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DSM MADE EASY

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1. Introduction

Complexity science is a relatively new, yet increasingly important field [Lindemann et al. 2009]. For example according to Weber, rising levels of complexity can be identified in all companies that produce technical products or systems [Weber 2005]. This is due to escalating competition in global markets.
Managing complex product development processes is a challenging environment. Since the early 1960s many methods have been developed to improve the understanding of a product's dependencies in order to achieve desired solutions. Early applications concentrated on system dynamics and investigated information-feedback in systems. An example of capturing and managing relationships in product development is the Design Structure Matrix (DSM) developed by Donald V. Steward. This has been a successful tool for analysing product structures, organisation structures and project planning. [Lindemann et al. 2009].
In most cases however, complexity management tools are developed for professional contexts and require complicated operation and analysis beyond the ability of most users [Kohn and Lindemann 2009]. A need exists to readily and easily integrate complexity management systems into organisations' everyday operations. A number of obstacles must be addressed before effective solutions can be introduced, including the demystification of complexity management and a set of appropriate tools to support users. Effective facilitation is also an invaluable component of the product or system development process.
This paper introduces Disposition Modelling (DiMo) as a complexity management tool for systems modelling; software especially designed for facilitated workshops. (Figure 1). This paper contributes to a broader project at Tampere University of Technology by introducing the DiMo tool as an effective support tool for decision-making in systems modelling within product development.

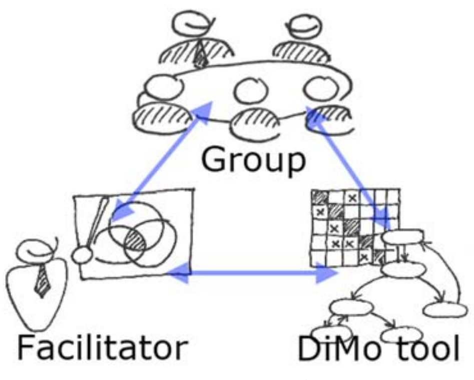

Figure 1. Facilitated workshop for systems modelling

This paper begins with introducing the research objectives along with the research question. This is followed by theory basis. Then the chosen solutions that DiMo uses are presented and the structure of the tool are introduced. Finally this paper culminates in results, discussion and conclusion.

2. Objectives

The development of the Disposition Modelling (DiMo) tool is part of a broader research project at Tampere University of Technology in the Department of Production Engineering, aiming to develop a complete facilitated workshop process for systems modelling in product development. The objectives of the DiMo tool were to:

- Facilitate the understanding of a system/situation
- Ensure high quality information is identified
- Enable easy and effective information acquisition process

These objectives inform the following research question:
How can we capture knowledge of the competing variables (dependencies) reliably in DiMo and further facilitate the understanding of complex structures?

3. Theory basis

3.1 Complexity science

Complexity management is a key function of the DiMo tool and complexity science theory is essential to understand the principles of problem solving and system design. The definition of complexity offered by Weber is most relevant to this paper whereby complexity is seen as an attribute of systems and can be divided into several aspects, including numerical, relational, variatonal, disciplinary and organisational complexity. These aspects consist of elements, relationships and variants. [Weber 2005] Furthermore, complexity in a system can be affected from a combination of internal and external sources, but only the internal sources can be actively managed. Complexity management in general is an application in the sense of variant management. [Lindemann et al. 2009]. In this paper the complexity management is viewed from a product development perspective.

3.2 Graph theory

Graph theory is the study of mathematical structures and how they are visually depicted. This can include the representation of entire structures and their substructures as trees and cycles, as well as specific structural attributes such as connectivity. [Lindemann et al. 2009]. It is relevant to many analysis methods used in product design, such as dependency/directed graphs and matrices [Gross and Yel- Ien 2006]. Numerous algorithmic equations used in matrix based solutions, such as DSMs, are attributable to graph theory. Graph theory is relevant to this paper, because it not only provides the platform where DiMo as a software is based on, but brings numerous algorithms that can be used to analyse dispositions.

3.3 Facilitation excellence

Facilitation is best described as any meeting of a group, or individuals, where a facilitator manages the process to help participants meet their goals [Rees 2005]. A facilitator is responsible for guiding and structuring the group's processes. Typically a facilitator works in meetings and workshops and often continues the same role outside of meetings. The word to facilitate means to make something easier or less difficult. Some benefits of a facilitation process are that the group members are more motivated to support decisions, productivity increases through heightened participation and the group's work is more focussed [Rees 2005].
The main difference between the role of manager and facilitator is the facilitator needs to remain neutral and unbiased. The group needs to focus on the issues raised, and that requires people to be able to trust the facilitator. Typically the manager has opinions or intentions that may divert the group process and decision making [Justice et al. 2006]. In the worst case people feel their contribution is wasted and the session results were determined beforehand.

In a facilitated workshop environment different tools are used to enhance the decision making process. In general these tools have some common characteristics that make them suitable for facilitation sessions. They are visual and logical processes, that help groups generate, organise and evaluate data and ideas. They allow material to be visually displayed for the entire group at the same time. Some tools enhance groups in decision making, other focus on troubleshooting problems. Currently there are numerous different group facilitation tools used. In the development of DiMo these requirements where considered. The aim to capture disposition knowledge requires an interactive tool, visual overview on the dispositions and capability to validate identified dispositions.

3.4 Disposition theory

Olesen defines disposition as the effect of coupling between two parameters. Dispositions are the relationships or parameter relationships that extend the traditional concept of a dependency. Olesen describes disposition as part of a decision taken within a functional area that affects the type, content, efficiency and progress of activities within other functional areas. By functional area Olesen means an organisation that is responsible for activities in a particular area of manufacturing [Olesen 1992]. A general example of a disposition modelling can be seen in Figure 2, where essentially, activity A affects activity B.

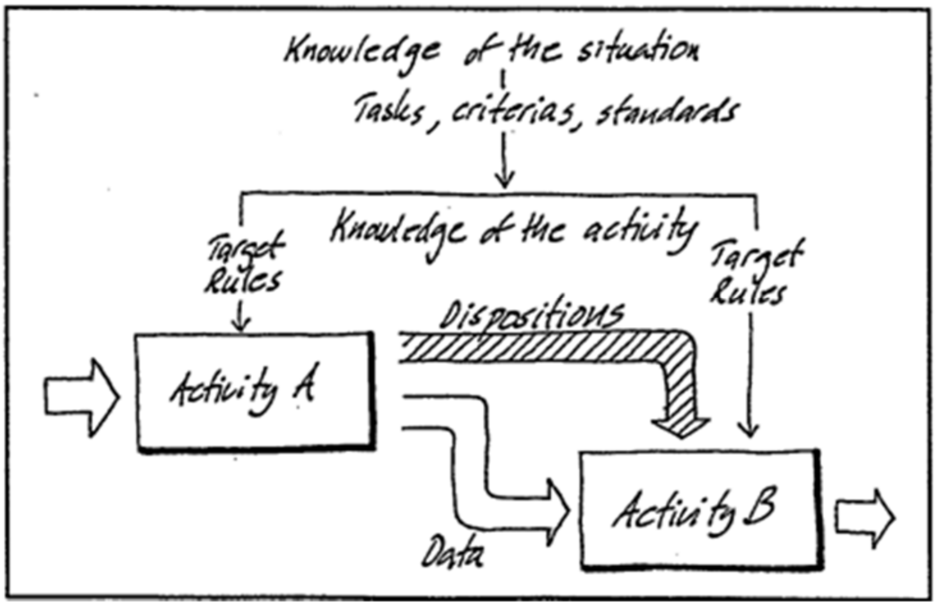

Figure 2. Model of a disposition between two functional areas A and B [Olesen 1992]

According to Olesen disposition mechanism includes activities from different functional areas. Every activity has its own targets, rules and design characteristics. Dispositions are modelled with calculating parameter changes that are effected to universal virtues through desicions made. Olesen's concept of disposition is adapted into DSM environment in DiMo. However, in the current version of DiMo dispositions are not fully modelled due to the restrictions of a DSM, where different domains cannot be separated.

