Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 50 (2016) 204 – 209

www.elsevier.com/locate/procedia

26th CIRP Design Conference

Unveiling fundamental relationships in industrial product development

Göran Gustafsson[a]*, Dag Raudberget[a], Mikael Ström[b]

[a]*Chalmers University of Technology, Department of Product and Production Development, SE-412 96 Gothenburg, Sweden*
[b]*Swerea IVF AB, PO Box 104, SE-431 22 Mölndal, Sweden*

*Corresponding author. Tel.: +46-31-772 13 57; fax: +46-31-772 13 75. *Email:* gorang@chalmers.se

Abstract

Identification and clarification of relationships between product properties is fundamentally important in industrial product development. The process is however frequently perceived difficult. The presented research aims at clarifying if a visual tool can provide help in this work. The tool is a combination of previously known techniques and has so far been implemented at two product developing companies. Results and reactions from the tests are hitherto positive and the conclusion is therefore that this extended casual diagram can be a useful addition to the product developer's toolbox.

Keywords: Causal diagram, trade-off curve, limit curve, product development

1. Introduction

A substantial part of industrial product development work is about redesigning existing products. An example of this is presented in a survey from the UK industry [1]. Various tasks can amount to anything from a slight modification or facelift of an existing design to a further development and extensive improvement of the product, which perhaps also includes a technology change. In these activities it is important for the design team to understand how the product works at present, how its different parts interact, what properties of it that the customers and other stakeholders value the most, how these properties are related, the physics behind the technologies employed and what is known, or perhaps not known, about those [2].

A company may of course have low awareness of and knowledge about several of these relationships in their existing products. They have designed, built and sold a product that "works". But product development is in practice sometimes not so much based on rigorous analytical work and detailed experimentation, i.e., fact-based decisions, as on more "practical" reasoning, estimates, rules of thumb, gut feelings etc., i.e. on other things than pure facts. This may be because the company simply lacks the competence or resources required to work in a knowledge-based fashion, but it may also be because they have for one reason or another developed a bad habit of cutting corners in their development work. In any case the result is that they have limited knowledge, or at the worst no substantial knowledge at all, of how a change in any of its properties would affect the behavior of the product. And the result of a change in several will then of course, if possible, be even more obscure. Will it go unnoticed, will the product behave slightly differently or will it cease to work altogether? The designers will neither know how much different, nor what properties can be changed before the product starts to behave dramatically different, what the limits of the applied technologies are and, consequently, what the solution space looks like. I.e., within which interval is it possible to change each variable?

Any attempt to change and/or redesign a product in a situation like the above will of course be a highly haphazard process with an unpredictable outcome. In order to be able to carry out predictable product development work, all critical *knowledge gaps* must be located and closed before the design work commences.

Without access to powerful tools, particularly in cases with complex designs, it is difficult for the designers to see the full picture and understand what is important and should be

doi:10.1016/j.procir.2016.05.092

prioritized when they alter a design. The consequence is that they may instead work on parts and aspects of the product that are less important when it comes to what they want to accomplish, or they attempt to solve problems that there already exist solutions to. In extreme cases, designers may be unaware of what is actually *not* well-known or understood about the product function when they change the technology, and therefore ought to be attended to.

Due to the properties of the human brain, visualization is often useful both to create an overview of something as well as to highlight details and connections in a larger pattern. This paper proposes a technique and a visual aid for product developers which combines several existing tools to accomplish this. The technique can guide product developers in their work as well as in discussions with customers on which product properties ought to be changed in a redesign process, and how to do that, i.e., which different sub properties should be altered. The tool has been tested at two product developing companies with promising results. The paper concludes with a discussion of how the tool can be further developed.

2. The research process

The setup is a multiple case study [8] of mechanical design with two main industrial design cases. The objectives were to clarify how causal diagrams can improve the understanding of a product or system, if they can provide a framework for storage and display of design knowledge and also to formulate a prescription for how to introduce the new tool in an industrial environment.

Since the researchers were actively involved in the studied process, it differs from the description of Yin [8] in that it involved a portion of action research [9]. The reason for using action research was to develop, introduce and evaluate a new design methodology which the participants of the study did not have sufficient knowledge to apply on their own, i.e. without the support of the researchers. The study was a joint venture between industries, Chalmers University of Technology and the research institute Swerea IVF AB as project manager. Empirical information was collected in four workshops, and by interviewing the participants.

The research process was inspired by the Design Research Methodology (DRM) that is used to develop design support [7]. DRM is based on four stages:

- Research Clarification
- Descriptive Study I
- Prescriptive Study
- Descriptive Study II

The process started with a hypothesis that causal diagrams would provide valuable support in the design process. To verify this idea a literature study was conducted in the Research Clarification stage. The result was that there is no good research results of how to implement a process for creating causal diagrams in practice, or what the effects of such diagrams might be, even though the concept is mentioned in Ward [6]. This indicated that a need for the suggested support existed. In order to be able to judge the practical usefulness of the proposed technique, four *success indicators* were formulated and are presented in Table 1.

Table 1: Indicators of successful research in this study.

Success indicators	**Description**
1	Does the methodology create a better understanding of the product than the current way of working in the company does?
2	Do experienced engineers accept the methodology as a new way of working?
3	Do experienced engineers accept the results that the methodology generates?
4	Can a firm use the methodology without the support from researchers?

The Descriptive Study I activities were carried out by the researchers and aimed at participants' understanding of causal diagram methodology to the extent that they were able to identify which parameters are important for its success and how these interact.

The findings from the Descriptive Study I formed the basis for the Prescriptive Study, in which the new *extended causal diagram* and the working process that together form the suggested support were worked out. In order for an extended causal diagram to constitute a framework for the product knowledge, apart from the important parameters with their interactions, it also has to display information on the causality and nature of the interactions (see below). On top of that, it shall also visualize the interactions in the form of e.g. trade-off curves as well as highlight critical knowledge gaps. It is not uncommon that engineers are unaware of the existence of the latter until they come to this step in the process.

The support developed in the Prescriptive Study was evaluated in a Descriptive Study II in industrial workshops in two different firms. One researcher introduced the working process and the extended causal diagram, and together with a colleague also observed the workshops and took notes to document them.

3. State of the art

There exist a number of tools which can be used both to help identify and in different ways illustrate relationships between product properties. Examples are Quality Function Deployment (QFD) [10], function analysis, causal diagrams [5, 6] and trade-off curves [4, 6]. Substantial work of relevance has also been done in the field of engineering change management. One example of this is the contribution by Rutka et al. [3].

Figure 1 is an example of the type of causal diagram discussed in this paper. It illustrates the structure of a laptop PC. This type of causal diagram shows four kinds of information: