The evolution of design requirements in the trajectory of artificiality: A research agenda

Position paper for:

NSF Design Requirements Workshop

Isabelle Reymen (Eindhoven University of Technology)

Georges Romme (Eindhoven University of Technology)

Corresponding author:

Georges Romme

Eindhoven University of Technology

Department of Technology Management

P.O. Box 513, 5600 MB Eindhoven

The Netherlands

E-mail: a.g.l.romme@tm.tue.nl

Key Words:

artificiality, research agenda, design requirements, discourse, projects, interfaces, multi-user systems

The evolution of design requirements in the trajectory of artificiality: A research agenda

The call for papers for this conference asked for a research vision and agenda for requirements identification, capture, verification, and management for complex socio-technical designs. Managing design requirements in heterogeneous and rapidly-changing environments demands new approaches. This position paper elaborates the need for new avenues in requirements research, to develop an agenda for research in requirements engineering and articulate some shortcomings of the requirements research tradition.

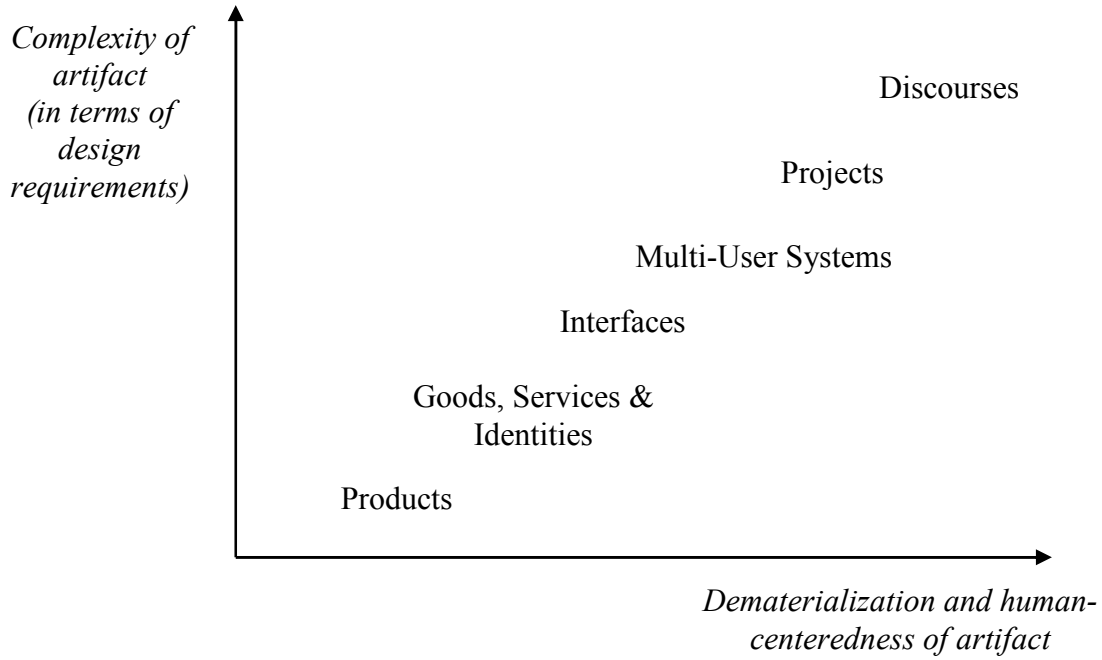
We aim at contributing to the design requirements debate by describing the evolution of requirements thinking, using the framework described by Krippendorff (2006), and deriving a research agenda for requirements research. We start the paper by introducing Krippendorff's framework. Subsequently, the design requirements literature is reviewed and assessed by means of this framework. Based on the evolution in this literature, we then discuss some implications for the design of complex socio-technical systems. Finally, a future research agenda is outlined.

The trajectory of artificiality

Krippendorff (2006) describes a trajectory of artificiality, involving a cumulative progression of six major kinds of artifacts, each adding to what designers can do. According to Krippendorff, this trajectory is not intended to "describe irreversible steps but phases of extending design considerations to essentially new kinds of artifacts, each building up and rearticulating the preceding kinds and adding new design criteria, thus generating a history in progress" (Krippendorff, 2006: 6). The six kinds of artifacts are material products; goods, services, and identities; interfaces; multi-user systems and networks; projects; and finally, discourses. Figure 1 provides an overview, suggesting that along the trajectory artifacts become increasingly complex (in terms of design considerations).