3.5 Theory of technical systems

The Theory of Technical Systems (TTS) was introduced by Hubka as a method of explaining the intrinsic nature of any technical system. Hubka suggests a technical system is, by definition, the process of achieving a desired outcome through a series of intermediate states. [Hubka 1984, 1988] This process is presented in Figure 3.

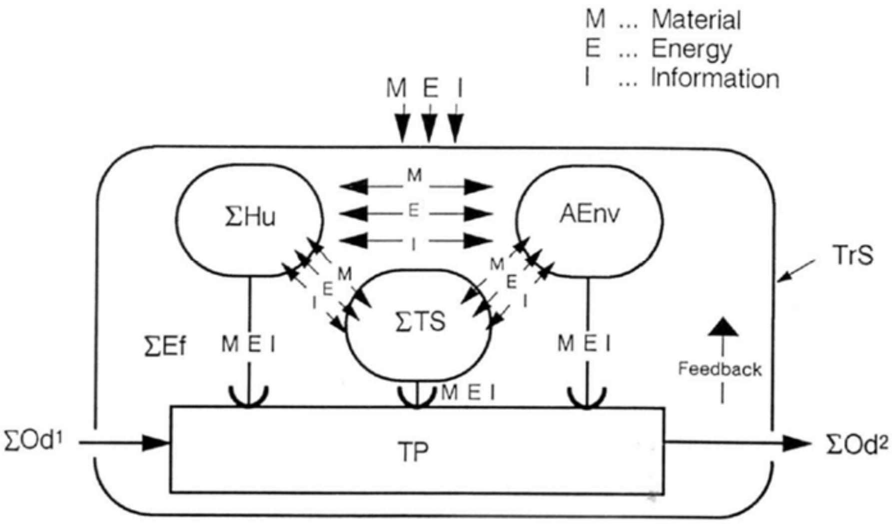

Figure 3. Theory of Technical Systems [Hubka 1984, 1988]

ΣOd^1 is the original state whereas ΣOd^2 is the final, desired state. The operation is called technical process (TP). The transformation is caused by ΣEf effects including the technical system (TS), the human system (Hu) and the active environment (AEnv). The streams between these three systems are material, energy and information. In DiMo, Theory of Technical Systems is used as a conceptual platform for dividing the relationships in the DSM. However, in this paper's example case four relationship types were considered relevant by the research team: information, work, material and control. As such these relationships are case sensitive and do not provide a generic model for relationship division.

4. Chosen solutions for the tool

4.1 Design structure matrix

Since Steward's research in the 1980s, the use of Design Structure Matrices (DSMs) have been applied to many types of system and design analysis, including product development, project planning, project management, system engineering, and organisation design [Browning 2001]. DSMs can be divided in to two main categories - directional matrix or static matrix. The fundamental difference is the relations in a directional matrix are time-based, whereas the static matrix only captures relations between system elements that exist simultaneously, such as components in product architecture [Browning 2001]. Furthermore these categories can be separated into four different DSM types as shown in the Figure 4.

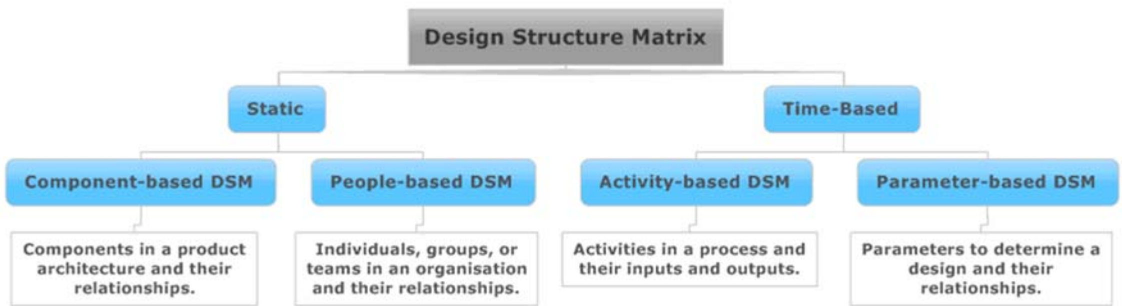

Figure 4. DSM types [Browning 2001]

The advantage of a DSM is the analysis of data through algorithms. This allows better management of design elements and an opportunity to identify efficiencies in the product development process. It manages the order of elements reducing design iteration and can rearrange elements to be designed in clusters. The time and activity-based DSMs used in DiMo provide a powerful and well researched method which supports the DiMo's initial phase's objectives.

4.2 Visualisation

Visual representations such as matrices and other graphs improve the communication and systematic evaluation methods of many modern design problems by helping to interpret and analyse data [Tilstra et al. 2010]. They provide a way of mapping complexity and the interdependencies of various design elements. However, data displayed in a matrix still requires interpretation by the user and not all users will feel proficient in doing so. Information contained in a matrix format is easily transferred into other forms of graphical representations to allow for better accessibility for data analysis. Already tools exist, that use other forms of graphs along with a DSM. [Kohn and Lindemann 2009].
To optimise user experience, an appropriate and effective visualisation technique must be available if needed to 'translate' data [Kohn and Lindemann 2009]. Digraphs are one of the most common visualisation approaches and were selected for DiMo. Ready-made graph generating software, *Graphviz* has been incorporated into DiMo to provide clear and diverse visual representations of the data gathered through the DSM. Both the DSM and a directed graph can be shown at the same time. The graph updates automatically as changes are made in the matrix.

5. Results

5.1 DiMo Tool

DiMo is a systems modelling tool that uses a design structure matrix and graphical visualisation to capture and analyse data during and after a facilitated workshop. The key attributes of this new software is that it is specifically designed for sessions where time and resources are limited. Other matrix based solutions do not fully support this context effectively.

