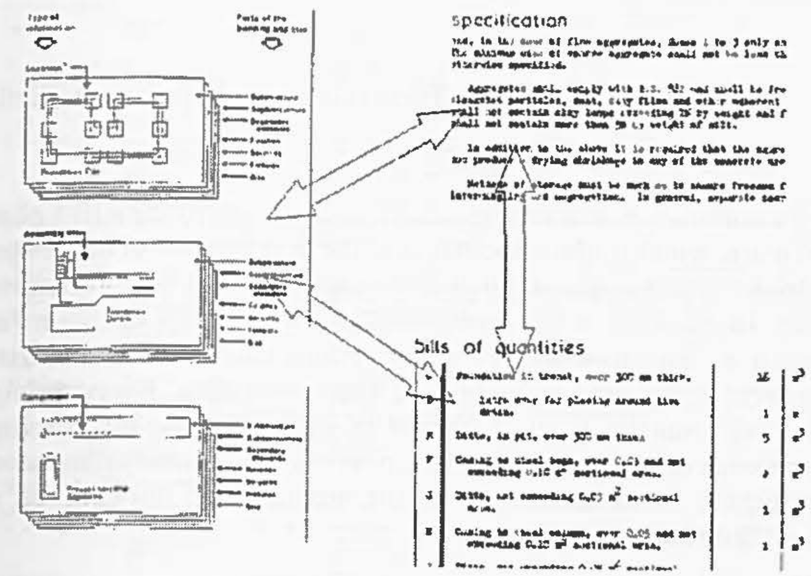


Figure 1 - Drawings/specification/bills of quantities information package
Source: Adapted from Styles, K, (1986) Working Drawings Handbook, Butterworth Architecture

The specifications

The function of the specification is to set out the quality standards for materials and workmanship in relation to building elements whose geometry, location and their inter-relationships have been described by means of the drawings. This suggests that in a properly structured information package neither the specification nor the drawings should trespass upon the other's territory. This addresses both the requirements of what has to be erected and how it is to be placed or fixed in place.

Bills of quantities

The bills of quantities inform the contractor of the amounts and quality of specific materials that he is to erect or install and this enables him to provide an overall price for the work. This, to some extent, addresses the requirement of what has to be installed or erected.

Drawings

Drawings are regarded as the only source of the location / component / assembly information in its entirety, or at any rate are the main starting points for the information search. The first question that is always asked is where? followed by the supplementary questions, what? and how?

The drawing may be regarded as the primary source of design information, which is then amplified by the specification and the bill of quantities as illustrated in Figure 1.

The hierarchy of design information

Evans in considering the potential contamination of the visual images used in architecture by other forms of communication is emphatic in the primacy of the drawing by stating that

"...for architecture, ... There is one unfailing communicant,

and that is the drawing."

The importance of drawings is further developed by the RIBA plan of work, which outlines the stages of the development of the design ideas, the tasks carried out at each stage and what documentation may be required. It represents a logical sequence of actions to be taken so that good and timely decisions can be made and that progress is not held up or abortive work undertaken. It is primarily in diagrammatic form as shown in Figure 2. The relationship between communications and the plan of work is clearly illustrated in Figure 3 and this confirms the emphasis on drawings as a communications tool.

The emphasis placed on drawings as shown above demonstrates the importance of their role in conveying the design intention in the construction of a building. They are the primary source of design information; either graphically illustrating what is required or giving directions to the sources of supporting descriptive information.

The role of architectural drawing

A number of writers reflect on the role of architect's drawings as part of the building development process. Groak in considering the significance of architectural drawing states

> "Designers have used graphic methods....for centuries, but without a clear acknowledgement of their power as an active tool, beyond the presentation of material for contemplation. They have used them in comprehending and identifying certain regularities in the organisation of buildings and spaces. These regularities have been captured as trophies in defining the stable or invariant properties of built form."

Ching suggests that although architectural drawings may be excellent two-dimensional presentations worthy of exhibition, their primary purpose was as a communication tool.
Kolb extends this simple notion further by suggesting that architectural drawings, with limitation, can appear to act like a language. The limitation is that it cannot be described by any grammar, its meaning cannot be conveyed by the use of other drawings in the same way that words can be used to describe meaning in verbal languages. Evans suggests that all things with a conceptual dimension are like a language and in this vein architecture may be considered to be language-like without being a language.

History of architectural drawing

Modern use of architectural drawings is clearly identified as playing a very important role in the development of design ideas