Products are seen here as the material artifacts that producers produce. Designing products thus implies adopting manufacturers' (design) requirements: for example, cost price, utility, functionality, and universal aesthetics (Krippendorff, 2006).

Figure 1: The trajectory of artifacts in design (adapted from: Krippendorff, 2006)



Goods, services, and identities are artifacts that are fundamentally different from products. Goods are manufactured to be traded and sold, not merely used; functions are secondary to their role in the marketplace and serve, at best, as sales arguments. Services need to be designed to be recognizable and trustworthy so that customers return and develop loyalty to the service provider. Identities, whether they are encoded in logos, brand names, or corporate images, are deliberately crafted to create various kinds of commitments. So, goods, services, and identities are products only in a metaphoric sense. In designing these artifacts, designers are concerned with marketability, symbolic diversity, folk and local aesthetics.

According to Krippendorff, the next type of artifact is one that mediates between complex technological devices and their users: *human-machine interfaces*. The design of interfaces shifts the designers' attention from a concern for the internal makeup and appearance of technology to what mediates between single users and technology. Important concerns here are natural interactivity, understandability, reconfigurability, and adaptability.

Multi-user systems and networks facilitate the coordination of many human activities across space and time, for example sign systems, information systems, or communication networks. Unlike in the design of interfaces, the design of multiuser systems deals with the information that such systems can provide to their participants, which in turn depends on their literacy and backgrounds, the diversity of their concerns, and even divergent personal aims. Design requirements here involve informativeness, connectivity, and accessibility.

An even more elusive kind of artifact are *projects*. A project typically arises around particular desires to change something, to develop a technology, for example, and leave something behind that is useful for others outside those directly involved. As artifacts, projects are realized in particular communicative practices among participants. Moreover, projects are designed to achieve cooperation among people without losing sight of what the project is about. As artifacts, projects always proceed in language, in narratives of what has to change, needs to be done, how, by whom, and at which time. They also have a purpose, a point, and an objective, however vague it may be at the outset. A project can rarely be designed single-mindedly by someone in charge. In fact, it is the very openness to details that can energize a project and motivate its contributors to excel. Following Krippendorff, projects are socially viable organizations, constituted in what people do, and last long enough to leave something behind. Important considerations are thus social viability, directionability, and commitment.

Finally, *discourses* are organized ways of talking, writing, and acting accordingly (Krippendorff, 2006). There are many distinct discourses: for example, professional, political, religious, and economic discourse. A discourse may be supported by a multiuser system, but its viability does not depend on this system. As an artifact, discourse may be enacted in a project, but does not require a (deliberately crafted) common purpose. Discourses reside in communities of people who collaborate in enacting what constitutes their community, thereby creating everything that matters to their sense of community. Design considerations here involve generativity, rearticulability, and solidarity (Krippendorff, 2006).

This trajectory of artificiality shows an ongoing dematerialization of artifacts. That is, artifacts become increasingly fluid, indeterminable, immaterial (or virtual), and embedded in language. Moreover, along the trajectory the human-centeredness of artifacts increases (Krippendorff, 2006).

Evolution of design requirements

The trajectory of artificiality previously discussed is used in this section to assess the literature on design requirements and to describe its evolution. We selected two representative journals in the design field, namely *Design Studies* and *Research in Engineering Design*. In these journals, we searched for all articles that have "requirements", "specifications", "demands", and "criteria" in the abstract, title, or key words. The search period begins with the first volume of each journal (Design Studies 1979; Research in Engineering Design 1989) and ends with the latest issue in 2007. The resulting set of articles involves either studies of requirements for the design of something (an artifact) or methodological papers about requirements elicitation, validation and management for a certain kind of artifact.

We categorized each article according to one of the 6 kinds of artifacts as introduced by Krippendorff, namely products; goods, services, and identities; interfaces; multi-user systems/networks; projects; and discourses. This categorization follows from the kind of artifact the requirements-

specifications-demands-criteria were related to. The result is shown in Table 1.

