A Fork in the Road: Systems and Design

Dr. Terence Love
Curtin University
tlove@love.com.au

Abstract

This paper challenges the widespread myth that Systems is sufficient to create a design or plan for intervention. It argues that conflating Systems and Design has caused many unnecessary difficulties in Systems theory and research. The paper redefines the relationships between Systems and Design.

Keywords: *Design, Systems, Theory, Methods, Information, Epistemology*

Introduction

The fields of Systems and Design have long been associated together (see, for example, Nelson and Stolterman, 2003, Power, 2002, Love, 2002b, Gregory and Bratteteig, 2001, ISIG, 2000, Marceau and Dodgson, 1999, Forrester, 1998, Schmidt-Belz and Hovestadt, 1996, Dasgupta, 1991, Eder, 1989, Hubka and Eder, 1988, Dittmayer, 1985, Andreasen, 1985, Gasparski, 1979, Ramscar et al., 1966, Jones, 1970, Nobre, 2003). An early and pervasive dream of the design research community was to automate design activity via systematic methods, and on the Systems side, it has been assumed systems approaches directly result in design solutions, especially in areas of knowledge-based systems and intelligent systems (see, for example, Sargent, n.d., Alexander, 1963, Archer, 1965, Jones, 1970, Director, 1974, Westerberg et al., 1974, Biggioggero, 1985, Dittmayer, 1985, Milacic and Pilipovic, 1985, Dixon, 1987, Gero, 2000, Liddament, 1999, Yoshikawa, 1985, Nobre, 2003).

This paper problematises the relationship between the fields of Systems and Design. It radically extends the analysis presented at ANZSYS' 95 on the relationship between Systems and Design (Love, 1995). The proposals presented in this paper are based on: intermediate findings of three ongoing international collaborative investigations focusing on the theoretical foundations of design research; doctoral research into the inclusion of social, ethical and environmental factors in engineering design theories (Love, 1998, Love, 2000b, 2002a); and recent work by Nelson and Stolterman (2003) concerning the relationships between, design activity, composition and problem solving.

The previous paper in ANZSYS 1995 drew attention to problematic aspects of the relationship between Systems and Design. . This paper argues the central activity of designing is *epistemologically different* from the application of systems methods, techniques, and approaches and perspectives. It suggests the uncritical conflation of the activities of designing and systems analysis seriously compromises theoretical and practical developments in both Systems and Design and this has led to confusion in both fields and to the development of extensive, unnecessary and over-complex theories targeting an epistemologically irresolvable problem. In practical terms, it has hampered the identification

of optimal designs, and hampered the identification of improvements to the efficiency and effectiveness of design processes and systems analyses.

By implication, there are significant benefits for both Systems and Design disciplines through understanding that designing is different from systems analysis and carefully differentiating between them. Practically, for researchers and practitioners this means avoiding the conflation and establishing an epistemologically justified conceptual boundary between theories about designing and the application of Systems methods and approaches. The benefits to be realised are in the areas of increased conceptual clarity, increased understanding of systems and designing, increased applicability of theories from both disciplines, reduced problems in the applicability of theories, the opening of new avenues of research, improved development pathways for both fields, and, not least, improvements to practical designed outcomes.

The concepts relating to Systems in the analyses presented in the paper are straightforward. The issues relating to design theory, however, are less straightforward and hence a significant portion of the paper necessarily focuses on design-related background issues.

The paper consists of seven sections including this introduction. The second section addresses terminological issues. The third section explains the importance of composition. The fourth part discusses the relationship between the core activity of designing and associated activities on the boundary with Systems. The fifth section differentiates between Systems and Design. The sixth section explores some implications for Systems theory of this differentiation, and the final section summarises the paper.

Terminological Issues

The term *design* has been used in many ways. Terminology is problematic in design research (O'Doherty, 1964, Hubka and Eder, 1988, Coyne, 1997, Ullman, 1992, Hubka and Eder, 1996, Harrison, 1974, Tovey, 1997). In the main, this is because key terms of design theory have a variety of meanings in everyday language The purpose of this paper is to develop epistemologically useful and coherent theory in Systems and Design. This requires technical definitions, which delimit concepts in theoretically useful ways that align with existing well-justified theoretical knowledge, and do so across all necessary scales of theorisation. The technical definitions below were developed specifically to fulfil these requirements. They are based on earlier research by Love (see, e.g., 1998, 2000a), Simon (1981) and others. Like most technical definitions, they differ from everyday meanings, and hence exclude many meanings implied in everyday usage. 'Design as an activity' is defined below in three ways that are regarded as conceptually and practically contiguous.