Stage	Purpose of work and decisions to be reached	Tasks to be done	People directly involved	Commonly used terminology
A Inception	To prepare general outline of requirements and plan future action	Set up client organisation for briefing. Consider requirements, appoint architect.	All client interests, architect.	Briefing
B Feasibility	To provide the client with an appraisal and recommendation in order that he may determine the form in which the project is to proceed, ensuring that it is feasible functionally, technically and financially	Carry out studies of user requirements, site conditions, planning, design, and cost, etc., as necessary to reach decisions.	Clients' representatives, architects, engineers and QS according to nature of project.	
Stage C begins when the architect's brief has been determined in sufficient detail.				
C Outline Proposals	To determine general approach to layout, design and construction in order to obtain authoritative approval of the client on the outline proposals and accompanying report.	Develop the brief further. Carry out studies on user requirements, technical problems, planning, design and costs, as necessary to reach decisions.	All client interests, architects, engineers, QS and specialists as required.	Sketch plans
D Scheme Design	To complete the brief and decide on particular proposals, including planning arrangement, appearance, constructional method, outline specification, and cost, and to obtain all approvals.	Final development of the brief, full design of the project by architect, preliminary design by engineers, preparation of cost plan and full explanatory report. Submission of proposals for all approvals.	All client interests, architects, engineers, QS and specialists and all statutory and other approving authorities.	
Brief should not be modified after this point.				
E Detail Design	To obtain final decision on every matter related to design, specification, construction and cost.	Full design of every part and component of the building by collaboration of all concerned. Complete cost checking of designs.	Architects, QS, engineers and specialists, contractor (if appointed).	Working drawings
Any further change in location, size, shape, or cost after this time will result in abortive work.				
F Production Information	To prepare production information and make final detailed decisions to carry out work.	Preparation of final production information i.e. drawings, schedules and specifications.	Architects, engineers and specialists, contractor (if appointed).	
G Bills of Quantities	To prepare and complete all information and arrangements for obtaining tender.	Preparation of Bills of Quantities and tender documents.	Architects, QS, contractor (if appointed).	
H Tender Action	Action as recommended in relevant NJCC Code of Procedure for Selective Tendering.	Action as recommended in relevant NJCC Code of Procedure for Selective Tendering.	Architects, QS, engineers, contractor, client.	
J Project Planning	To enable the contractor to programme the work in accordance with contract conditions; brief site inspectorate; and make arrangements to commence work on site.	Action in accordance with RIBA Plan of Work.	Contractor, sub-contractors.	Site operations
K Operations on Site	To follow plans through to practical completion of the building.	Action in accordance with RIBA Plan of Work.	Architects, engineers, contractors, sub-contractors, QS, client.	
L Completion	To hand over the building to the client for occupation, remedy any defects, settle the final account, and complete all work in accordance with the contract.	Action in accordance with RIBA Plan of Work.	Architects, engineers, contractor, QS, client.	
M Feedback	To analyse the management, construction and performance of the project.	Analysis of job records. Inspections of completed building. Studies of building in use.	Architect, engineers, QS, contractor, client.	Feedback

Figure 2 - Outline plan of work Source: RIBA Plan of Work for design team operation, (1997), RIBA Publications.

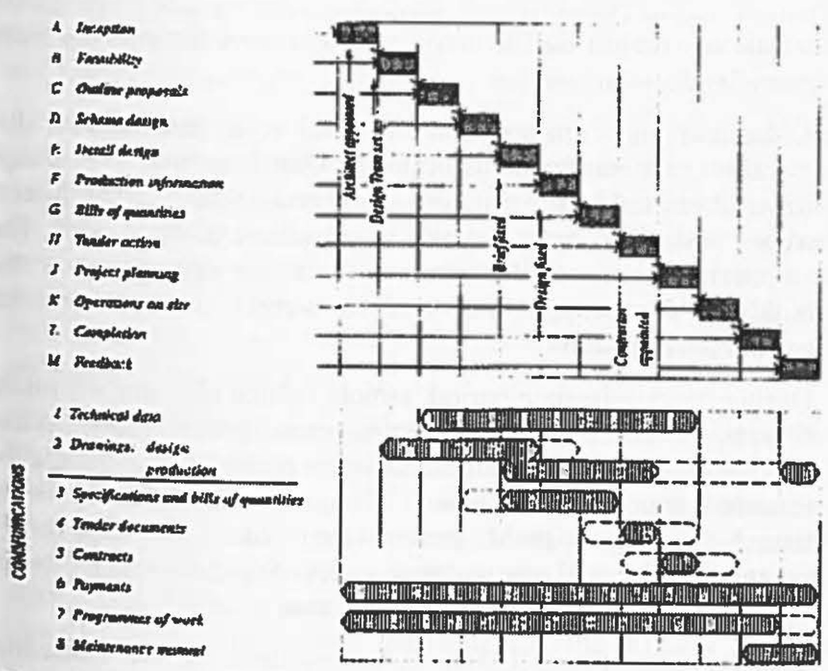


Figure 3 - Communications within the RIBA plan of work. Source: Osbourn, D & Greeno, R, (1997) Introduction to Building, Longman ltd.

and in conveying the entity of the building.

However this was not always the case as can be seen from an examination of how the use of architectural drawings has evolved over the centuries.

Historically, building design was craft based undertaken by master masons and was required to be in-situ with the actual construction work. Robbins and Porter describe the significant changes in the use of drawings, as part of the building process, from ancient times to the present.

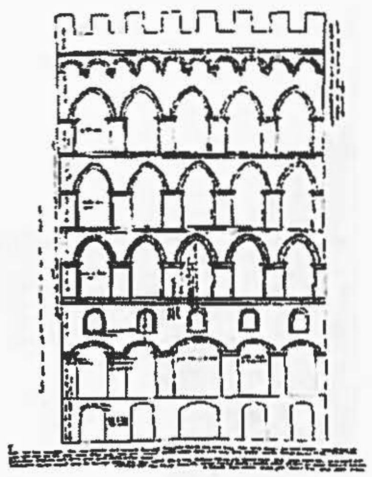
In ancient Egypt, despite archaeological evidence of drawing fragments showing ground plans, actual production was based on a combination of working from drawings and actual projections on site requiring the architects regular presence in-situ. Similarly in ancient Greece there was reference to the extensive use of drawings such as the plan, the elevation and perspectives in the interaction of the architect and the patron. Despite the role of drawing in ancient architecture it was still not a dominant instrument of design nor had it freed architects of their craft responsibilities. It was simply one of many techniques used by architects in crafting the design of the building for which they were responsible, being utilised as the building went up rather than in any conceptual role.

The role of drawing probably did not shift much after the fall of Rome and its use may even have declined although medieval architects did make use of drawings. However, because technical supervision had to be constant, and for the most part was conveyed verbally, the master mason was tied to the building site throughout its construction. Additionally the design was developed piece by piece, governed only by the principles of symmetry and a sense of size. The design developed completely within the 'mind's eye', evolving on a trial and error basis with the architect/craftsman pausing during construction to translate concepts into crude plans and incomplete, fragmented elevations. There was as yet no notion, nor the possibility, of using drawings to guide the project in a way that would enable architects to remove themselves from everyday decision making.

