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Perceived industrial usefulness of the ACD³-matrix - an interview study with product developers

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Abstract

Today, a large number of tools are available to support the organization and documentation of product development. However, a tool is not successful merely by virtue of being available; it is in the actual use of the tool that its utility and value emerges. To increase the probability that a tool is used, it is also important for it to be perceived as useful by its potential users.

The ACD³ (Activity Centred Design)-matrix is a product development mapping tool based on systems theory. It visualizes how design decisions can be made coherently, through a clear hierarchical structure that visualizes logical chains of interdependent design decisions, yet allows flexibility so as not to inhibit a design organization's innovation and creativity.

This paper presents a study of how potential users perceive the ACD³-matrix. Seventeen product developers were introduced to the ACD³-matrix and then interviewed about how they perceived the tool; the interview probed what strengths and weaknesses were perceived, the tool's usefulness in relation to the interviewees' practices now and in the future, and whether they saw opportunities to implement the matrix in their business operations.

The main identified perceived advantages were that the ACD³-matrix could be a good tool for identifying knowledge gaps within a project, and that ACD³ could provide a common structure and language throughout the whole project, facilitating communication between different competencies and domains within the work organisation. The main disadvantages interviewees perceived were that the terminology and contents of the matrix cells need to be adapted to the terms used at the specific company and that the matrix might seem difficult at first to understand.

The study showed that there was an interest in the industry for the ACD³-matrix tool and all participants saw opportunities (to varying degrees) to implement the matrix in their own practice. The study also provided good insight into how product developers reacted initially when introduced to the ACD³-matrix. The input provided by the product developers is valuable for the further development ACD³-matrix and how to introduce the tool in organisations.

Keywords: Product development tool, Method usefulness, ACD³-matrix, Interview study

1 Introduction

The reality of product developers today involves the organization of many stakeholders involved in the decision-making processes and activities that enable commercially viable products and services to be designed, realized and improved. In an environment of high customer demands, the pathways by which these activities and decisions take place are the combinatorial product of the organization's chosen project management models, the time management plan of choice and the individual developers' knowledge and skill in carrying out this kind of teamwork, as well as the tacit knowledge of the organization's teams. In such a complex environment, methods have a central role in design and product development to support and make apparent which activities, organisation and documentation are necessary.

For a method to be successful in that context, it needs to be available and useful. A number of method properties that contribute to a method's use and staying power have been presented by for example (Norell, 1992; Shorrock & Williams, 2016), but two essential properties that a method must have to be successful are utility and usability (J. Andersson, Bligård, Osvalder, Rissanen, & Tripathi, 2011). Having utility pertains to being able to yield results that enable the progression of product development, while having usability means that the method is practically possible and desirable to use within its context in the company's working procedures and project constraints.

However, a method is not successful merely by virtue of being useful and available; it is in the actual use of it that its utility and value emerges. To increase the probability that a tool is used, it is important for it to be perceived as useful and beneficial by its potential users. But for comprehensive new methods aiming to facilitate product development, there may be many barriers both to gaining industry attention and creating enough know-how for users to decide whether to replace familiar structures with something new and unknown. Therefore, the perceived usefulness for potential users is a prerequisite for the utility to emerge at all and is worth exploring further before use cases and usability studies are undertaken.

This paper reports on the perceived usefulness potential of a novel product development mapping tool, the ACD³ ("Activity Centred Design in three dimensions")-matrix (Cecilia Berlin, Bligård, & Simonsen, 2017; Bligård, Simonsen, & Berlin, 2016). The structure and development of this tool has been maturing in recent years, and it has been tested as a project framework in a number of stand-alone thesis projects at MSc level (A. Andersson & Sandström, 2016; Bung & Magnell, 2016; Gustafsson & Yxhage, 2016; Nayeri & Olsson, 2016). This paper takes a step further and describes a first study of how ACD³-matrix's intended users in industrial companies perceive the possible benefits and drawbacks of the tool in relation to their current work goals and practices in product development, based on f interviews. First the paper introduce the ACD³-framework and the ACD³-matrix tool, followed by the method for the study. Then the result and discussion the implications are presented.