- 'Design' - a noun referring to a *specification* for making a particular artefact or for undertaking a particular activity. A distinction is drawn here between a *design* and an artefact - the design is the basis for and precursor to the making of the artefact. In this sense, this distinguishes the outcomes of designing from the outputs of craft or art alone.
- 'Designing' and 'design' (verb) – (internal version) non-routine physiologically based human internal activity leading to the production of a *design*.
- 'Designing' and 'design' (verb) – (external version) human activity of producing a plan (a design) to change an existing situation into a preferred situation (based on Simon, 1981, pp. 129)

- ‘Designing’ and ‘design’ (verb) – (functionalist version) designing is a process of composition to create a plan (a design) to change an existing situation into a preferred situation (Nelson and Stolterman, 2003)
- ‘Designer’ - someone who is, has been, or will be *designing*. Someone who creates *designs*
- ‘Design process’ - any process or activity that includes at least one act of ‘designing’ alongside other activities such as, calculating, drawing, information collection many of which are, or can be, routine or automated.

A significant issue is the differentiation between the concepts of *designing* and *design process. Designing* is regarded as a specific human activity focusing on compositional judgements. It is an activity at a similar primary level of human cognitive functioning to *thinking* and *feeling:* distinct from both, though utilising both. *Design process*, however, includes alongside *designing* many associated but different activities such as reading, drawing, calculating, gathering information, discussions with constituents etc. These associated activities are undertaken by, and used by, designers as part of the broader task but are not part of the core activity of designing.

This distinction is significant because, as will be argued later, Systems methods and approaches are *associated* activities in design processes rather than part of the core activity of *designing*. This is important because it clarifies many difficult issues in Systems theory. It offers particular benefits through its role in defining epistemologically more satisfactory systemic boundaries: for the systems field; for the scope of systems theories; for understanding the dependence of Systems analyses and perspectives on designing; and for enabling the systems field to avoid re-creating theory that is already well developed in the fields of Design Research, Design Science and Design Cognition.

The Importance of Composition

A key differentiator of the human activity of designing from other human activities is ‘composition’ (Nelson and Stolterman, 2003). All designs consist of compositions of sub-system elements. The relative value offered by a design emerges from the relationships between these sub-system elements and their relationships with the environment. The choice of elements and their relationships depend on human compositional judgements. In most design scenarios, there are many possible designs that offer solutions to a project brief, or produce improved situations as compared to existing situations. In some cases, these alternative designs differ fundamentally. In other cases, they differ only in terms of the relative balance of different elements of the composition. In anything other than the simplest deterministic situation, however, all designs for improving situations involving objects, systems, services, organisation and policies, are compromises. Choosing the balance of compromise depends on human compositional activity and judgement. Designing is the essentially human activity by which these compositional judgements involving compromise are made through embodied processes.

Central, therefore, to designing as a human activity is this physiologically based ability of human beings to make compositional judgements aimed at identifying preferred potential outcomes for the future. These compositional judgements result in the imagogenic output of a coherent solution whose value production is appropriately distributed amongst a complex of competing criteria, many of which are grounded in qualitative human values held by differing stakeholders and constituents. In this paper, compositional ability and compositional

judgement is used as a means of differentiating between designing and other activities, and as a way of gaining greater understanding of where designing is also found in these other activities.

To summarise, in technical terms, the activity of designing appears best defined as an internal human physiological process functioning at a similar cognitive level to, and different from, rational cognition and the feeling associated with emotion. The biological processes are complex (see, for example, Damasio, 1994, Damasio, 1999, Pert, 1999) and in cognitive terms their focus is on developing satisfactory or improved 'compositions' of appropriate solutions that improve adaptation between organism and environment. It is this compositional aspect, and the affective mechanisms associated with the judgements necessary to devising compositions in situations marked by multiple options, indeterminate brief, complex criteria based on human values, and inadequate information that provides a strong differentiator between the core of human design functioning and other associated human activities and processes.