A familiar and consistent architectural style ensured that this practice remained the same up to the Gothic period. The design was still limited by the rules of Gothic architecture and architects were constrained by the social organisation of their craft. The emphasis was on the attainment of divine proportion in the building. Visual appearance and the weight of stone were not major considerations.

During the renaissance period, simple related plan and elevation drawings, models, perspective drawings and pattern drawings had begun to play a more dynamic role in the process of simulating the intended structure of a space. Designers used these tools to translate their visual perceptions into an apparently comprehensible and manipulative series of spatial events, capable of accurately portraying a design intention.

This process of redefinition is exemplified by the Sansedoni elevation illustrated in Figure 4. This was used to enable on-site



craftsmen to work from a drawing within the exigencies of the site. This provided the basis for remote design and the idea of the conceptual designer. This signalled the beginning of a change in the architect's role and status.

Other significant landmarks in the development of architecture occurred throughout the nineteenth century, namely first angle orthographic projection and the formalisation of the architectural profession and its associated education.

By the mid-nineteenth century the use of drawings in representing design ideas was further enhanced with the modification of the orthographic drawing system. Physicist and military engineer Gaspard Monge developed this refinement that came to be known as 'First Angle Projection'. His development of a means to graphically portray a complex object by means of a precise and standardised viewing relationship between the upper, side and front views of the object had a profound impact on visualisation techniques. The system co-ordinated the plan views with the elevation and the section views as illustrated in Figure 5. It was deemed so important that it was initially classified as top secret by the French government. Despite the initial censorship, the system soon achieved widespread acceptance and use in both the architectural and engineering disciplines. It is worth noting that it was developed in time to accurately visualise the many new inventions that emerged during the industrial revolution.

The architectural profession was institutionalised and its education formalised by the turn of the nineteenth century. This formalisation led to a growing emphasis on fine-line drafting skills to the extent that technical drawing was considered to be tantamount to an art form. Aesthetically, the architect became less concerned with the sculptural qualities of form and space and instead turned to designing in terms of the pictorial nature of the façade and silhouette. In addition, the growth of the print medium as a means of disseminating information led to a proliferation of design ideas through journals. The combination of the educational emphasis was on drafting skills and the easy dissemination of ideas through journals meant that by 1900 the drawing had become the accepted language of the architect.

As a result of the evolution of the design discipline and its associated tools, architecture became a more distinct profession with architectural drawing as its dominant instrument and a symbol of what made the architect unique. The drawing had become the means by which architects could transform their design ideas into the built form and was also an aid in the transformation of the social division of labour through which architecture was produced.

Thus, the process of building design developed over a long period of time. It evolved from an ad-hoc and instructional craft based site operation, carried out primarily by master masons with limited use of graphic information, to an independent professional practice that utilises graphical information to develop design concepts remote from the actual site of the building. The main point must be that the use of architectural drawings was the primary force in enabling this change and the following statement from Robbins summarises this well:

