B 3 5

The Use of 'Structured Data Analysis' as a Design Tool for Computer Integrated Construction

by
Dr Norman Fisher

Department of Construction Management & Engineering
University of Reading
UK

Introduction

Micro-computers have now been used in the construction industry for more than ten years. Gradually more difficult areas, computer aided design (CAD), project simulation and project costing have been computerised. Innovations such as CAD and project simulation, have demonstrated in a limited way the benefits that can be derived from the technology, but not so far the promised 'holistic systems' and 'quantum jumps' in design management and construction methods. There are never the less some promising projects at trial and development stages, in particular in areas such as expert systems and robotics. As Kuhn suggests(1), in research and development terms progress is normally accelerated by new techniques or technology breakthroughs; in for example robotics possibly by better sensors, in expert systems perhaps by the availability of cheap larger faster processors, in holistic computer integrated construction management systems probably by the use of a systematic and structured method for dealing with and partitioning the complex data flows encountered; that allow major advances.

Several major research studies have suggested that the flow of data between the key members of a traditional construction project team is critically important. The research results suggest that dealing with it, occupies a very considerable amount of the time of those with important managerial responsibilities (2).

Structured Data Analysis

To look holistically for example at the data aspects of a management system behind the procurement of a major construction project, will require a rule driven research tool that is robust enough to cope with the partitioning, recording, mapping and analysis of very complex transmitted data. It will need to be in a form that allows repetition and challenge and important aspects of the 'data flow model' (DFM) of the organisations to be compared one with another. Extensive research at Reading involving in excess of 120 separate studies at the various stages of the construction procurement process, stages such as feasibility study, evaluation of clients needs, selection of design consultants, preparation of design, selection of contractor, construction phase and post construction phase, suggests that 'structured data analysis' (SDA) may well meet the requirements outlined above for holistic computer integrated construction management systems. A new technique that in the spirit of Kuhn could lead to '...accelerated progress'. The early experimental work with SDA, the methodology used and results obtained are in the 'public knowledge domain' - see references(3),(4),(5),(6) and (7).

This paper includes a sample of three 'data flow diagrams' (DFD's) which form a small part of a typical study using SDA. Fig 1 shows part of a contractor's 'internal cost control and profit monitoring' sub-system. Fig 2 shows part of a typical contractor's 'supplier selection' sub-system and Fig 3 part of the 'plant management' sub-system. All three DFD's are part of the same overall company system. The partitioning logic can be observed by reference to the numbering system. The complete set of DFD's of which these are a part, if put together would form a DFM of the company.

The technique involves developing a general DFM of for example the construction management system used by major UK contractors on large commercial building projects. SDA consists of a number of related systems analysis tools. The first the DFD is a technique to assist in the partitioning of the overall system and to document that partitioning clearly in a rule driven and therefore repeatable and refutable way. A DFD consists of a network of inter-related processes expressed graphically (see Fig 1). Unlike the common 'flow chart' the DFD records the observed flows from the point of view of the data itself. An analyst attaches himself to an individual piece of data, and follows it through the system, in a precise, logical, and rule driven manner. This is clearly very different to other 'hard' and more traditional forms of systems analysis such as for example Jackson [8], and the 'soft systems' methodologies of others such as Checkland [9].

A second set of tools is the 'mini specification /data dictionary'. A 'mini specification' is used to provide a clear and precise description of each DFD (process) bubble and data flow which cannot be further decomposed (a functional primitive). A 'data dictionary' (DD) is used to show the hierarchy of descriptions of data flows, files, terminators, and processes[10], building up from the functional primitive to higher more complex and less partitioned diagrams. For example an entry in a DD might be:

Project Brief = **Initial Requirements+Decision to Proceed+Detailed Brief**

or

Job Set-up Arrangements = **Conditions of Appointment+Sub Consultancy Agreement with Architect+Job Organisation**

Data Flow Models and Computer Integrated Construction

Fieldwork is typically undertaken in a number of broadly similar organisations. As the technique is rule driven and therefore consistent, it allows management systems researchers to describe data flows within an organisation, and compare specific systems within different organisations. It provides construction management researchers with a new and potentially beneficial avenue of research. For example it allows the construction of a 'general data flow model' (GDFM); the combination of a number of DFM's, drawn from fieldwork in several companies that represent the best of current practice. The best of the observed company systems are combined into one GDFM DFD's and mini-specifications/DD's can be created either manually or by computer from fieldwork data. Creation by computer using commercially available system's analysis 'workbench' software, has clear benefits, not only in terms of speed and drafting, but because of the general checking, 'verification' and 'system balancing' sub-routines available.