Designing and associated activities

In this section, the relationship between this core activity of designing and four design-related activities associated with systems methods are briefly reviewed. These are:

- Information and design
- Problem solving and design
- Modelling and design
- Application of systems perspectives in design

Information and Design

Designing is a human activity of making a plan to change an existing situation into a preferred situation (after Simon, 1981, pp. 129). Information is needed by, and used by, designers in the process of making the compositions and compositional judgements that are the main role of designing. In undertaking successful composition designers depend on the amount and quality of relevant information. This information is used in bounding the range of potential design possibilities, and also to provide cognitive cuing of potentially useful ideas for designs. Designers are also influenced by information in that it can also result in fixation (Purcell and Gero, 1996).

In undertaking design activity, designers use different sorts of information in many different ways and for many different purposes, e.g.:

- Information about the existing (un-preferred) situation.
- Information about the context of the existing situation
- Information about problems with the current situation
- Information that might contribute to designing a better situation
- Information about techniques, design processes to make more efficient and effective the human design activity
- Information that they generate, that emerges as a contribution to a plan or specification (the design and all its partial incarnations) for changing the existing situation into a preferred situation

- Information that emerges from evaluating or analysing partial design prototypes and evolutionary stages of a design
- Information from a model of a situation and its functioning
- Meta-information about the design process

The composition processes of designing, however, are: different from the information itself; different from the processes of gathering of the information; and different from information-based modelling processes. In fact, the outcomes of these latter modelling processes are simply more sophisticated information sources with less entropy as a result of the effort committed to the modelling process.

Problem Solving and Design

Significant differences between *designing* and rational / deterministic problem solving emerge from investigating the roles of composition. Composition in designing requires judgement as to which issues should be given more or less prominence in the project brief and in the final solution. The aim of a 'good' composition for a design is measured in terms such as: 'how well things fit together conceptually, stylistically and operationally '; 'how coherently the relationships between the elements of the design are arranged'; and 'how easily understandable and useable is the design for those for whom it is a part of their lives'. In human terms, this balance is closely tied to the human values and aesthetic sensibilities of those involved in design activity and the users – even when it is in areas involving highly technical knowledge.

These require composition-based processes of designing that present a strong contrast to the more deterministic rationalist approaches associated with problem solving methods. The main role of problem solving methods for designers is in providing information that designers and design stakeholders can draw on to make better judgements about the compositional issues that are central to the core activity of designing. The information that emerges from the problem solving processes, and the problem solving processes themselves, are, however, epistemologically distinct from the core activity of designing. A more detailed discussion of design activity, composition and the difference between designing and problem solving is found in Nelson and Stolterman (2003).

Modelling and Design

Models and modelling techniques are widely used by designers and are an effective part of design processes. They are part of designers' repertoire of design tools to increase the efficiency of design processes, their reliability, the reliability of solutions, and to improve the ratio of success to failure. The roles design tools fulfil are (Love, 2003):

- As memory aids
- As symbolic functional representations (e.g. formulae, systems diagrams and case studies)
- As means of *making* symbolic representations (e.g. languages such as UML, software such as Vensim)
- As representations of partial solutions (e.g. morphological sketches)

- As means of making representations of partial solutions (e.g. techniques of paper prototyping of websites)
- As prototypes
- As means of making prototypes
- As information sources
- As information searching tools
- As data gathering tools
- As process guides
- As surrogates and conceptual substitutes
- As means of affective sensitisation
- As means of cuing, prompting or modifying an individuals internal thought processes
- As exemplars.

Modelling processes, and the analyses that underpin modelling, are used in design processes in any of these roles. The output of modelling processes, like problem solving, is improved information. It is this information that is of use to designers. The information and the provision of information is, however, epistemologically distinct from the core design activity.

Systems perspectives in design

The application of a systems perspective is different from the use of systems methods of analysis (Nelson and Stolterman, 2003):

- Systems perspective – a way of looking at objects, systems services and processes, organisations etc as *systems*
- Systems method – analytical and modelling technique aimed at providing increased understanding of the systemic functioning of objects, systems, services, (this functioning can also include qualitative issues relating to human values).

In essence, taking a systems perspective means regarding the objects of study, their environment and relationships as systems. In many cases, simply regarding an object, process or thing as a system, rather than a discrete object or entity, can provide significant benefit of itself without the application of Systems analytical and modelling methods. A practical example is in the design of organisational business processes where the move from a process-based focus to a systems-based focus is sufficient to require the inclusion of stakeholders and business constituents in analyses. This then opens the situation to methods such as constituent market orientation analysis and other approaches that offer increased understanding (information) and heuristics (more information) for the designing of business processes (see, Tellefsen, 1999, Tellefsen, 2000). At root, however, the application of a systemic perspective to a situation is also one whose most significant product is, in design terms, increased information about the system in focus. This information, and the application of systems perspectives through which this information emerges, are epistemologically distinct form the core compositional processes of designing.