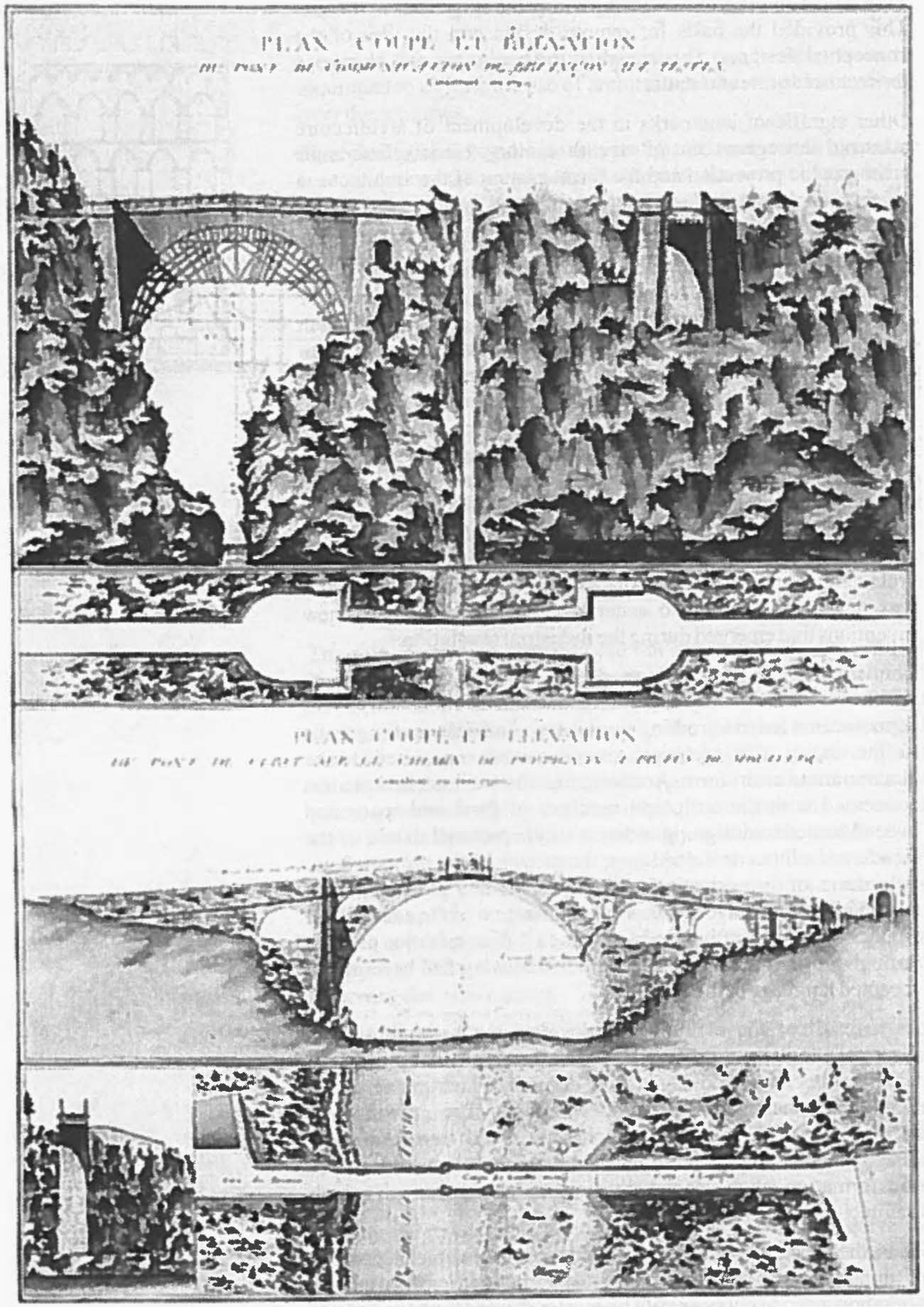


Figure 5 - First angle orthographic projections Source: Porter, T. (1997), The Architect's Eye, Visualisation and Depiction of Space in Architecture, E & F N Spon

Utilising information

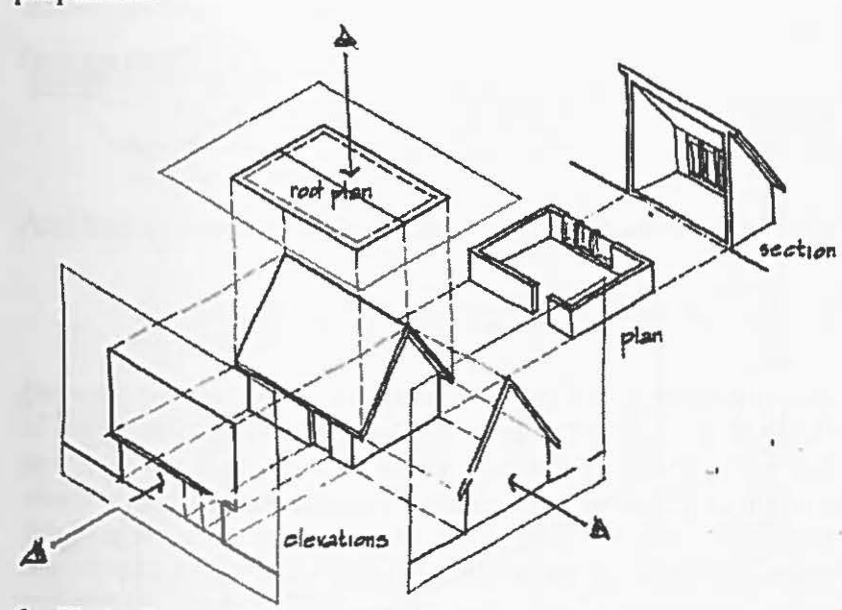
"In a sense, the working drawing provides a disembodied but authoritative architectural presence."

How architectural drawings work

The way in which architectural drawings work as a communication tool has also been the subject of some consideration by researchers.

Robbins noted that architectural drawings were generally relational, and use projective and geometrical techniques for depicting a three dimensional object in two dimensions. The different viewpoints offer designers a number of different approaches with which to represent a design. The most commonly used method of representation in modern architectural practice is orthographic projection. This represents a solid object meeting a two-dimensional plane at a 90-degree angle. The plan represents a view of a horizontal slice of the design from above and can portray the patterns and dimensional relationships of a floor or ground plane. Sections depict a view of a vertical slice through the building or object being represented and provide a sense of how it works internally.

Ching provides a more technical/practical description of orthographic drawings by noting that while the observer's line of sight is perpendicular to both the drawing plane and the principal surfaces of the building viewed the drawing surface is always parallel to the major surfaces of the building. This is clearly illustrated in Figure 6. He also suggests that the greatest advantage of using orthographic drawings is that all facets of a form parallel to the drawing surface are represented without foreshortening or distortion. They retain their true size to scale, shape and proportion.



6 - Plan/section/elevation views Source: Ching, F (1978) Architectural Graphics, Architectural Press, London.

Functional role of drawings

Cheng's research into the use of diagrams for problem solving suggests that the functional roles of the diagrams play an important role in supporting the reasoning to enable the problem to be solved. These functional roles are capacities and features that a diagram possesses. It was suggested that several functional roles of a single diagram might be used to solve a problem. The motivation for this approach is to provide a principled method for the selection and design of effective diagrams for particular problems.

In the case of the architectural drawing, tradition and convention already define the diagrammatic arrangement and functional roles. The related plan, section and elevation views drawn using orthographic projection has been in widespread accepted use for a long time.

He notes that the functional role of architectural drawings is to depict the spatial features of objects and the arrangement of their components with accuracy. They have close spatial mappings, from the shape and location of target objects to the shape and position of symbols representing them. Details hidden by intervening material may be shown by cut-away sections and symbolic conventions used to hide unnecessary detail or provide additional information, such as location grids and centre lines. He suggests that this is to support the reasoning required for the construction of the building.

Styles extends this by suggesting that the information requirements of constructors consists of what?, where? and how?, and argues that this information is primarily found in the drawings. This is illustrated in Figure 7. Therefore, a practical functional role for architectural drawings must be to depict the spatial features and components to enable an understanding of what it is, where constituent parts are placed and, finally, how they are to be fixed or assembled.