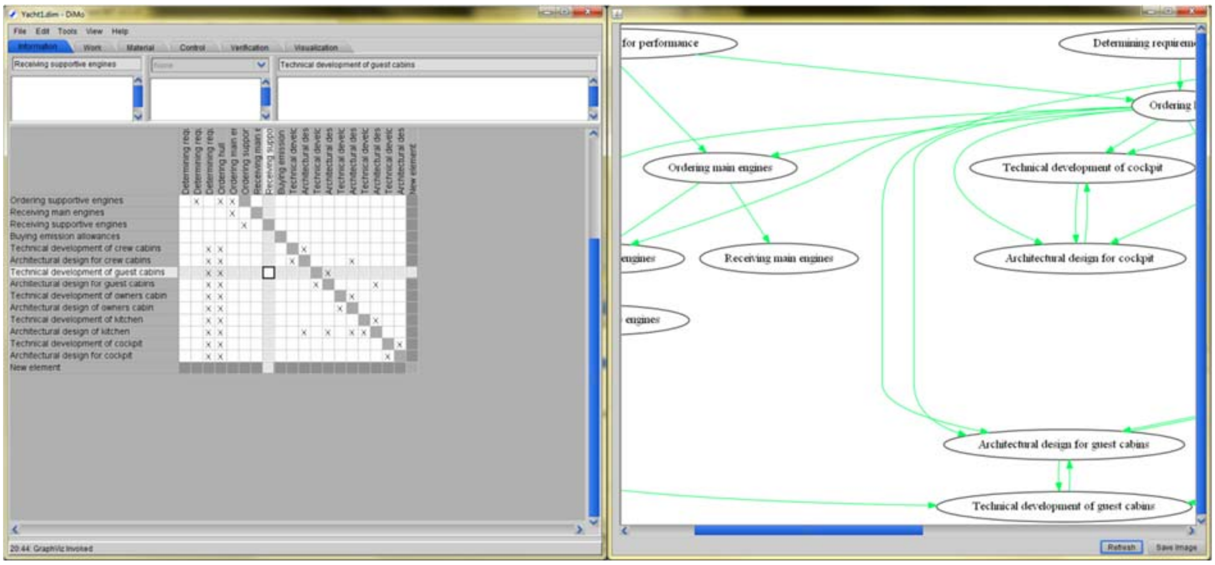

Figure 5. Basic working environment in DiMo

A typical facilitated workshop featuring the DiMo tool would begin by gathering relevant project contributors, including the workshop facilitator and experts and determining the purpose of the session and the approach for analysis. Any goals or parameters to be considered are noted before any information is gathered.
Determining the approach for analysis helps define any product structures, production or organisation models that will be relevant to the session. The initial phase of DiMo development offers a time and

activity-based approach, however it is intended that future versions of DiMo will offer a variety of other approaches to support different user requirements.

To effectively use DiMo the following steps are necessary:

1. Capture relevant system elements
2. Capture relationships between the elements
3. Capture the behaviour/quality of the relationships
4. Capture disposition mechanisms
5. Verify the quality of acquired information

In the following these five steps are explained along with an example case. The example is part of reference material, where aim is to practise project management in designing a yacht. In the example some of the tasks related to the project's work brakedown structure are captured into DiMo.

5.1.1 Capture relevant system elements

Choosing the right elements to be included is a critical step in the success of the workshop and the effectiveness of DiMo. Here workshop participants determine which elements are relevant for the project. Elements are saved into DiMo's matrix as a list that can be easily modified during the session.

5.1.2 Capture relationships between the elements

After identifying required elements, every element is compared to the others and relevant dependencies are recorded. In the initial phase of DiMo relationships are saved within four different relationship types: work, material, information and control. These were identified relevant for this case. This approach follows Hubka's theory of technical systems. Relationships between elements are captured with binary dependencies and marked with "X" symbols. Figure 6 shows how relationships are captured in the tool. The different relationship types are chosen from the tabs signified with a red box in the figure. In the example, tasks belong to information stream.