Systems and Design

The roles and functions of systems analyses and perspectives map, in the main, onto the four subsections above and, in parallel, onto the taxonomy of roles of design tool. The picture that emerges is that systems analyses, modelling processes and perspectives are design tools

whose central focus is as effective means of deriving higher order *information* about situations.

The above analyses indicate that Systems methods and perspectives are epistemologically different from the core activity of designing and that the role of these Systems approaches is to provide information for use by designers in making compositional judgements. They are associated activities that are part of *design process* through their role in generating improved information. In no cases, however, is there any obvious evidence that systems analyses and perspectives are directly part of the core activity of *designing* and its compositional judgement activities.

For example, systems focused, knowledge-based computer software may be developed about aircraft components, their characteristics, and likely locations on an aircraft and their combinatorial effects on the aircraft performance envelope. The establishment of such systems software reduces the time and effort individual designers need to commit to assembling drawings or the characteristics of morphological instances. It does not, however, replace the compositional judgements that need to be made about the relative benefit of these instances. A key issue in this is that representational processes provide subsets of reality. The systems contribution is sophisticated but partial information. The compositional design judgements undertaken by designers, however, have to take into account issues, often inadequately defined in formal terms, in addition to these informatic systemic representations,

To recap, designers use systems methods and perspectives in a similar manner to other design tools. They are sophisticated means of gathering information. Systems analyses are part of design process in the same ways that calculating, drawing, discussions and gathering data from libraries or texts are part of the design process, but not of the core design activity.

Implications for Systems Theory

The implications for improving Systems theory are complex, significant, and potentially offer important benefits for theory making and for the Systems field as a whole. The above analyses indicate that there are many areas relating to designing within the broader system remit that systems analyses and perspectives do not apply.

The core activity of *designing* is found, however, in many micro-situations of Systems activity, and this *designing* is essential to systems analyses and the use of systems perspectives. Different stages in the use of systems methods and the application of systems perspectives depend on small and large elements of design activity. For example, the development of a Soft Systems ‘rich picture’ requires human internal non-routine compositional activities of designing to make the judgements necessary to the composition of the picture. The same is true of the compositional design judgements necessary to choosing the elements, rates, levels and relational linkages in systems dynamics diagrams. Similar is true of making compositional design judgements about preferred system boundaries and system elements. These compositional design activities are found in all systems applications. There is no ‘correct ‘ answer in each of these situations – the best answer depends heavily on judgements about the composition of the best attributes for a systems model in terms of its purpose and the resources available.

Systems, and systems theory, therefore, is strongly dependent on understanding and modelling the core of designing and design processes. In theory, terms, these are foundational issues and hence epistemological clarity and coherency about the roles of designing in systems and systems in design processes potentially offers many benefits.

The benefits of identifying where design activities exist within systems models is that for these activities, it is not necessary nor appropriate to attempt to build systems theories to represent these issues (and in any case is likely for epistemological reasons to be unsuccessful). Instead, it is possible to draw on research and theory from the literatures design research, design science and design cognition. Typical areas to which this design knowledge applies are those that involve the composing of design solutions or the making of compositional judgements for the designs of solutions and interventions. There are several points in systems diagrams such as Fig 1. that design activities predominate. Compositional judgements involving core activities of designing are central to the system analysis in, for example:

- Choosing the system boundaries and sub-system elements
- Choosing which relationships between sub-system elements to model in the system
- Choosing the criteria or variables used to represent the system's behaviour
- The activities of human actors in a system involved in addressing questions such as 'what to do next?' or "how to improve things?"
- Deciding whether sufficient effort has been put in to modelling or analysing the system, or deciding whether the systems model is satisfactory

The activity of 'intervention' is perhaps the most significant in understanding the relative roles of Systems and Design. The implication of the above analyses is that Systems perspectives and methods can never result in the design for a solution or the design of an intervention. The application of Systems approaches result instead in information about the outcomes of particular, system-based representational processes. Designers use this sophisticated system-based information, a partial representation of the real world situation in guiding their compositional judgement in creating designs for solutions and interventions. .

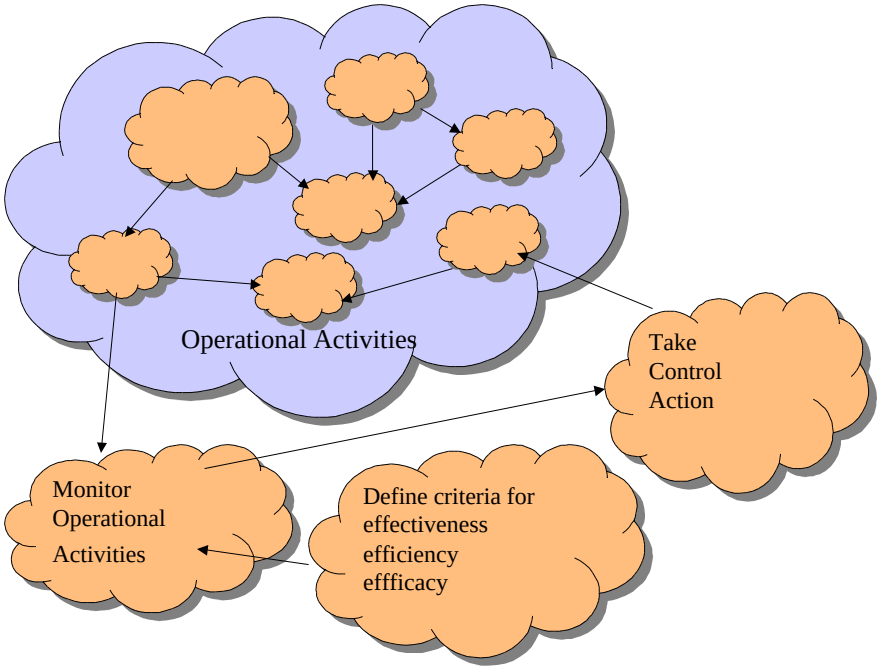

Fig 1: Example of Systems model of a purposeful activity system (after Jackson, 1993, p. 155)

Conclusions

This paper has explored the roles of systems perspectives and methods in designing and design processes, and the role of designing in Systems perspectives and methods. The paper reported research in design that differentiates between a core activity of *designing* and a broader more general *design process*. The paper argued that systems applications and perspectives are epistemologically different from the core activity of *designing*. In addition, the paper identifies that the role of Systems perspectives and methods is in providing sophisticated information to designers to support compositional judgements central to the creation of designs. That is, systems approaches are associated activities and part of the broader design process.

Several implications for Systems theory are drawn from the analyses of the paper. The first is there are many areas concerning design within what is presently regarded the systems field that cannot be addressed by the application of systems perspectives, methods and theories. Material for addressing these areas is available from the literature and research findings of the fields of design research, design science and design cognition. The second is that the outcome of systems analyses is information that is preparatory to and feeds into the designing of solutions or interventions as undertaken by human designers via compositional processes requiring judgements strongly shaped by human values that cannot be adequately or completely represented by systems methods.
Implied in the above is the understanding that Systems analysis and modelling does not produce designs for solutions – designing solutions and interventions is an epistemologically, and physically, different activity.

References

Alexander, C. (1963) In *Conference on Design Methods*(Eds, Jones, J. C. and Thornley, D. G.) Macmillan, New York.

Andreasen, M. M. (1985) In *Design and Synthesis*(Ed, Yoshikawa, H.) Elsevier Science Publishers B.V., Amsterdam.

Archer, L. B. (1965) *Systematic Methods for Designers,* Design Council, London.

Biggioggero, G. F. (1985) In *Design and Synthesis*(Ed, Yoshikawa, H.) Elsevier Science Publishers B.V., Amsterdam.

Coyne, R. (1997) *Design Studies,* **18,** 135-142.

Damasio, A. (1994) *Descartes' Error: Emotion, Reason and the Human Brain,* Grosset, New York.

Damasio, A. (1999) *The Feeling of What Happens,* Random House, London.

Dasgupta, S. (1991) *Design Theory and Computer Science,* Cambridge University Press, Cambridge.

Director, S. W. (1974) In *Basic Questions of Design Theory*(Ed, Spillers, W.) North-Holland Publishing Company, Amsterdam.

Dittmayer, P. J. (1985) In *Design and Synthesis*(Ed, Yoshikawa, H.) Elsevier Science Publishers B.V., Amsterdam.

Dixon, J. R. (1987) *Artificial Intelligence in Engineering Design Analysis and Manufacturing,* **1,** 145—157.