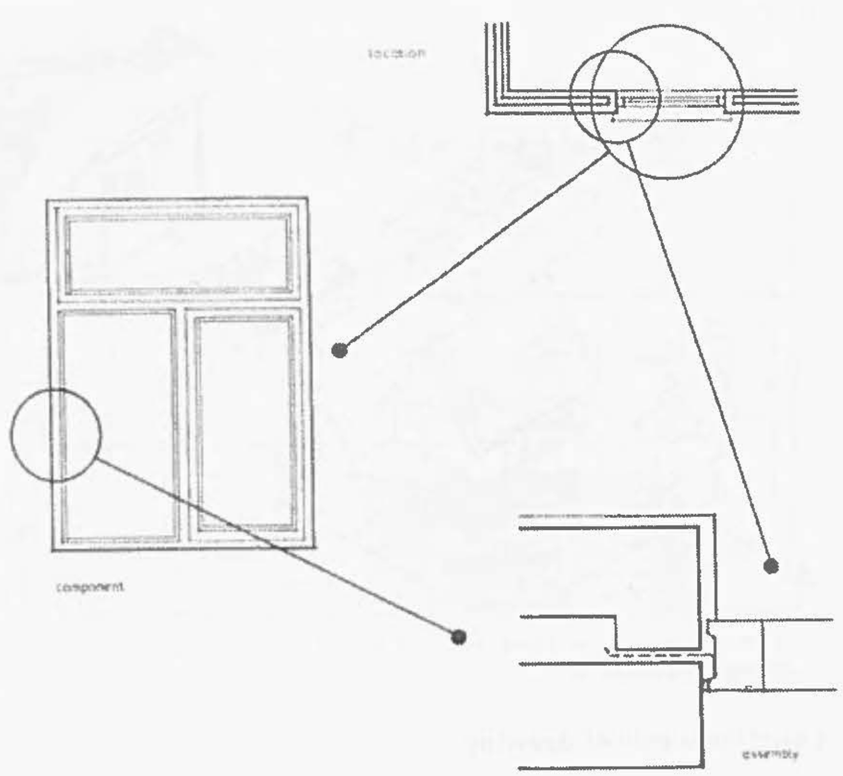


Figure 7 - Drawings indicating where?, what? and how? Source: Styles, K (1986) Working Drawings Handbook, 2nd edition, Butterworth-Architecture

Drawings, and in particular the information on them, have a very extensive range of uses from simply informing the client what it is that is to be built, to providing the constructors with all the spatial and compositional information required to build it. Everybody with input into the development of buildings has some use for some, or all, of the information contained within the drawings.

Problems with drawings

Orthographic drawings, by their very nature, may not be the ideal tool for communicating information. Ching notes that

> "In using plan/section/elevation drawings to represent architecture, we are in fact utilising an abstract method to represent reality."

This point is simply illustrated in Figure 8 where four objects have different forms but have the same plan view.

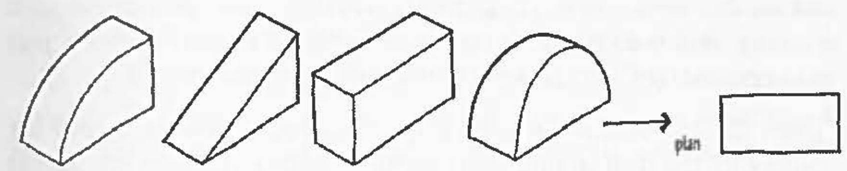


Figure 8 - Plan view of different forms Source: Ching, F (1975) Architectural Graphics, Architectural Press.

Robbins also confirmed that drawing was in general ambiguous but asserted that it must work as a clear and direct communication. To ensure that this occurs, drawings were conventionalised and used within an organised network of communication that shares those conventions used to read the drawing.

Newton noted that

> *"Architects use the visual conventions of documentation as though they are an accurate shorthand describing the construction process."*

And therein, perhaps, lies another problem as suggested by Styles

> *"It is not possible for drawings to show activities, only the completed event."*

He notes that the contractor's main problem lies in the organisation of his resources, both material and human. Success lies in careful and accurate planning. Bricks have to arrive on site at the right time, the bricklaying labour force has to be sufficient to optimise the length of time scaffolding is on hire. It must then be re-deployed smoothly and economically when the work is finished, either to another part of the project or to another project altogether. Such information is not normally forthcoming from the design documentation. It does not point out that:

1- The last brick will be laid some eighteen months after the first.

2- It will be laid on an entirely different part of the site.

3- The nature of the construction work involves the total bricklaying operation being split into three separate stints, with substantial gaps in between.

Whilst, he notes that none of this is communicated by the specification and bill of quantities he did, rather hopefully, suggest that it may well be deducible from the drawings, although only after careful and intelligent examination. Thus, a time factor may be added to the functional roles of drawings. In addition to what?, where? and how?, the question of, when? can be added to this list.

An additional problem lies in the focus of attention on the drawings themselves. Evans argues that drawings have come to be treated as works of art and as such are repositories of effects and the focus of attention while the transmutation that occurs between drawing and building remains to a large extent an enigma. He suggests that there is a lack of recognition of the deviations that occur in the translation from the drawing to the building. He alludes to the gap between drawing and building as a locale of subterfuges and evasions that one way or another get around the enormous weight of convention that has always been architecture's greatest security and at the same time its greatest liability. The properties of a drawing, that is its peculiar powers in relation to its inferred object as suggested by Cheng above, are hardly recognised at all.

Given the importance of drawings as a communication tool for conveying the design intention to other parties of the development process and their abstract nature of representation it is worth examining whether it is effective in its intended role. This is considered in the next section.

Research into the effectiveness of drawings

Some research has been carried out which indicates that there are some problems with the effectiveness of the information conveyed in drawings.

Daltry conducted an analysis of site management queries on eight sites and found that the vast majority of technical queries could be related to deficiencies in working drawings or schedules.

The objective of a further study by Daltry and Crawshaw was to isolate features of drawing practice that effected and, more importantly, contributed to the technical information requirements of the site.

A key finding was that information was frequently inadequate even in sets of drawings that had been prepared with particular care. Each set of drawings had some inadequacies in the information it contained. A lack of guidance about what was to be communicated and the information needed to build was identified as the main cause of many deficiencies in working drawings.