2 The ACD³-framework

ACD³ is a novel coherent framework for product development, based on principles of Systems Theory and Activity Theory. Its purpose is to visualize how design decisions can be made coherently, in relation to phases and activities in product development. It does this

through a clear visual hierarchical structure that reveals logical chains of design decisions, while allowing flexibility so as not to inhibit a design organization's innovation and creativity. The ACD³ framework is intended for use in product development projects to manage decisions and activities that should be addressed among the different actors in the process. The ACD³ framework presents three independent design process dimensions: design levels, design perspectives and design activities. From this foundation, the ACD³-matrix is derived, which visualises the precedence relationship between design decisions in the design process. It should be noted that the ACD³-matrix itself has been elaborated in earlier publications (C. Berlin & Bligård, 2016; Bligård et al., 2016), and the novelty of this paper lies in the user validation aspect. In the ACD³ framework, additional tools also exist.

The ACD³-matrix consists of the two dimensions *design levels* and *design perspectives*. The design levels describe the product with shifting degrees of precision and specification. For each level, the precision of detail in the decisions gradually increases while the design space gradually decreases. ACD³ includes five design levels:

- Effect - The effect that the product is intended to achieve the context
- Usage - The use of the product by humans
- Architecture - The technical architecture of the product
- Interaction - The interaction between human/context and product in details
- Elements - The technical elements of the product

The second dimension, design perspectives, highlights that the same solution can be described from different points of view that emphasize different aspects. The design perspectives provide a structure for organising the design variables. ACD³ contains five perspectives:

- Problem - What issues are in focus and drive the development process forward?
- Structure - What entities are included in the system and how they are related?
- Function - What abilities must the system have to reach the goals?
- Activity - What do the actors need to do in the system?
- Realisation - How is the system concretely realised?

		Design levels				
		Effect	Usage	Architecture	Interaction	Elements
Design perspectives	Problem	Main problem	Usage problem	Architecture problem	Interaction problem	Element problems
	Structur	Users, stake-holders & context	Human-machine system	Architecture machine	Subdivision machine	Architecture elements
	Function	Capabilities & values	System functions	Machine functions	Control & information	Element functions
	Activitet	Intended use	User tasks	Overall interaction	Detailed interaction	Machine process
	Realisation	Possibilites & limitations	Technical principle	Overall design	Physical form & interfaces	Implementation elements

Figure 1. The ACD³-matrix in detail, with type of design variables in each cell.

Since the design perspectives are present throughout each of the five design levels, they can be combined into a matrix (Figure 1) in order to visualise the relationships and interdependencies between design decisions. Each cell in the matrix contains one or more types of design variables that need to be specified and determined, i.e. concretising the *result* in the design process. In the columns of the matrix, each design decision is a consequence of the cell above it and affects (constrains) the perspectives that are underneath; e.g., the *system*

functions depend on the *human-machine systems* and affect the *user tasks*. In the rows, the design space is increasingly constrained from left to right and the design decisions become more and more specified; e.g., *overall interaction* is more specified than the *user tasks*, which in turn are more specified than the *intended use*.

The purpose of the matrix is to work as a tool to visually organise the design decisions and design variables. The goal is that all design decisions should be made intentionally, and that the right decisions are made at the right time in the in the development work. This is achieved by acting as a map that helps designers with a systematic and systemic structure of the design decisions and supports the relevant design decisions in the proper order, i.e. clarify the governing conditions that need to be considered first and then focusing the synthesis.

The ACD³-matrix should not be interpreted as prescribing a specific order of the design work, rather clearly showing the design variables that need to be examined and determined during the development. Therefore, the matrix is meant to work with both top-down and bottom-up approaches of product development.

3 Method

The study adopted a qualitative approach, seeking to explore reasons for whether the ACD³-matrix would be perceived by potential users as useful or not. The study was carried out with a total of 17 participants from Swedish companies, recruited according to a "purposive sample" strategy (Maxwell, 2005), in order to be able to sufficiently experienced and currently involved with product development to be able to judge the ACD³-matrix's potential as a tool at face value. The participant sample was to some extent also a convenience sample, as available participants from industry were recruited in the authors' local existing networks. The participants worked with product development in the Gothenburg region, representing different sectors: seven from vehicle industry; four from power plant control room design; three in other mechanical industry; two product development researchers with extensive experience of company collaboration; two in electronics/software; and one in other industry. Common to all participants was that they had experience working with formalised and structured methods of product development. Many of the participants also had knowledge of ergonomics and human factors.

Interviews took place in the form of ten individual interviews and three focus group interviews with between 2-4 participants – we will collectively refer to these interview occurrences as cases. The group interviews lasted 1-1.5h and the individual interviews 1h. All interviews were conducted in Swedish and began with a 20-minute presentation where the basics of the ACD³ framework were reviewed and the ACD³-matrix was emphasized. The matrix was chosen as the focus since it was considered the most novel part of the framework, and it would have been too extensive to cover all the tools in the presentation.

After the presentation, a semi-structured interview was conducted based on five themes:

- Initial spontaneous reactions to the matrix
- Perceived advantages of using the matrix in participants' (organisations') work processes
- Perceived drawbacks of using the matrix in participants' work processes
- Opportunities for implementing the matrix in participants' product development operations
- Obstacles to implementing the matrix in participants' product development operations

Interviews were audio-recorded as documentation. The researchers then listened to the recordings and extracted relevant summary statements from each interview. All the statements were then compiled in a long-list and a thematic analysis was conducted. The first author made the initial analysis, which was reviewed by the other authors as well as a researcher external to the study (who had not taken part in any previous activities).

4 Results

The initial comments from most participants indicated that they perceived the framework as relevant, but complex. They appreciated the structure of the matrix as logical and the content as comprehensible and useful when it was presented, but that its scope seemed extensive, with many in-depth parts and terms, when it was shown as a whole.

During the focus groups and interviews, many perceived advantages and disadvantages emerged. The benefits named on most occasions (in 6 out of 13 cases) were that the ACD³ matrix would be a good tool to determine which aspects of a project are known and whether crucial knowledge is missing, and (in 5 cases) to provide the same structure and language throughout a whole project, thereby supporting and providing opportunities for communication between different competencies and knowledge domains throughout the development work. The main identified disadvantage that emerged was that the terms in the matrix cells needed to be adapted to the specific company to be applicable to their proprietary design processes (in 6 cases).

All participants, to varying degrees, saw potential to implement the ACD³-matrix in their own organisation. The greatest perceived implementation opportunity was to use it as a simple tool to clarify the need for knowledge and skills when launching projects (in 6 cases). Another perceived opportunity was to use the matrix as a checklist to ensure the inclusion of ergonomics and human factors in a project (in 3 cases). Factors that were seen as possible barriers to a successful introduction were (in 5 cases) insufficient adaptation of the matrix to the company's existing process terminology, and (in 3) that project participants might experience the matrix as an extra administrative burden, if its benefit is not clear to them.

When all the answers from the 13 cases were analysed, two overarching themes emerged from the more detailed answers: 1) potential use of the matrix as a product development tool, and 2) organisational factors influencing its potential usefulness.

4.1 Potential use as a tool in product development

The participants identified that the matrix had potential to be useful during product development as supporting tool in different ways. The first was as a tool for overview of central design variables in a project, providing clarity and overview of the design variables in a project and in what sequence the various design decisions should be made. The matrix could be used as a map or checklist to see the wholeness and also to see how design variables are connected through the project; it helps to clarify how changes in some design variables affect many other subsequent (and sometimes preceding) design variables.