Eder, W. E. (1989) In *International Conference on Engineering Design 1989: proceedings of the IMechE,* Vol. 2 Mechanical Engineering Publications Ltd Bury St Edmunds, UK, Harrogate UK, pp. 1307–1320.

Forrester, J. W. (1998) *Designing the Future,* Universidad de Sevilla, Seville.

Gasparski, W. W. (1979) *Design Studies,* **1,** 101-106.

Gero, J. S. (2000) University of Sydney, Sydney.

Gregory, J. and Bratteteig, T. (2001) In *Proceedings of the 24th Information Systems Research Seminar in Scandinavia (IRIS 24) Volume III*(Eds, Solveig, B., Moe, R. E., Mørch, A. I. and Opdahl, A. L.) University of Bergen, Ulvik, Norway.

Harrison, M. A. (1974) In *Basic Questions of Design Theory*(Ed, Spillers, W.) North-Holland Publishing Company, Amsterdam.

Hubka, V. and Eder, W. E. (1988) *Theory of Technical Systems,* Springer-Verlag, Berlin.

Hubka, V. and Eder, W. E. (1996) *Design Science: Introduction to the Needs, Scope and Organization of Engineering Design Knowledge,* Springer-Verlag, London.

ISIG (2000) Innovation Policy Branch, DISR.

Jackson, M. C. (1993) *Systems Methodologies for the Management Sciences,* Plenum Press, New York.

Jones, J. C. (1970) *Design Methods: seeds of human futures,* Wiley-Interscience, London.

Liddament, T. (1999) *Design Studies,* **20,** 41-56.

Love, T. (1995) In *Systems for the Future*(Eds, Hutchinson, W., Metcalf, S., Standing, C. and Williams, M.) Edith Cowan University, Perth Western Australia, pp. 238–246.

Love, T. (1998) In *Mechanical and Materials Engineering*University of Western Australia, Perth, pp. 358.

Love, T. (2000a) *International Journal of Design Computing,* **2**.

Love, T. (2000b) *Design Studies,* **21,** 293-313.

Love, T. (2002a) *Design Studies,* **23,** 345-361.

Love, T. (2002b) In *Proceedings of the We-B Conference 2002, E-Conomy - from Here to Where. 3rd International We-B Conference,*Edith Cowan University, Perth.

Love, T. (2003) In *Proceedings of the 6th Asian Design Conference*Tsukuba.

Marceau, L. and Dodgson, M. (1999) DISR.

Milacic, V. and Pilipovic, M. (1985) In *International Symposium on Design and Synthesis*(Ed, Yoshikawa, H.) Elsevier Science Publishers B.V., Amsterdam.
Nelson, H. and Stolterman, E. (2003) *The Design Way -- Intentional Change in an Unpredictable World*, Educational Technology Publications, New Jersey.
Nobre, F. (2003) The University of Birmingham, School of Engineering / Manufacturing and Mechanical Engineering.
O'Doherty, E. F. (1964) In *Conference on design methods*(Eds, Jones, J. C. and Thornley, D. G.) Macmillan, New York, pp. 197–204.
Pert, C. (1999) *Molecules of Emotion*, Simon & Schuster, USA.
Power, D. J. (2002) *A Brief History of Decision Support Systems*, DSSResources.COM, World wide Web.
Purcell, A. T. and Gero, J. S. (1996) *Design Studies*, **17,** 363-384.
Ramscar, M., Lee, J. and Pain, H. (1966) *Design Studies*, **17,** 465-488.
Sargent, P. M. (n.d.), Vol. 2001.
Schmidt-Belz, B. and Hovestadt, L. (1996) *Design Studies*, **17,** 489-509.
Simon, H. A. (1981) *The Sciences of the Artificial*, MIT Press, Cambridge Mass.
Tellefsen, B. (1999) *Journal of Market Focused Management*, **4,** 103-124.
Tellefsen, B. (2000) In *Doctoral Education in Design: Foundations for the Future*,(Eds, Durling, D. and Friedman, K.) Staffordshire University Press, UK.
Tovey, M. (1997) *Design Studies*, **18,** 5-32.
Ullman, D. G. (1992) *Research in Engineering Design*, **3,** 179-189.
Westerberg, A. W., Stephanopulous, G. and Shah, J. (1974) In *Basic Questions of Design Theory*(Ed, Spillers, W.).
Yoshikawa, H. (Ed.) (1985) *International Symposium on Design and Synthesis*, Elsevier Science Publishers BV, Amsterdam.