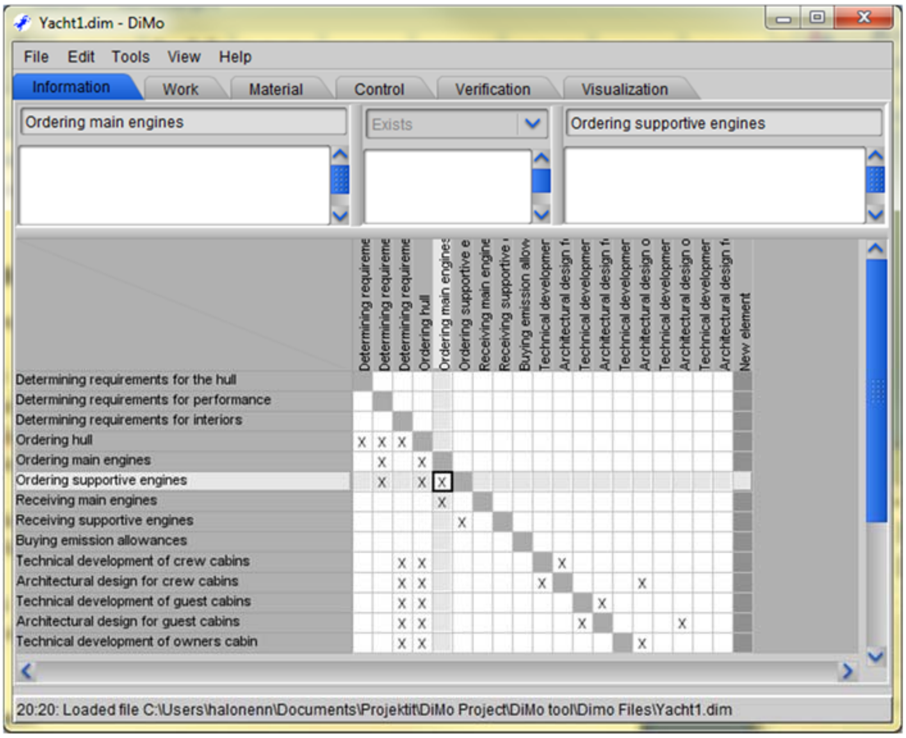

Figure 6. Capturing relationships in DiMo

5.1.3 Capture the behaviour and knowledge of the situation

The next step is to include information that may effect the quality or behaviour of the relationship. The information is recorded as text linked to the relevant elements. Figure 7 shows how knowledge of the situation is saved in DiMo. In the example ordering hull has a relationship with task architectural design for crew cabins. Knowledge of the situation in this case is information of the ordered hull's specifitations are required before architectural design can be started.

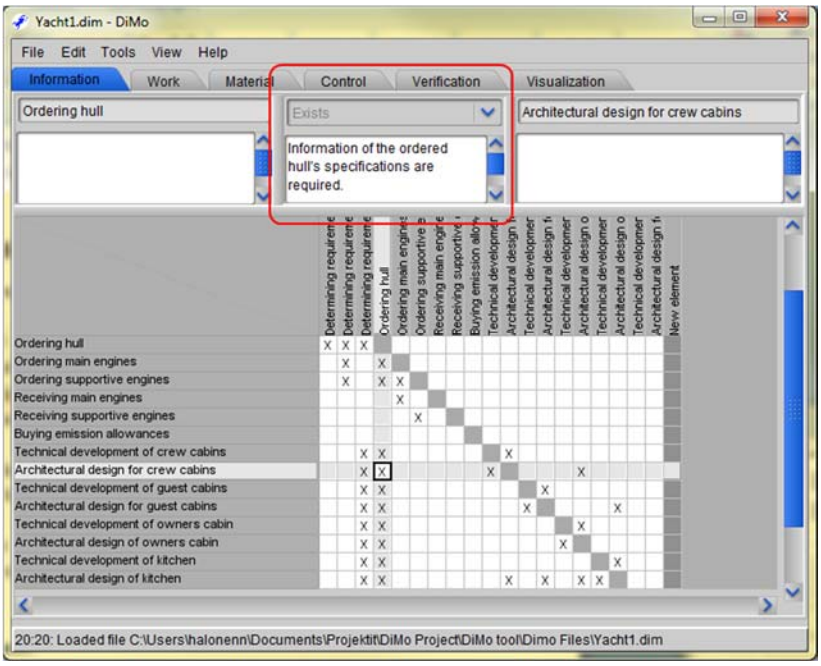

Figure 7. Defining behaviour and knowledge of the situation in DiMo

5.1.4 Capture disposition mechanisms

At this point of tool development disposition modelling is not fully attained. Currently DiMo only captures cause and effects without dividing elements into different organisations. Disposition mechanisms are captured in both activity A and activity B. These mechanisms include targets, decisions in activity A and dispositions in activity B. Refer to Figure 8.

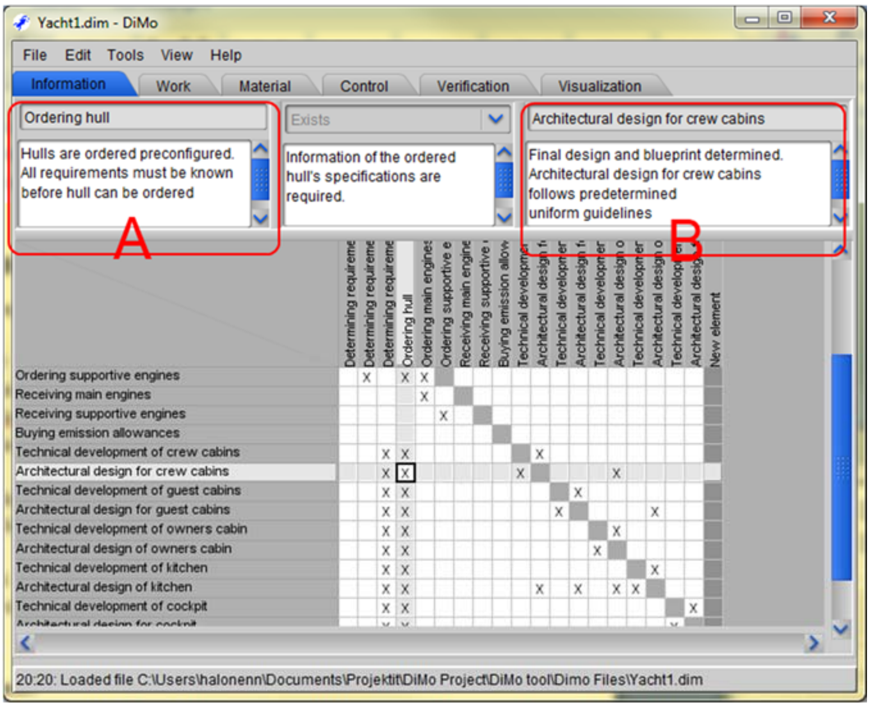

Figure 8. Capturing dispositions in DiMo

5.1.5 Verify the quality of acquired information

As DiMo is used during a workshop, there can be a need to verify the data captured. For this purpose DiMo has a verification feature, located in its own tab in DiMo. Here the elements can be cross-examined (by ticking "is verified" box) and additional information can be documented for later use. The process is aided by a directed graph presenting the matrix which can be opened in a separate window simultaneously (figure 5). Figure 9 shows how verification is recorded in DiMo.

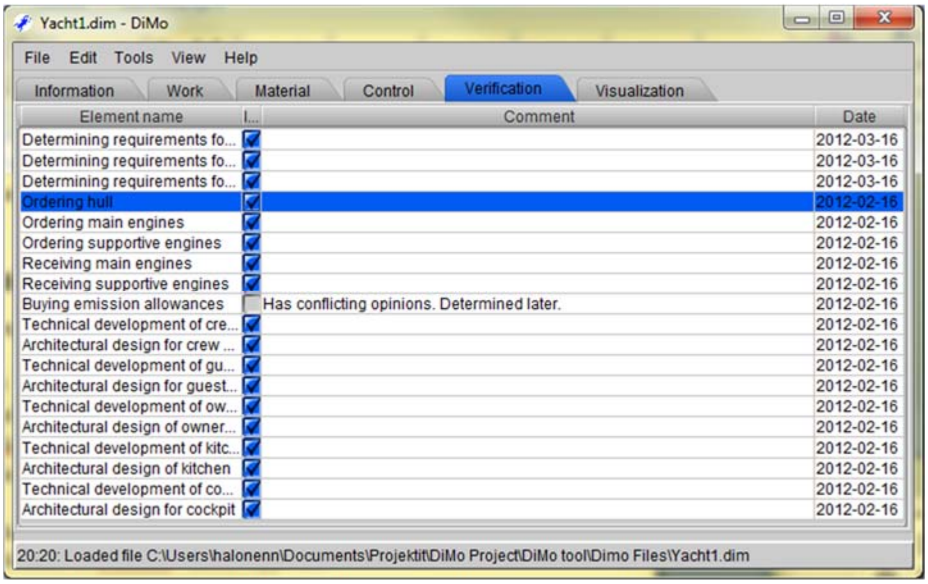

Figure 9. Verifying the quality of acquired information in DiMo

5.2 Tool as a main contributor for facilitated process

DiMo aims to facilitate the understanding of a system by using a DSM and directed graph. DSMs provide an effective framework to understand and examine systems and are an important starting point for this tool. A directed graph further supports analysis through visual representation. DiMo is intended to be used by the facilitator and the group during a workshop session and can be projected for everyone to see. The knowledge captured will be fed directly into DiMo and all the changes updated in real time. In figure 10 is presented a typical workshop situation, where DiMo is used with projectors.