The GDFM's that have been developed so far appear to have important implications for 'expert systems', robotics, the building process and the systems design of 'integrated management EDP systems' for computer integrated construction.

Firstly for expert systems:

Attempts at linking together into one 'structured data systems map' (SDSM) all DFD functional primitives of one sub-system of the construction process; for example the GDFM of the construction management system used by major UK contractors on large commercial building projects, with another GDFM such as 'the project design process', have proved to be successful. This is possibly because the SDA technique accurately identifies and specifies the interface points between the two sub-systems of the overall management system behind the procurement of a major construction project. By building up an SDSM of the total construction process in this manner; showing in a structured way the flows of data and the process points where data is manipulated or processed in some way, existing 'stand alone' expert systems can be plotted onto the SDSM and interfaces between them specified. This could have two very important consequences: Firstly gaps where 'expert systems' do not currently exist or are inadequate can be identified in a systematic and planned manner. Much of the initial work developing the algorithm for a new or improved 'expert system' will have been done as part of the SDA process. Secondly the SDSM will demonstrate where interaction between the 'stand alone' systems might be fruitful.

Secondly for robotics:

A cockpit flight management system on board a modern airliner needs to know amongst other things, and on a continuous basis, the exact position of the aircraft and in three dimensions. The implications drawn from this data will affect the assessment of other data generated or automatically captured. It will affect a decision on the importance of data such as fuel reserves, navigation heading corrections/adjustments and safe altitude. In just the same way a truly 'smart' robot; as opposed to a 'quasi-robot' with umbilical cord to a remote control console; will need amongst other things to know its exact position (on a map) in the construction process, and use this position knowledge for the identification and a decision on the relevance, importance and priority afforded to other data, tasks and robots. Clearly if a truly 'smart' robots; or a robot management system for a gang of 'smart' robots, has access to a SDSM, one that has been personalised for a specific project, it will open up a number of exciting possible ways in which the robot could be used.

Thirdly for the building process and the systems design of 'integrated management EDP systems':

The European construction industries like most others have evolved their systems and procedures over many centuries in an evolutionary way, and have thrown off surprisingly few of their medieval practices. Many ways of working can be shown by historians to have evolved slowly and only in response to sustained client or market pressure. By using SDA to develop a full SDSM of the total construction process; showing best current practice; it will allow the systems engineer the unique opportunity to design holistically an efficient new total construction process that can utilise effectively the benefits of modern electronic technology. This step forward will enable the building process and the systems design of 'Integrated management EDP systems' for computer integrated construction to be developed rapidly in a systematic and effective way.

References

1 Kuhn T, (1970), The Structure of Scientific Revolutions, 2nd Edition, Chicago University Press, Chicago.
2 Karlen I (1982), Information Methodology - Information Management, IN Information Study Group, CIB Publication 65, Stockholm, pp134-175
3 Fisher GN (1984), Towards a General Model of Project Monitoring and Control Systems as Used by Broadly Similar and Successful Building Contractors, Proceedings of CIB W-65 Volume 4, July 1984, Waterloo, Canada, pp1351-1362.
4 Fisher GN (1985), Project Monitoring and Control systems as Used by Broadly Similar and Successful Contractors, Science and Engineering Research Council Report.
5 Fisher Norman (1989), Marketing for the Construction Industry - A Handbook for Consultants Contractors and Other Professionals, Longman, London, 287pp.
6 Fisher GN and Shen LY, (1990), How Contractors Manage Construction - A Structured Data Analysis, CIOB Ascot. It is planned that the final report of this study will be presented to the Chartered Institute of Building, Ascot, UK, by late 1990.
7 Fisher GN, (1991), The Use of Structured Data Analysis as a Construction Management Research Tool Part 1 - The Technique, has been accepted for publication in Construction Management & Economics, and is scheduled for publication early in 1991. The paper outlines the technique in a modified and tested form, for use in management systems research. The benefits and limitations of the technique are discussed.
8 Jackson MA, (1975), Principles of Programme Design, Academic Press, London.
9 Checkland PB, (1981), Systems Thinking - Systems Practice, Wiley, Chichester.
10 For basic conventions, terms and rules suggested for management systems researchers see reference 7 above.