This was confirmed by another study by Crawshaw BRE research paper 60/76, entitled 'Co-ordinating working drawings', that suggests that there were over 700 conflicts between drawings in a sample of 25 building projects and that most of these led to abortive or additional work. This is graphically illustrated in Figure 9.

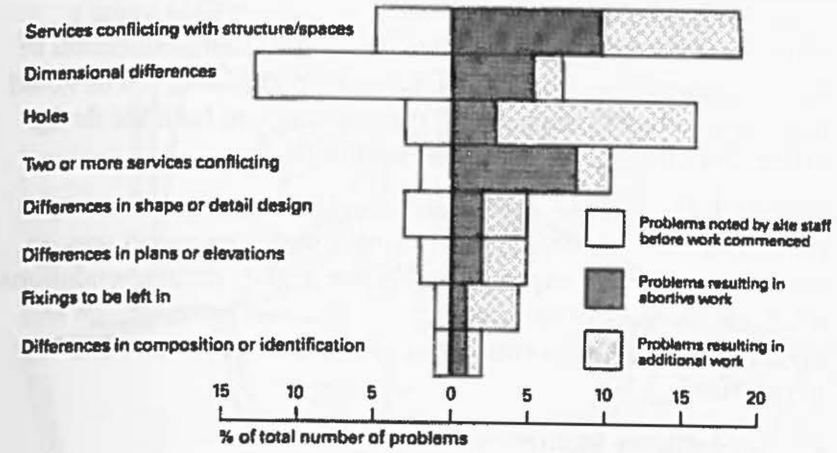


Figure 9 - Conflicts between drawings and their effects on site working. Source: Crawshaw, D T, Co-ordinating working drawings, BRE current paper 60/76

A study by the European Foundation for the Improvement of Living and Working Conditions suggests that as much as 11% of the cost of a typical building arose from a combination of design errors, organisational errors and implementation errors. Typically, some of these errors could be attributed to poor communication of information between the parties involved in the construction project. Whilst the report is not explicit in identifying drawings as being a source of any problems, it does identify the scale of the problem associated with errors on construction projects.

It is clear that there are recognised difficulties in the use of architectural drawings as a means of communicating information. Perceptions of the difficulties are confirmed by research into their effectiveness on site but these studies also gave some thought to the means of overcoming these difficulties.

Solutions proposed in research reports

The study by Daltry and Crawshaw made the following recommendations:

1- A set of working drawings should have a systematic structure.

2- The sizes of drawing sheets from all sources should conform to international 'A' dimensions.

3- Location drawings should be contained on sheets that are large enough to minimise fragmentation of overall plans and elevations.

4- The set should incorporate references that lead the user of drawings directly to individual sheets in the majority of searches for information.

5- Where no reference is provided each sheet should have a short and explicit title.

6- Detailed views should include information that fixes the position of each view. Grids and controlling lines representing key reference planes, such as finished floor level, were recommended.

7- For any set of drawings to be used effectively a brief guide to the arrangement of the set is important.

It was suggested that these recommendations would make a significant contribution to the more effective communication of design information from drawing board to site. But, it was noted that a sound basis for checking the drawings, in both the design office and on site, would also be required.

The main focus of the European Foundation for the Improvement of Living and Working Conditions report was on working conditions experienced on site and its recommendations focussed on ways of improving these through better design and organisation. Its recommendations consisted of three routes to innovation:

- A cluster of client-supplier relationships.
- A cluster of processes and products.
- An integrated organisation where consultation replaces part of the decision-making process.

Solutions proposed by government or professional authorities

In addition to the solutions proposed in research, there are a number of solutions that have been attempted by government or professional authorities as a result of concerns for the problems associated with the construction process, such as Co-ordinated Project Information (CPI), as illustrated in Figure 10 and Figure 11, or Systematic arrangements of drawings using CI/SfB coding, as illustrated in Figure 12.

A study by Crawshaw and Snook tested the benefits of the use of the different systematic arrangements and found a flexible approach to these arrangements was appropriate. Experience in practice indicated that the relevance of one system for all situations was open to question. They hypothesised that there might be a more sensible approach to drawing arrangements depending on the characteristics of the project and this is shown graphically in Figure 13.

C Demolition/Alteration/Renovation

C10 Demolishing structures
C20 Alterations - spot items
C30 Shoring
C40 Repairing/Renovating concrete/brick/block/stone
C41 Chemical dpcs to existing walls
C50 Repairing/Renovating metal
C51 Repairing/Renovating timber
C52 Fungus/Beetle eradication

D Groundwork

D10 Ground investigation
D11 Soil stabilization
D12 Site dewatering
D20 Excavating and filling
D30 Cast in place concrete piling
D31 Preformed concrete piling
D32 Steel piling
D40 Diaphragm walling
D50 Underpinning

E In situ concrete/Large precast concrete

E10 In situ concrete
E11 Gun applied concrete
E20 Formwork for in situ concrete
E30 Reinforcement for in situ concrete
E31 Post tensioned reinforcement for in situ concrete
E40 Designed joints in in situ concrete
E41 Worked finishes/Cutting to in situ concrete
E42 Accessories cast into in situ concrete
E50 Precast concrete large units
E60 Precast/Composite concrete decking

F Masonry

F10 Brick/Block walling
F11 Glass block walling
F20 Natural stone rubble walling
F21 Natural stone/ashlar walling/dressings
F22 Cast stone walling/dressings
F30 Accessories/Sundry items for brick/block/stone walling
F31 Precast concrete sills/lintels/copings/features

G Structural/Carcassing metal/timber

G10 Structural steel framing
G11 Structural aluminium framing
G12 Isolated structural metal members
G20 Carpentry/Timber framing/First fixing
G30 Metal profiled sheet decking
G31 Prefabricated timber unit decking
G32 Edge supported/Reinforced woodwool slab decking

Figure 10 Sample list of CAWS work sections and groupings. Source: Co-ordinated project information for building works, CCPI 1987.

Figure 11 Information arrangements Source: Co-ordinated project information for building works, CCPI 1987.

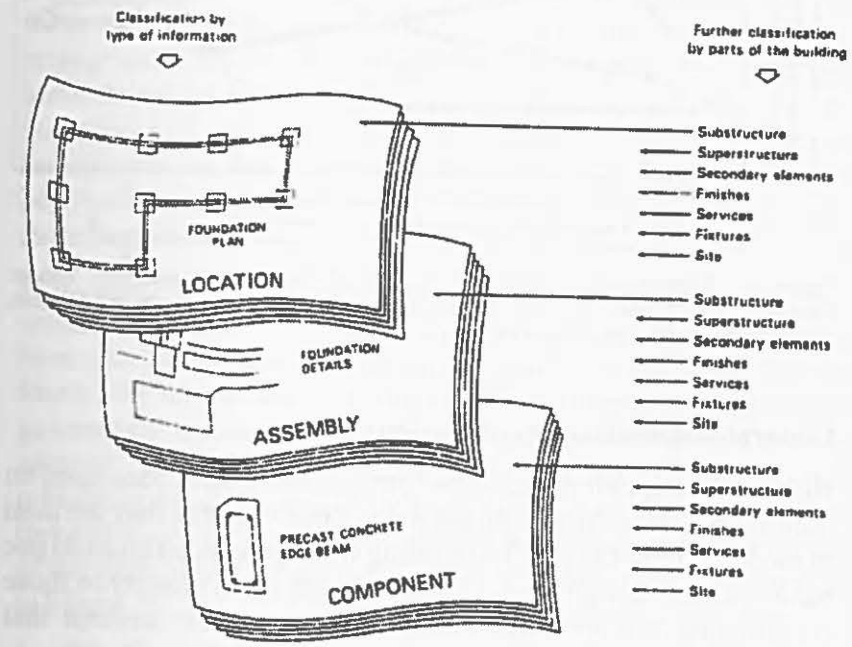


Figure 12 - Advanced systematic arrangement of drawings.

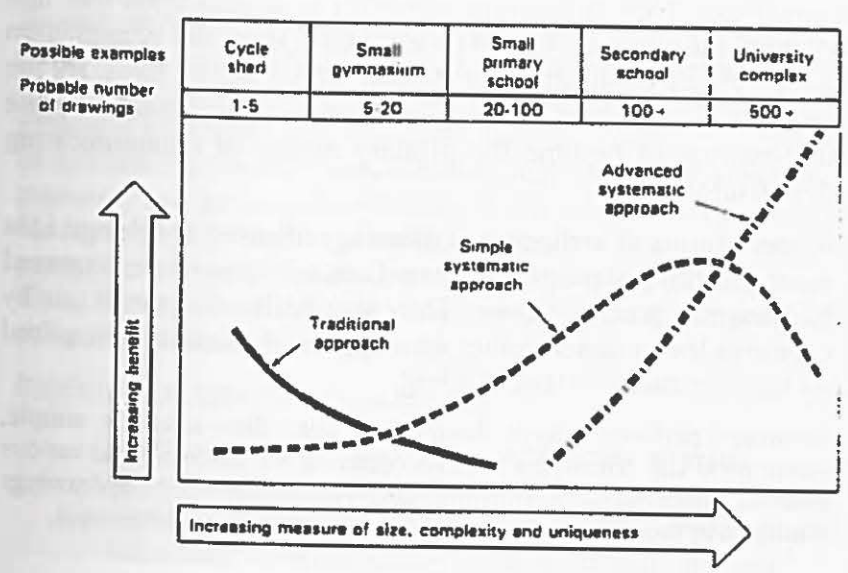


Figure 13 - Hypothesis of effect of drawings arrangements. Source: Crawshaw, D T & Snook, K (1988) Production Drawings Arrangement and Content, Building Research Establishment current paper 3/88

This hypothesis was then tested on the information packages for a sample of 15 projects. A league table was developed based on simulated searches for information and interviews with designers and users of the information on site. The findings of the experiment are illustrated in Figure 14. The findings confirmed the hypothesis that a flexible approach to the use of systematic arrangements is required to yield optimum benefits. What was clear from this research was that as projects become more complex, benefits do accrue from the use of more systematic drawing arrangements.

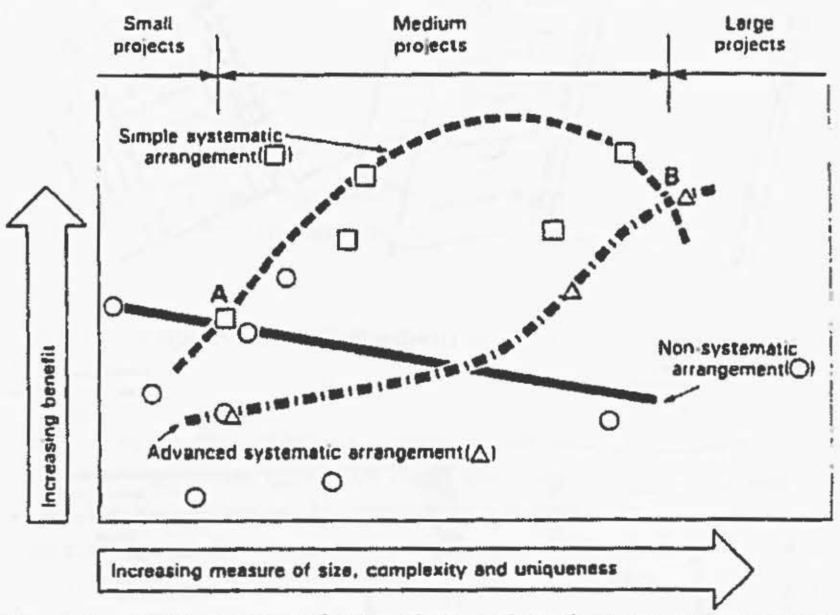


Figure 14 - Experimental investigation of effect of drawings arrangements. Source: Crawshaw, D T & Snook, K (1988) Production Drawings Arrangement and Content, Building Research Establishment current paper 3/88

General discussion and conclusions

Historically, drawings, in some form or other, have been used on building projects. Although, not in the same way that they are used in modern times. Originally, building work proceeded on an ad hoc basis with the designer relaying his design ideas directly to those constructing the building. This direct supervision ensured that there was no ambiguity between design idea and the built entity.