The next use was as a tool for reviewing competences and aiding prioritisation. Here the matrix can ensure that nothing is overlooked and helps development teams prioritise activities by highlighting the design decisions that are of specific interest at the on-going development phase. The matrix covers aspects often missed in early phases, including consideration of socio-technical systems. The matrix makes it easier to frontload the development process,

includes ergonomics and human factors and end-user focus, and connects these aspects to others in the product development. The third identified use was as a tool for mapping knowledge and completed work. The matrix makes it easier to map what is known and unknown; in other words, helping to avoid unknown unknowns. The matrix also shows which design variables are already determined and cannot be changed, and what the project can still influence.

The matrix was also considered useful as design tool since it supports the breakdown of requirements in order to make explicit design decisions. It facilitates the justification of design decisions and provides a structure that frees up energy and resources for creativity. The fifth use was as a tool for project management. The matrix reveals the need for specific competencies at the beginning of a project in order to make informed design decisions. The matrix makes it easier to assign roles and stakeholders to the appropriate cells in the matrix, to clarify responsibilities and work tasks. Furthermore, participants recognized that the matrix could help with identifying which order tasks should be carried out in.

The matrix was considered useful as tool for communication since it provides the same structure and language throughout a whole project, increasing possibilities for communication between domains and competences. The matrix makes it simpler to communicate in larger, agile, distributed or multidisciplinary teams. The matrix can also be used as meeting tool for status reports (among project members and stakeholders) and to help the team focus (so the discussion does not drift away). The last identified use was as a tool for documentation and knowledge transfer. Here, the matrix was considered useful to structure and document design decisions in a consistent way. The matrix makes it easier to see if documentation is complete, but also facilitates the re-use of previous design work in the next project.

4.2 Organisational factors influencing potential tool usefulness

The participants talked about factors in the organisation that need to be considered in order for the matrix to be successfully implemented. The first factor was the integration with existing approaches and processes in product development. Here the participants' perceptions were divided; some stated that the matrix ought to work well with existing approaches like Lean and Agile, while others suggested that it might be hard to implement in existing work processes, since many companies already employ detailed working processes, for example with stage-gates.

The second factor was the motivations of project members to use the tool. Some of the participants mentioned that there exists a general "method fatigue" in their organization after trying to learn and apply several different approaches (e.g. Lean and Agile), which means there may be an established reluctance to adopt yet another new tool. I addition, participants suggested that it could be hard to direct see the utility/benefit of the matrix, since you need to understand the whole matrix and have a system view. The matrix might be considered extra administration and a waste of time, especially if project managers and project members think that they already are dealing with all the aspects covered by the matrix ad-hoc, or that they have tools that cover the same things as the matrix. The matrix can also be perceived as too labour-intensive to use in a single project.

The third factor was that learning how to apply the matrix would require considerable time and resources. The matrix would also need to be adapted to the company and project, mainly regarding the wording in the cells. The current wording was perceived to be too academic and

generic; another example of the latter was that automotive participants felt unsure about whether the matrix scope was to cover a whole vehicle, or just part of it. Furthermore, one participant stated that the machine system cell of the matrix would be easier for their organisation to relate to if it followed their existing internal vocabulary and were to be called "driver cabin", instead. All users would require training and instruction in to how use the matrix in their work, and a need might arise for additional enabling technical resources, such as new software, documentation templates or a new database.

Another mentioned factor was practical problems with entering data properly into the matrix. Here, the participants mentioned potential problems with getting enough information from their organisation to populate the whole matrix. Another issue was unfamiliarity regarding how to divide the work into cells, and how to keep decisions clearly delineated when a product is complex or tightly coupled. The participants foresaw potential problems with getting all parts of the organisation to define "design variables" the same way, as well as deciding unilaterally what is "good enough" when describing design decisions and design variables.

The last factor was potential pitfalls resulting from using the matrix. Some participants saw a danger that the ACD^3-matrix might induce a false sense of security by users assuming that using the matrix will automatically lead to benefits, without additional thought. Another potential issue was that the project might only focus on aspects clearly stated in the cells and miss things in-between that are not so well defined in the matrix terms. The participants also saw an issue with taking a too large or to small scope for the matrix, which might either greatly increase the work involved, or forgo the potential of the matrix.

5 Discussion

The purpose of this paper was to study the perceived usefulness and potential of the ACD^3-matrix. The participants provided insight into their organizational work reality and processes, including the demands that existing, implemented tools already placed on their work and how a new tool could - at face value - be seen as both an opportunity and a threat (primarily of creating additional work). Participants were able to elaborate the perceived usefulness of the ACD^3-matrix and described several potential uses, which is a clear indication that the intended users could recognize the value and benefits of the tool. They also made comments related to the utility, usability and the organisational context.

Generally, the issues and potential barriers identified by the potential users are consistent with observations in literature (Araujo, 2001) for why new methods in general do not get adopted in the product development process. Such reasons include a lack of interest and/or reason by the organization to use methods; fear of changes; negative attitudes toward new method introductions; a lack of appeal or comprehension of the method's usefulness; lack of resources such as time, staff and competence; defects in the design of methods; poor promotion of the method(s); or too many alternatives to choose from. This fits with the notion that the perceived barriers to introducing and using the ACD^3-matrix depend more on issues within product developing organisations, rather than issues within the matrix itself.

5.1 Aspects of use and usability

An interesting pattern emerged from the thematic analysis: most positive comments on the matrix were related to its utility (i.e. its usefulness, or ability to yield valuable results that enable the progression of product development), while most of the negative comments

concerned its usability (i.e. its potential to be practically and correctly employed within the company, and its appeal). Usability perceptions were related both to the matrix itself, and to organizational barriers that ACD³ must overcome in order to be accepted and used. The usability issues identified can be categorised into three main groups:

- Barriers in the organisation as such,
- Barriers related to user perceptions of the matrix, and
- Barriers related to the actual use of the matrix

The results indicated that some organisational barriers exist, which are independent of the design of the ACD³-matrix. Examples of inherent barriers in the organisation were e.g. the pre-existing processes, fatigue among developers towards new methods, general (lack of) method familiarity and a lack of time and interest to learn more. As an indication of future research work, the target organisation for the tool needs to be studied to find out how to best introduce and integrate the framework, including how to motivate the project members and to overcome "method lethargy".

One barrier related to the perception and use of the matrix that was highlighted by the participants was that the matrix needs to be interpreted, and that the content needed to be adapted for each project. Many participants asked for a simpler version of the matrix that would be perceived as less comprehensive and potentially confusing, and requiring less effort. A common comment from the responses was, "*I get the usefulness of the matrix, but how do I convince my project manager or project colleagues?"* Since the ACD³-matrix, just like other new methods and frameworks, aims to change the existing working procedures and mental models, convincing stakeholders is a barrier that needs to be overcome through the introduction and integration, rather than through changing the tool (as that would reduce its utility). To change the ACD³-matrix is therefore not a feasible option, since the comprehensiveness is needed to help users cope with the complexity of a socio-technical system, which is otherwise hard to get an overview of in product development.

Two main suggestions to address the convincing-of-stakeholders aspect can be formulated. The first is that a cost-benefit analysis, showing that that the matrix is worth using, seems crucial to create an interest in the organisation. This could be achieved by highlighting the value of using the matrix as a knowledge transfer tool in several projects in succession; the efforts involved in the second and subsequent projects would be obviously lower than in the first, and greater clarity regarding determined and undetermined design variables would be achieved early, reducing time and cost. There also is a need to present example cases, especially to demonstrate how the matrix works for complex and tightly connected products, and to clearly demonstrate how the matrix could be used. Thesis projects may partially satisfy this need but a "sharp" industrial case would constitute even better evidence. The cases also need to be based on a clear definition of the target system scope, e.g. if it is a whole vehicle or just the driver cabin that is of interest in the specific project. Clear examples are also needed of how the matrix integrates with different overall development approaches, such as Lean, Agile, Stage-gates etc. The second suggestion is related to how the matrix should be introduced. There is a need to find out a good point of entry for presenting the matrix (i.e. what to present first), and to determine which order the different elements of the tool should be introduced in. There is a need for a pedagogical introduction material for the matrix, that motivates users to learn more about it.

