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# A Hypermedia based Delphi Tool for Knowledge Acquisition in Model Building

D.A. Corben and E.F. Wolstenholme

University of Bradford Management Centre  
Bradford, West Yorkshire, United Kingdom

## ABSTRACT

The Delphi method has been used as a method of knowledge capture and consensus building in a variety of social and managerial areas for a considerable period of time and more recently it has been applied in the field of System Dynamics.

This paper describes research into the development and application of a computerised version of the Delphi method to assist the development of System Dynamics models. It has been developed in the context of project aimed at improving the design and assessment of computer based information systems.

The features of a Hypermedia based Delphi system that has been developed for the Apple Macintosh are described and the results of its application to a modelling exercise are discussed, with particular emphasis on its ability to create consensus influence diagrams.

## THE PROBLEM

The problem this paper addresses is in the area of knowledge acquisition for System Dynamics model building. In particular, how is it possible to involve a large group of geographically dispersed people in the model development process and in creating consensus influence diagrams? Logistical considerations make meetings difficult or impossible, but it is widely accepted that much of the benefit of a System Dynamics modelling exercise, comes about because of personal involvement in the actual process of model development (Richardson, Vennix, Andersen, Rohrbaugh, and Wallace, 1989).

The need to conduct this type of modelling exercise has arisen out of the development of a System Dynamics based method of information system design and evaluation, the Bradford Information Systems Evaluation Methodology (Wolstenholme, Gavine, Watts and Henderson ----). This methodology is specifically aimed at the development of large information systems, where the host organisation is correspondingly large and complex.

## THE DELPHI METHOD

The Delphi method was developed by researchers at the Rand Corporation in the late 1960's (Dalkey 1969). It was initially used as a method of consulting a group of experts with a view to predicting long term technological change. The method has been widely applied in the years since its development. The procedure is characterised by the following:

### **Anonymous response.**

The opinions of experts is obtained through questionnaires.



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**Iteration and controlled feedback.**

Experts are exposed to the opinions generated in previous iterations.

**Statistical group response.**

The experts collective opinion is some aggregate of the individuals opinions as expressed in the responses to the final questionnaire.

The major way that the Delphi method differs from more conventional questionnaires, is in it's use of iteration and feedback. The individual experts being consulted are given a summary of the results of the preceding iteration and the questions asked of the experts are also influenced by this information. The Delphi thus allows the exchange of ideas, to occur and promotes the emergence of a consensus view.

A successfully performed Delphi will allow the same discussion to occur, as if the group had actually met face to face. The anonymous and remote nature of the interaction between differing points of view, prevents any unfavourable group dynamics, that might occur in an actual meeting.

The Delphi method has recently been applied to the field of System Dynamics, in the development of a model of the Dutch health care system. (Vennix 1988). In this study a group of over sixty health care professionals were successfully involved in the modelling process.

**THE SYSTEM DYNAMICS DELPHI**

In the System Dynamics Delphi the model assumes the role of expressing the group consensus. To allow the member of the group to inspect and modify the model, diagrams must be incorporated into the Delphi questionnaires. The System Dynamics Delphi is characterised by the following:

**Anonymous response.**

The opinions of experts is obtained through questionnaires, which include the use of diagrams.

**Iteration and controlled feedback.**

Experts are exposed to the opinions generated in previous iterations and also to the state of the group consensus as expressed in the current state of the evolving System Dynamics model.

**Group response represented by the model.**

The experts collective opinion is some aggregate of the individuals opinions as expressed in the final System Dynamics model.

The structure of the System dynamics Delphi is shown in figure 1. To start the process off, an Initial Model is required. This model should be a high level overview model, it is developed by the Facilitator in consultation with Key Experts.

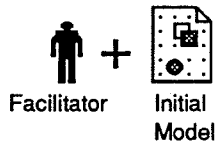
**THE NEED FOR A DELPHI TOOL**

The Delphi based method is highly suitable for consulting large, geographically dispersed groups, while still allowing the exchange of ideas and the sharing of mental models that are the great strength of the modelling workshop based methods, such as the Strategic Forum (Richmond 1987). There is of course a price to pay for this in the form of the effort require to administer and process the Delphi. It was therefore decided to produce a tool to computerise the Delphi process.

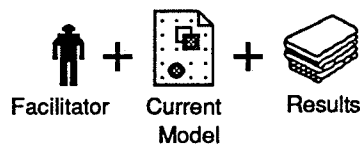


**Fig. 1 The System Dynamics Delphi**

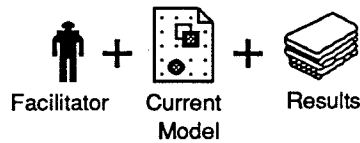
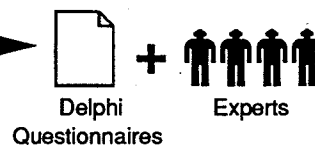
**Questionnaire on:  
Initial Model**



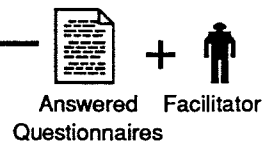
**Questionnaire on:  
Current Model  
Results of Last Iteration**



**Experts Answer  
Questionnaire**



**Update Model**



**Analyse Questionnaires**

### REQUIREMENT OF A DELPHI TOOL

If the production and analysis of the Delphi questionnaires was to be computerised, it seemed logical to computerise the actual questionnaires themselves. If the questionnaires were not computerised then, most of the potential for savings, would be lost in the data entry effort required to code up the questionnaires. The manual processing of diagrams would be particularly difficult and time consuming in this respect.

The following requirement were drawn up for a tool that would fully support the System Dynamics Delphi method:

- 1 The tool should enable the creation and editing of a computerised Delphi questionnaire, with support to be provide for both **text** and **diagram** based questions.
- 2 The Delphi Questionnaire should be easy to use, no assumption of previous experience with computers should be made of the user. Context dependant help should be available to the user at all times.
- 3 The Delphi Questionnaire should have a facility allowing the users to explain and give reasons for their answers, the users should be encouraged to use this facility as much as possible.

- 4 The tool to automate the process of collating and analysing the completed questionnaires.
- 5 The tool should create an archive, containing the results of all the iterations. The Facilitator to be provided with the means to browse this archive and to add text and diagrams, summarising the experts' opinions.

### IMPLEMENTATION OF A DELPHI TOOL

The main requirement of the Delphi tool, the ability to manipulate text and graphics, immediately suggested that a HyperMedia solution should be used. HyperMedia systems are specifically designed to allow the creation, mixing and linking of text, graphics and sound. The tool-set was built using SuperCard on an Apple Macintosh computer and became known as the SuperDelphi tool-set.

The Apple Macintosh was chosen because of its user friendly graphical interface, the availability of a range of HyperMedia software and for its compatibility with the STELLA/iThink software.

SuperCard was used in preference to HyperCard because in addition to its general superiority, it has the ability to produce standalone applications, thus enabling the questionnaire to be run on any Macintosh without the need for any specific software to be present.

### THE SUPERDELPHI TOOL-SET

The SuperDelphi tool-set consists of six parts:

- SuperDelphi Creator
- SuperDelphi Builder
- Standalone Delphi Questionnaire
- SuperDelphi Analyser
- SuperDelphi Archiver
- SuperDelphi Archive

The use of the individual tools to support the System Dynamics Delphi is shown in figure 2, which depicts the performance of one iteration.

**Fig 2 The Use of the SuperDelphi Tool-Set**

#### SuperDelphi Creator

The SuperDelphi Creator is used to create and edit a Questionnaire File.



#### SuperDelphi Builder

The SuperDelphi Builder is used to turn the Questionnaire File into a Standalone Delphi Questionnaire, this is then duplicated and sent out to the Experts being consulted.