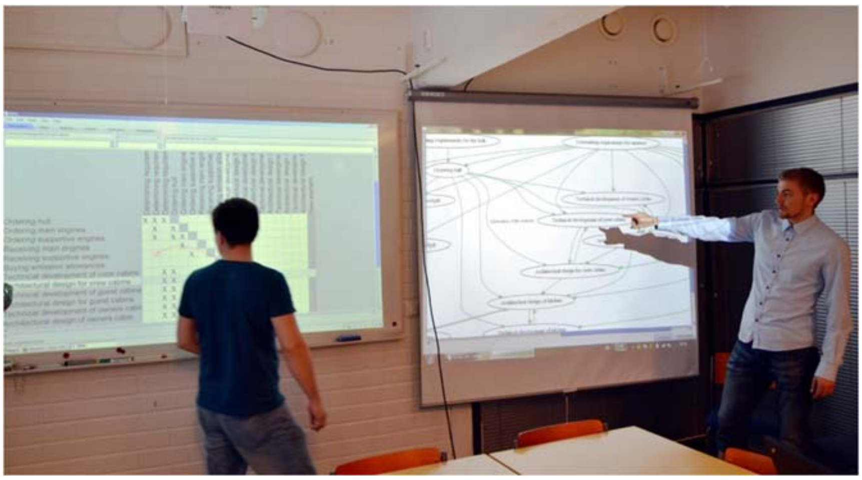

Figure 10. DiMo used in a workshop environment

Whereas it is often difficult to indentify unnecessary or irrelevant information collected in a typical DSM, DiMo provides a visual representation of the system design to aid quality information acquisition. Directed graphs provide the information quickly and do not require complicated interpretations to be understood. The tool provides a verification feature to further ensure the captured information is relevant and can be documented properly after the workshop.

DiMo enables easy and effective information acquisition process by providing a considered user interface. The software is kept plain, simple and easy to navigate in order to record information quickly during the session. Shortcut keys are also available to further optimise data entry. Almost all of the features in the tool can be managed without a mouse.

6. Discussion

Initial testing of DiMo, indicates the tool is functional and capable of enhancing the systems modelling process and further facilitate the understanding of a system. A number of technical constraints in the software however, require further development. The outcome of further research into facilitated workshop processes being undertaken within the broader project at Tampere University of Technology will influence future iterations of DiMo by better defining how this tool can be effectively used in a workshop context.

The list of the elements identified at the beginning of the workshop critically effects the overall quality of information. It is the responsibily of the facilitator and workshop participants to generate this information and therefore, DiMo's effectiveness is largely dependent on the user. The advantage of DiMo however, is its ability to assist the users in identifying missing elements and verifying the various relationships and dispositions. It does this by generating a visual representation of the entire system design that is easy to interpret during a group session.

A key objective for DiMo is to enable easy and effective information acquisition, even when analysing more complex systems. When modelling systems consisting of more than 50 elements, DiMo should provide a working environment where data entry and visual representation is still effective. However, during simulations of larger modelling processes, the increased numbers of elements led to data acquisition taking proportionally longer than expected. Ideally, data capture will not hinder the overall acquisition process, but instead bring up new findings instantly during the session.

Continued consultation with workshop facilitators and other potential users of this tool will influence the development of DiMo significantly. Additionally, since all data is represented in graph form, there is great potential for other algorithms to be incorporated that increase DiMo's functionality. This might include identifying critical/strong relationships between elements or loops in the system arising from dispositions. There are also a number of common algorithms used in other DSM environments that require further consideration.

DiMo has been specifically designed for time & activity based approach, which is to meet the current objectives of the broader project. However, other systems modelling approaches will be considered, which may influence the number of relationship types and overall functionality of DiMo.

7. Conclusion

DiMo is a complexity management tool for systems modelling designed to be used in a facilitated workshop. DiMo incorporates a DSM with a specifically designed user interface that is capable of easy and effective data capture. The tool is able to capture elements, their interrelationships and generate directed graphs that enhance analysis. Relationships are divided into four different types and qualitative information of the dependencies and dispositions can be documented and verified. Dispositions are apapted from Olesens disposition theory.

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