Figure 1 A contractor's 'internal cost control and profit monitoring' sub-system

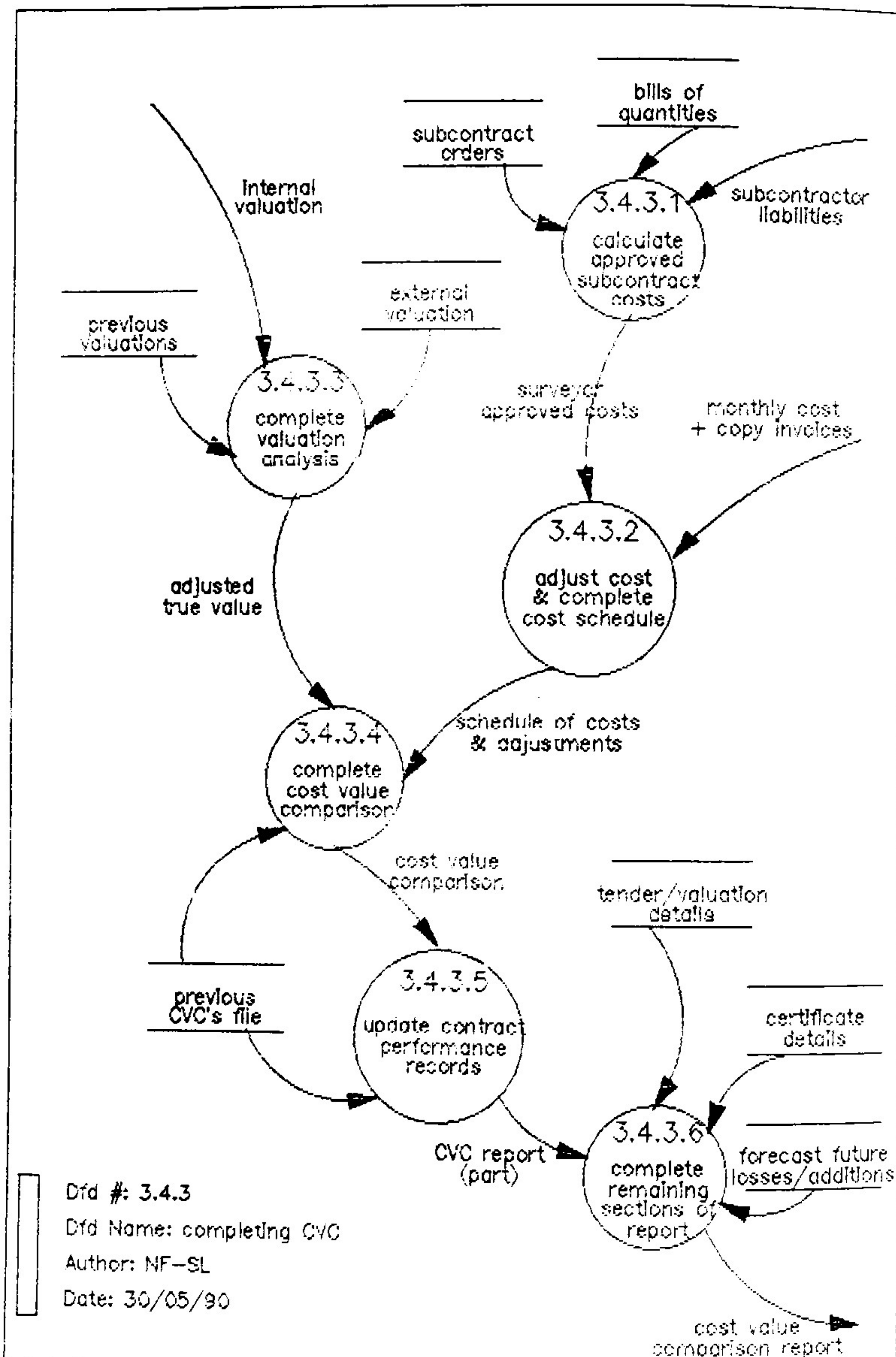

Figure 2 Part of a typical contractor's 'supplier selection' sub-system

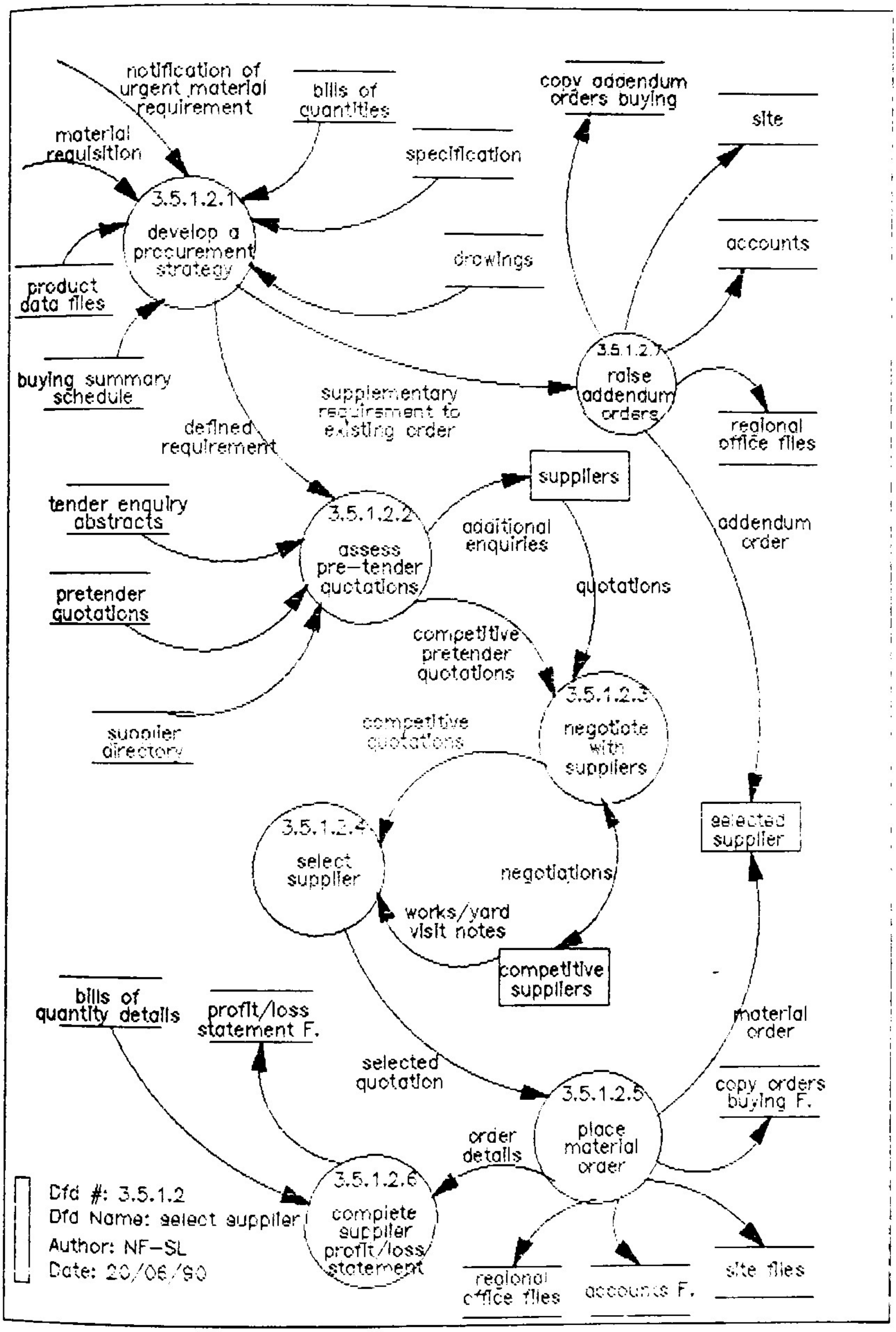

Figure 3 Part of a typical contractor's 'plant management sub-system'