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## Standalone Delphi Questionnaire

The experts answers the questionnaire and then returned them.



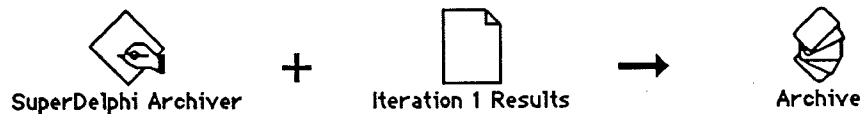
## SuperDelphi Analyser

As each completed Standalone Questionnaire is received it is analysed, and this analysis is added to the Results File.



## SuperDelphi Archiver

When all the Questionnaires have been analysed, the SuperDelphi Archiver is used to update the Archive, with the Results File, which contains the iteration's collected results.



## SuperDelphi Archive

The Archive can be browsed and annotated, it is used in conjunction with the current model as the basis for the design of the questions to be posed in the next iteration.



The most important parts of the SuperDelphi system from the modelling point of view, the SuperDelphi Questionnaire and the SuperDelphi Archive, are described in the next sections. The other parts of the tool-set perform a mechanical, supporting role and are not further described.

## THE SUPERDELPHI QUESTIONNAIRE

The Standalone Delphi Questionnaire is the only part of the SuperDelphi tool set that the Experts being consulted uses. The Delphi Questionnaire consists of a window in which the question cards are displayed and two floating palettes, the Standard Palette and the Drawing Palette.

### The Standard Palette

This palette is permanently displayed and contains four buttons that enable the user, to perform the following operations:

- Go to the Next Question
- Go to the Previous Question
- Add a Comment
- Request Help

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Help is available in two forms, general and specific. The user is asked which kind of help is required when they request help.

**General help:** This gives help on how to move around the questionnaire, add a comments, quit the questionnaire, enter and edit text etc.

**Specific Help:** This gives help on how to answer the current question.

### The Drawing Palette

This palette is displayed when the user is asked to draw or modify a diagram, it contains four buttons that allows the user to select one of the following tools:

**Browse**                      **Pencil**                      **Eraser**                      **Text**

### Encouraging Answers and Comments

When the user asks to quit the questionnaire, the response rate is calculated, if the user has left some of the questions unanswered then a dialog appears, warning that there are some unanswered questions and offering the opportunity to go to the first of these unanswered question.

To encourage the Experts to make as many comments as possible, the use of the comments facility is monitored. If the Expert appears to be making little use of the comments facility, then a series of dialogs appear at random, encouraging the Expert to make more comments.

### QUESTIONS AVAILABLE FOR THE SUPERDELPHI QUESTIONNAIRE

The questions designed for the SuperDelphi Questionnaire fall into four types:

**Text**                      **Factors**                      **Diagram**                      **Graph**

### Text Based Questions

These type of questions use text alone to ask questions. In the second and subsequent iterations, the text will usually contain some feedback, summarising the replies to the previous iteration. Three different type of text based questions were developed.

**Multi-choice:** The user selects one of the displayed options, with a mouse-click, to indicate their opinion of the text statement.

**Choose:** The user chooses between two alternative statements, by clicking with the mouse.

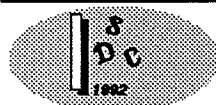
**Opinion:** This question allows the user to provide a written reply.

### Diagram Based Questions

The diagram is essential to the System Dynamics methodology. It is therefore important to allow the experts being consulted to view, modify and create diagrams. The diagram based questions are available in two sizes, small and large the large diagram being four time the area of the small. In all other aspects the questions are similar.

**Multi-choice:** Same as the text based version, except that the user is asked for their opinion about some aspect of a given diagram.

**Draw Comments:** This question allows the users to add comments and make changes to a given diagram. The provided diagram can be a complete diagram, in which case the question will ask the experts to annotate or modify it.



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Alternatively a partial diagram can be given which the experts are requested to expand, by creating links and adding new model elements.

**Draw Diagram:** The user draws their own diagram in reply to the question.

### Factor Based Questions

These questions are designed to investigate the factors that influence a particular aspect of the system being modelled and so identify causal relationships.

**List Factors:** The users are asked to make a list of factors in response to a text question. This question is used early on in the modeling process, to identify causal relationships.

**Select Factors:** The users are given a list of factors and are then asked to indicate their opinion of the importance of these factors. The expert answers the question by clicking on a "Tick" or a "Cross" next to the description of each factor.

**Order Factors:** This question asks the users to consider a list of factors and to place them in order of importance. The expert answers the question by selecting a factor and then clicking a numbered button.

### Graph Based Question

Graphical relationships are often used in the System Dynamics methodology. It is therefore important to allow the experts being consulted to view, select and create graphs.

**Multi-choice:** These questions asks for the users' opinion of a graph, they are answered in the same way as the text based version.

**Select:** This question asks the user to choose a curve, from a selection of twelve, that in their opinion best describes a given relationship.

**Draw Graph:** This user is asked to draw a graph in response to a question.

## THE SUPERDELPHI ARCHIVE

The SuperDelphi Archive holds the results and the collected comments of an iteration. The Archive can be browsed and annotated to produce a summary of the experts opinions, that can be used as the basis for the design of the questions in the next iteration. The SuperDelphi Archive consists of four windows, Results, Comments, Summary and Diagrams. For every card in the original questionnaire, there is a corresponding card in each of these four windows.

### Results Window

The first card of this window contains details of the identity of the iteration and the name of the modelling project. A list of the questionnaires who's analysis is contained in the Archive is also available at the click of a button.

The other cards in the window contained the results. The type of the information that is displayed by the results cards is dependant on the nature of the original question. All results cards give details of response rate and the number of comments made. The results cards for the multiple choice questions provide a histogram and some simple statistics to give an indication of the group view. The results card for questions that ask the Expert to draw or modify a diagram, displays the resulting diagrams. These diagrams can be viewed either singly or they can be superimposed, to show at a glance, all the changes that have been made.



### Comments Window

This window contains a card with a scrolling text field, in which all the comments made by the Experts about a particular question are collected together. The Facilitator can browse these comments, search them for a particular text string and copy the text as required.

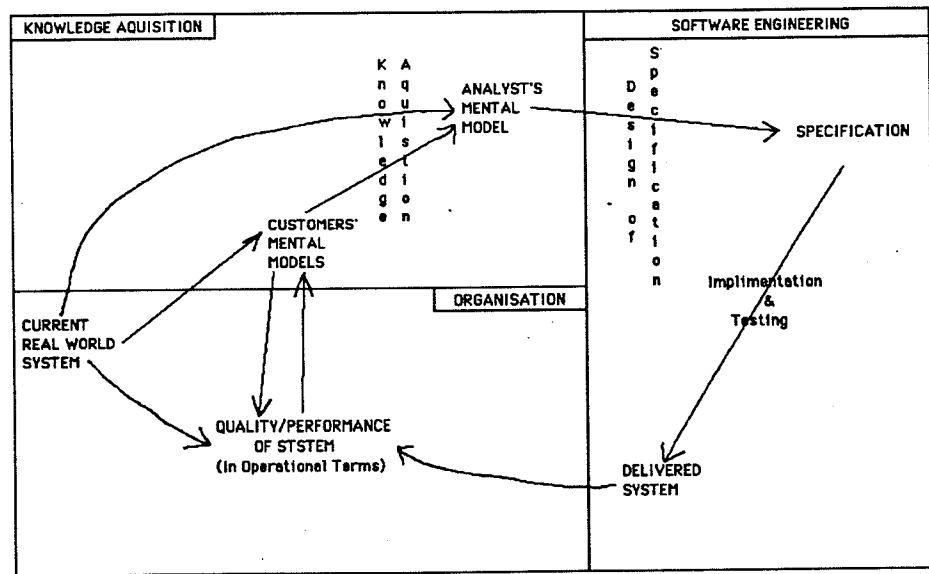
### Summary Window and Diagrams Window

These window are used by the Facilitator to summarise the replies and comments to each question. The Facilitator can use text or diagrams to record his thoughts.