Table 1: Categorization according to type of artifact discussed in articles on requirements in two design journals

artifact	# articles in Design Studies (n=100)	# articles in Research in Engineering Design (n=43)
products	47	8
goods, services, and identities	8	0
interfaces	35	29
multi-user systems/networks	7	4
projects	3	2
discourses	0	0

The evolution of attention to design requirements for each of the artifacts in the two design journals is depicted in Figure 2. The results in Table 1 and Figure 2 suggest a prevailing focus on the product and interface level. The attention for artifacts conceptualized as goods, services and identities is rather underdeveloped, as are multi-user systems. Projects and discourses hardly get any attention in requirements thinking. The five studies at the level of projects are: Eppinger et al. (1994); Lauche (2005); Pons and Raine (2005); Reid et al. (2000); Smith and Morrow (1999). These general patterns are similar in both journals, with the exception of the data for goods, services and identities (see Table 1).

To illustrate the kind of requirements defined and used for each type of artifact, we explore representative papers in each category. For products, *functionality* (Owen, 2007) and *just-in-time production* (Whitney, 1993) are important requirements.

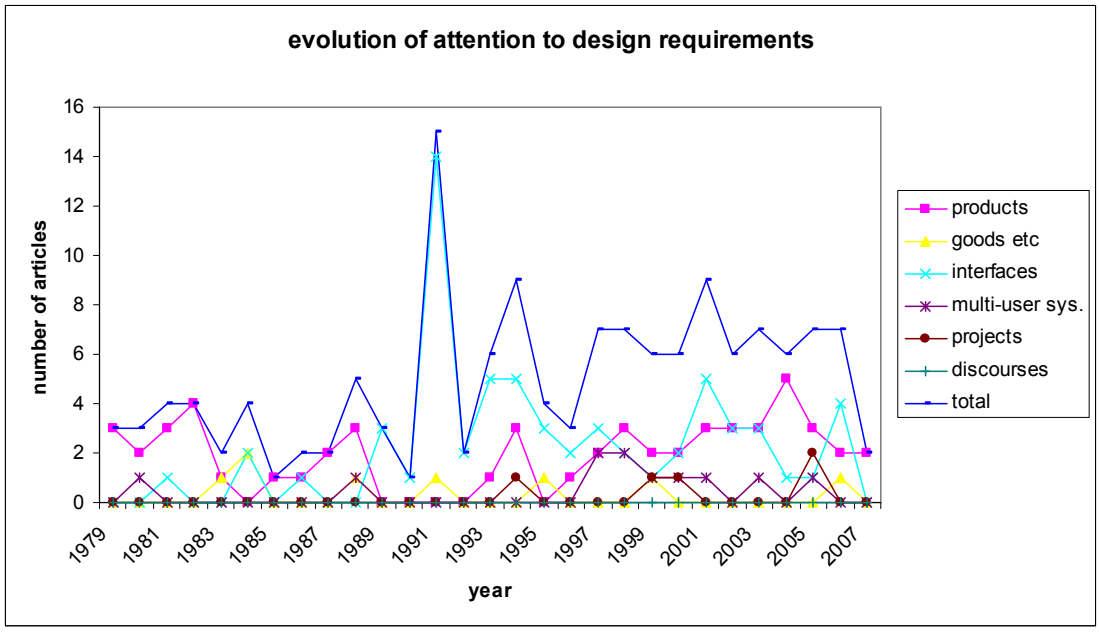
For goods, services, and identities, Foque and Lammineur (1995) derive *user-oriented and user-friendly, functionality, and emotion* as important requirements for service design. Wright (1984) argues that for designing the documentation that explains how IT works, there is a requirement for an initial involvement of the technical writers during product development. This requirement thus concerns *links between writer and system designer*. There is a subsequent requirement for an ability to think about the reader's needs (*links between writer and reader*). And there is a final requirement for means of evaluating the usability of the documentation (*links between writer and text*).

For interfaces, requirements are they for example need to be *extensible, reusable, multi-agent,* and *concurrent* (Cartwright, 1997) and *functional* and *accessible* as well as exhibiting short *interactive response times* (Elsas and Vergeest, 1998).

For multi-user systems and networks, an interesting requirement involves the *distributive characteristics of collaborative product design*. These characteristics involve, for example, extended time; multiple places, cultures,

practices, policies and behaviors; multiple languages and tools; interchangeable interaction methods; and usability and adaptability to workers with different levels of education (Reich et al., 1999). In addition, the *evolutionary nature of the environment* (e.g. group evolution and learning, supporting variable-term relationships) is defined as an important requirement (Reich et al., 1999). For interactive video game design, for example, Jacobs and Ip (2005) discuss *multi-user functional requirements* such as graphics, sounds, technical realism, structure and challenge, multiplayer features, and online features.