The last barrier relates to issues concerning not knowing how different stakeholders and roles ought to use the matrix in the project. Many of the participants recognised the ACD³-matrix as

a useful tool for a project manager, e.g. as a map to plan activities or a checklist for making sure that activities are done. Here, plausible solutions are instructions and education. So there is a need make a specific instruction of how the ACD³-matrix can be used by a project manager. Furthermore, there is a need for clear instructions on how to adopt the matrix for a specific project and company. The participants' identified issues with getting the organization to establish a common way to describe design variables, and to determine how to uniformly describe design decisions, points to a need for standardisation of terms and criteria levels.

The information from the participants also indicated that there might be a general need for education on how methods like the matrix are useful. For both project managers and other members in a development project, a critical minimum level of methods understanding and systems understanding is necessary to appreciate the tool. There may be a need to educate potential users in preconditions necessary for successful application of the ACD³-matrix, since simply demonstrating the ACD³-matrix and its elements may not suffice to ensure successful use. This implies that such efforts may be wise to include in education of future engineers and managers.

The organisational barriers highlight the importance of considering the usability of the matrix. J. Andersson and Osvalder (2015) presented a number of crucial features for methods to be useful in practice. One especially important feature is that methods should be inspiring and fun to use. Enhancing this feature of the matrix would likely facilitate its introduction and implementation in an organisation. Still, the world is complex and needs methods that are flexible enough to handle this complexity. Finding this balance between usability and utility can be guided by the words of Shorrock and Williams (2016, p. 472), who stated that "*methods should only be as complicated as is necessary with regard to purpose*".

5.2 Limitations of the study

Three limiting factors affect the validity of the present study. The first is that the selected participants all had previous experience of using methodological frameworks in product development. This might have made them more positively inclined towards the ACD³ methodology, compared to if they would not have had experience with theoretical frameworks; on the other hand, this predilection gave them a better experiential frame of reference with which to judge its usefulness. The second factor is that the present study was performed by the creators of ACD³, which in all likelihood influenced how the data collection, presentation of ACD³ and analyses were made. On one hand, the expertise of the researchers regarding the tool is as high as practically possible, but the downside may be the decreased replicability of the presentation of the matrix. Third, the participants did not actually attempt to use the ACD³-matrix on an actual case or project. The results of this face-value study should therefore be considered as a positive first indication, but not as a sufficient condition, for confirming the perceived usefulness of ACD³-matrix.

5.3 Future work

To ensure the true usefulness of the ACD³-matrix, it needs to be tested in a real company context. However, this face-value assessment is a helpful first step to gauge potential users' first impressions and initial willingness to engage with the tool. Further replication studies by other researchers than the creators of the ACD³-matrix would be ideal. These studies could be performed with a greater focus on quantifying the perception, including a greater sample size, comparing responses and perceived barriers and facilitators across different industrial sectors and application scopes.

More studies are also needed to investigate which organisational contexts and product development scopes that are ideal to start testing the ACD³-matrix within, as well as which models for product development and project management that ACD³ needs to co-exist with. Remaining open questions are who should "own" the control of the ACD³-matrix, and how the responsibility should be shared between stakeholders and the organisation as a whole.

6 Concluding remarks

The study presented in this paper clearly shows a perceived usefulness (face validity), so the ACD³-matrix seems to be promising as a tool for its target group. The study also brought up barriers that the ACD³-matrix in particular, and perhaps design tools in general, need to overcome to be accepted and used in an organisational context. The way forward seems to be through documentation, training and pedagogical strategies for introduction of the ACD³-matrix; future work includes testing the matrix in real cases to see if the actually obtained utility and usability match the perceived usefulness.

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