From the renaissance period onwards this began to change as the drawing evolved into a more powerful communication tool that enabled the designer to distance himself from the construction work, relying on the drawings to convey his design ideas. By the start of the 20^{th} century drawing methods had developed to enable the drawing to become the primary means of communicating design information.

Modern forms of architectural drawings illustrate the design idea by representing separate but related sets of views of the proposed building in a precise manner. They also fulfil a functional role by capturing the spatial structure that supports the reasoning required for the construction of the building.

Drawings perform a very demanding role; they must be simple, economical and effective whilst also catering for the many and various needs of numerous users. The information contained within the drawings is utilised by most, if not all, participants in the development process.

However, there are problems associated with drawings; they are recognised as being ambiguous in the way that they convey the information. They require and rely on an understanding of the conventions used in drawings to clearly read and understand the meaning that is being conveyed. They also only illustrate the completed event, they do not portray the sequence of construction although it is tentatively suggested that this could be deduced from an intelligent examination of the drawings. The focus of attention on drawings themselves as an artistic art form rather than their functional role is another cause for concern in that the latter is subdued by the quest for artistic merit.

Research confirms that there are inadequacies or conflicts in drawings that lead to problems during the construction of the building. This results in abortive or additional work that is suggested as representing a significant proportion of the cost of the building.

The general solutions that are proposed to overcome these problems focus on the improved administrative procedures or on the presentation of the drawings. The principle solution is in the form of co-ordinated project information, a systematic arrangement of design information organised by grouping information contained in drawings, specifications and bills of quantities in a coherent manner that would enable easy access to the information. Research suggests that considerable benefits can be obtained form the use of such arrangements as projects become more complex.

It is, perhaps, unfortunate that Latham whilst supporting co-ordinated project information, and advising that it should have been a technique that became normal practice some years before, found that its use was still limited. This, despite its support by government ministers and strenuous efforts to ensure it was adopted in architectural education, indicates a significant reluctance to adopt its use by both clients and the construction industry itself. It could also be that these systematic arrangements of information are simply too complex as is humorously illustrated in Figure 15.

It might also be argued that these solutions, in focussing on the presentation of the design information, equate to the emphasis on the drawings themselves and, in particular, their artistic integrity. As such, they might only be part of the solution to the problem. Just as the focus on the artistic elements of drawings is detrimental to the true functional role of the drawings, solutions to the identified problems associated with drawings that focus on the presentation of that information may miss solutions that address the functional aspects of the drawing. Another part of the solution may lie in the functional roles that a drawing possesses that can support particular forms of reasoning or specific problem solving tasks. Thus, the ways in which users of drawings utilise the information in the drawing is a distinct area of potential research.

Robbins hints at this by suggesting that

> 'drawing as it is used in contemporary practice .... assumes the availability of a body of visually literate workers capable of reading architectural drawings and translating them into three-dimensional material form.'

Thus, the role of the user of architectural drawings in successfully utilising the functional roles in drawings, information concerning what?, where?, how?, and when?, that underpins the actual construction of the building, may be another part of the solution to the identified problems associated with these drawings.

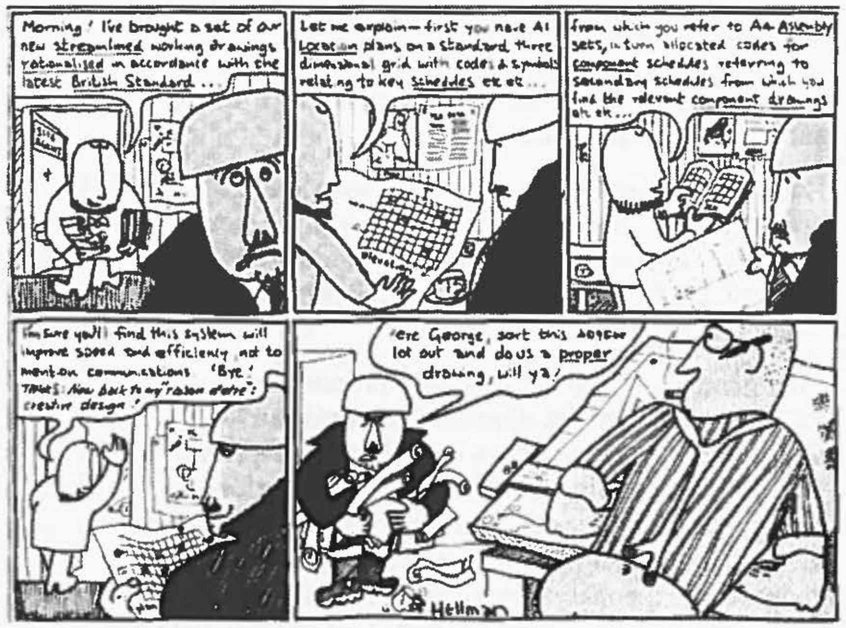


Figure 15 - Hellmann's view of the problem. Source: Styles, K (1986) Working Drawings Handbook, 2nd edition, Butterworth-Architecture,

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