Figure 2: Evolution of attention to requirements in the community of design researchers



For projects, Eppinger et al. (1994) derived the following information *transfer requirements of a technical project* (to improve the product development process): 1. Documenting existing procedures for scrutiny of the team, 2. Resequencing and regrouping design tasks to reduce complexity, 3. Sharing engineering data earlier and/or with known confidence, 4. Redefining critical tasks to facilitate overall project flow, 5. Exposing constraints and conflicts due to task interactions, 6. Helping design managers to place emphasis on task coordination, 7. Allowing design iteration to be strategically planned. Lauche (2005) determined the following requirements for job design: *control over the design process, availability and clarity of design-relevant information, feedback on results, and management support*. Pons and Raine (2005: *page number?*) discuss how to deal with requirements when designing projects: "In real situations, designers have to determine constraints from incomplete and qualitative specifications, using subjective processes. Furthermore, they subsequently have to negotiate with others for the relaxation of constraints, as

the design space may be over-constrained. This negotiation involves interaction with others, and adds the organizational behavior factors to the design process. Decision-making during design needs to be able to *accommodate multiple viewpoints, cope with uncertainty of analysis* (incompleteness of knowledge), *propagate uncertain variables,* and *accommodate varying degrees of information abstraction*" (italics in this citation are added by us).

Other authors in the area of project design, for example Reid et al. (2000), see design coordination and team integration as most important dilemma's for design team management. Reid et al. argue that successful project management requires project leaders to continuously steer an acceptable path through these dilemmas. They suggest these problems can be addressed by adopting a *flexible, dynamic approach to team coordination* in which moment-to-moment demands are met by appropriate management actions.

Given the fact that projects and discourses hardly get any attention in requirements thinking in the selected journals, we also searched other journals. In this respect, three journals that were created recently are explicitly human-centered in their aim and scope. These are *Journal of Design Research* (e.g. the work of Sebastian, 2003), *Co-Design* (International Journal of CoCreation in Design and the Arts) (e.g. Marshall and Pengelly, 2006), and *The Design Journal* (of the European Academy of Design) (e.g. Chung and Wang, 2007). These journals may publish more work on projects and discourses as artifacts than the two journals we have studied in this paper.[1] The choice for the two latter journals may, however, somewhat bias our findings – in particular the low number of studies regarding projects and discourses in Table 1.

Design requirements of complex socio-technical systems

The trajectory of artificiality involves an evolution in the kind of artifacts being designed. In this respect, requirements elicitation, validation and management should evolve in parallel. This means that for each type of artifact, the corresponding requirement (management) techniques should be considered. As such, requirements thinking needs to be congruent with the kind of the artifact being designed.

Given the results of the literature review and interpretation in the previous section, requirements thinking has recently developed up to the design of multi-use systems and networks. In this respect, the design of socio-technical systems currently tends to be situated on the level of multi-user systems and networks (e.g., Mumford, 2006; Weigand and de Moore, 2007). However, developing and managing design requirements in heterogeneous and rapidly changing environments can, and must, also be viewed from a project and discourse perspective.

[1] The low number of published volumes of these journals severely constrains opportunities to study papers on design requirements and compare the findings with the two design journals used in this paper.

Evidently, the role of requirements changes along the trajectory of artificiality. Moving from products to discourses as artifacts, the process of defining and managing requirements becomes more participative, dynamic and flexible. Moreover, more attention needs to be given to social and semantic instead of technical and material aspects. Along the trajectory of artificiality, system boundaries become more diffuse and complex and system design becomes more context dependent.