## TESTING THE DELPHI TOOL

A small scale test was performed on an existing project concerned with the development of tools to support the Jackson System Development (JSD) methodology (Jackson 1983). An initial causal model model of the software development lifecycle was produced and the first iteration was based upon this. The results of the first iteration were analysed and a second iteration produced.

Fig 3 Initial Model



## RESULTS

The tool-set successfully performed all the tasks necessary to conduct a Delphi. Figure 4 shows an examples of the responses to one of the diagram based questions, the responses are shown superimposed.

The test highlighted several areas where the software could be improved, these are discussed below.

**Modifying Diagrams:** The users are currently provide with a simple set of Paint based tools with which to annotate and modify diagrams, while these

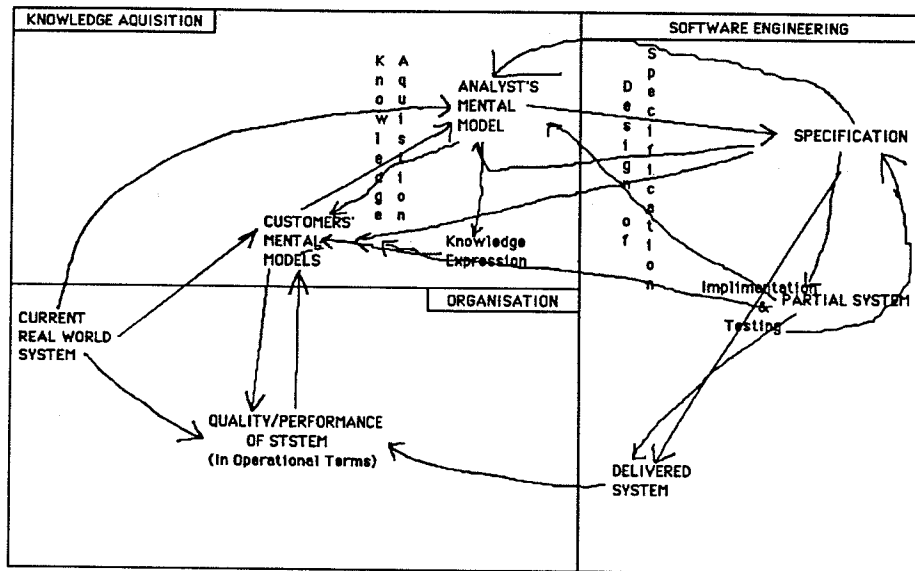


proved serviceable, it was felt by the users (all Mac power-users), that a more elegant method of modifying diagrams was required, and Draw based tools were their preferred option. Draw tools are superior to Paint tools, but are also initially harder to master, it was felt that the more typical inexperienced user, would find Draw tools too much to cope with. The best solution to this problem would be the production of diagrams that may be modified and annotated through use the mouse, thus eliminating the need for any drawing.

**Report Generation:** From the Facilitator's point of view, the Archive would be improved by the addition of a report generation facility, such a capability would be easy to provide.

**Ideas for New Types of Questions:** The current questions are general in nature and it was felt that, some question cards, that were more specifically adapted to the System Dynamics methodology should be produced. To encourage the development of systems thinking by the users, cards asking no specific question, but giving help and information on the concepts of systems thinking would be a useful addition

**Fig 4 Superimposed Modifications to Initial Model**



## CONCLUSIONS

The SuperDelphi tool-set has demonstrated that the Delphi method can be successfully computerised and used for knowledge acquisition. In particular, it has been shown possible to allow clients to be directly involved in the creation of diagrams for either model building or MIS development. Additionally much valuable information has been obtained on the design of such systems and a number of refinements to the tool-set, based on this experience are under development.

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## ACKNOWLEDGEMENT

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