Future research agenda: Designing projects and discourses

The last two sections identified several emerging patterns in the evolution of requirements thinking. We argued that requirements thinking needs to be congruent with the kind of the artifact being designed. In this respect, in addressing complex socio-technical systems designers will increasingly have to explore design requirements at the level of projects and discourses as artifacts. Questions that future research should target are:

1. What are design requirements for the design of a project and how should they be managed? Starting points can, for example, be found in agile developments and methods like SCRUM (Schwaber and Beedle, 2002). Agile development sets up the design process in a pragmatic way with team-based, bottom-up design processes. The concepts for organizing design projects might be useful for the design of other projects as well; the requirements formulated for agile projects can then also be re-used.
2. What are design requirements for the design of (effective) discourse and how should these be managed? An example of the deliberate attempt to design a discourse is branding "Poland" (Olins, 2005). Another interesting example is the way the Bush government in the USA has been redesigning the political discourse toward the key idea: 'if you criticize the Bush government, you criticize our soldiers in Iraq.'
3. What is the role of requirements in designing projects and discourses? The human-centered as well as participative nature of these artifacts evidently affects the role of requirements in the design process, but how?
4. Meta-requirements of requirements linked to each type of artifact should be developed; these meta-categories are perhaps better labeled the 'demands' for requirements. At the product level, for example, systems engineering has already defined meta-requirements (e.g. IEEE Std. 1233, 1998).

References

Cartwright, A.J. (1997) Interactive prototyping, a challege for computer based design, *Research in Engineering Design*, 9(1), pp. 10-19.

Chung, W., Wang, C. (2007) Knowledge –based design and desicions: accommodating multi-disciplined product development teams, *The Design Journal*, 7(1). (online)

Eppinger, S.D., Whitney, D.E., Smith, R.P., Gebala, D.A. (1994) A model-based method for organizing tasks in product development, *Research in Engineering Design*, 6(1), pp. 1-13.

Foque, R., Lammineur, M. (1995) Designing for patients: a strategy for introducing human scale in hospital design, *Design Studies*, 16(1), 29-49.

IEEE Std. 1233 (1998) *Guide for developing System Requirements Specifications*, IEEE, New York.

Jacobs, G., Ip, B. (2005) Establishing user requirements: incorporating gamer preferences into interactive games design, *Design Studies*, 26(3), pp. 243-255.

Krippendorff (2006) *The Semantic Turn: A New Foundation for Design*, Taylor and Francis, New York.

Lauche, K. (2005) Job design for good design practice, *Design Studies*, 25(4), pp. 393-413.

Marshall, J., Pengelly, J. (2006) Computer technologies and transdisciplinary discourse: critical drivers for hybrid design practice?, *CoDesign*, 2(2), pp. 109-122.

Mumford, E (2006) The story of socio-technical design: reflections on its successes, failures and potential, *Information Systems Journal*, 16(4), pp. 317-342.

Olins, W. (2005) National branding in Europe, *Business at Oxford*, 7, pp. 4-6.

Owen, C.L. (2007) Evaluation of complex systems, *Design Studies*, 28(1), pp. 73-101.

Pons, D.J., Raine, J.K. (2005) Design mechanisms and constraints, *Research in Engineering Design*, 16(1-2), pp. 73-85.

Reich, Y., Konda, S., Subrahmanian, E., Cunningham, D., Dutoit, A., Patrick, R., Thomas, M., Westerberg, A.W. (1999) Building agility for developing agile design information systems, *Research in Engineering Design*, 11(2), pp. 67-83.

Reid, F.J.M., Culverhouse, P.F., Jagodzinski, A.P., Parsons, R., Burningham, C. (2000) The management of electronics engineering design teams: linking tactics to changing conditions, *Design Studies*, 21(1), pp. 75-97.

Schwaber, K., Beedle, M. (2002) *Agile Software development with SCRUM*, Prentice Hall, Upper Saddle River, New Jersey.

Sebastian, R. (2003) Multi-architect design collaboration on integrated urban complex development in the Netherlands, *Journal of Design Research*, 3(1). (online)

Smith, R.P., Morrow, J.A. (1999) Product development process modeling, *Design Studies*, 20(3), pp. 237-261.

Van Elsas, P.A, Vergeest, J.S.M. (1998) New functionality for computer-aided conceptual design: the displacement feature**,** *Design Studies*, 19(1), pp. 81-102.

Weigand, H., de Moore, A. (2007) Formalizing the evolution of virtual communities, *Information Systems*, 32(2), pp. 223-247.

Whitney, D.E. (1993) Nippondenso Co. Ltd.: a case study of strategic product design, *Research in Engineering Design*, 5(1), pp. 1-20.

Wright, P (1984) Designing the documentation that explains how IT works, *Design Studies*, 7(2), pp. 73-78.