UNIVERSITY OF MANITOBA

LIMITATIONS TO THE CONCEPT OF WICKED PROBLEMS WITHIN ARCHITECTURAL DESIGN METHODOLOGY

by

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A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE
STUDIES IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE
MASTER OF ARCHITECTURE

DEPARTMENT OF ARCHITECTURE

WINNIPEG, MANITOBA

April, 1979

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Abstract

The work presents an argument for the continuing relevance to architectural design methodology of investigations into the methods of science, mathematics, and engineering.

The historical dependence of design methods upon scientific techniques is demonstrated. A challenge, posed by the work of Horst Rittel, to the assumption that design problems are solvable by such techniques is presented.

It is argued that the characteristics of design problems which were elaborated by Rittel are limited in their ability to distinguish design and planning problems from those amenable to techniques derived from the sciences. This contention is supported by the presentation of studies in the theory of algorithms, the psychology of problem solving, computer science and system science.

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Statement of Purpose

The purpose of this thesis is to investigate the continuing relevance of scientific methods to design problems in contemporary design methodology.

Significance of the Study

A major theme of the modern movement in architecture has been that it become consistant with contemporary technology (1)(2)(3). Few of the pioneers of the movement, however, could have envisioned that a dominant technology of the twentieth century would be that of the collection, processing, and dissemination of information. Design theoreticians, such as Geoffrey Broadbent, recently have argued that the failure of the architectural profession to cope with rapidly increasing knowledge may be one of its most crucial shortcomings (4). The challenge represented by the proliferation of information impingant upon the concerns of architecture has been a motivating force in the development of modern design methods.

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(1) Le Corbusier, Towards a New Architecture, trans. from the French by Frederick Etchells (London, 1952).

(2) Frank Lloyd Wright, "The Art and Craft of the Machine," The Future of Architecture (New York, 1953).

(3) Philip C. Johnson, Mies van der Rohe (New York, 1953) pp. 203-204.

(4) Geoffrey Broadbent, Design in Architecture (London, 1973).

Colin Rowe has suggested that modern architecture has gained much of its strength from a dialectical struggle between its scientific and humanistic roots:

> " . . . between a retarded conception of science and a reluctant recognition of poetics . . . it is apparent that modern architecture, in its great phase, was the great idea that it undoubtedly was precisely because it compounded and paraded to extravagance the two myths which it still most publicly advertises." (5)

The historical motivation for the interest in science by the pioneers of modernism in architecture lay in the belief that the objectivity of science could be socially therapeutic. This view has been central to the concerns of design methods research:

> "The motives for adopting rational methods and incorporating scientific methods and knowledge in the design process are many, various, and contradictory. First, there was and is the desire to use scientific results to humanize the environment - a task which has so far been criminally reglected." (6)

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(5) Colin Rowe and Fred Koetter, Collage City (Cambridge, 1978).

(6) Gui Bonsiepe, "Arabesques of Rationality - Notes on the methodology of design," Kommunikation, Vol. 3 (1967) p. 143.

Until recently, such views had been largely unquestioned within methods research. Indeed, it has been proposed, by Herbert Simon, that the means are at hand to establish a science of design. Such a discipline would differ from more traditional science only in that its objects of study would be the artificial processes man uses to create artifacts, rather than those of the natural world (7).

By 1970, however, a challenge had emerged to the assumption that problems of science and design were sufficiently related to make both amenable to similar solution methods. This challenge, lead principally by Horst Rittel, has resulted in the development of a "second generation" of design methods (8).

Four assumptions were seen as underlying the first generation of methods:

1. The problem is separable from its solution.
2. There is at least one method by which a problem may be solved: a technique will lead to a solution.
3. Expertise in problem solution is trainable.
4. The problem is depoliticized; it can be dealt with objectively. (9)

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(7) Herbert A. Simon, <u>The Sciences of the Artificial</u> (Cambridge, 1969) Ch. 3.

(8) Horst Rittel, "The State of the-Art in Design Methods," in <u>The D.M.G. Fifth Anniversary Report</u> (Berkeley, 1972) pp. 5-10.

(9) Unpublished lecture notes prepared by Prof. Bruce Dexter following the visit to the University of Manitoba of Jean-Pierre Protzen, March 22-25, 1977. p. 2.

For reasons which will be presented later, Horst Rittel did not believe that these assumptions hold for design or planning problems. The proposed second generation of methods was to be founded on three conditions:

1. The assumption of a symmetry of ignorance, with designers and planners possessing instrumental knowledge, and with those for whom the design plan is intended possessing experiential knowledge. Participation is to be developed and encouraged.
2. Optimization methods ought to be replaced by argumentation.
3. Knowledge and argument is to become objective in order that a basis for judgment be made as explicit as possible. (10)

While this thesis wishes to acknowledge the value of investigations in the second generation of methods, their critical evaluation lies beyond its scope. The central concern of the thesis is directed at the attempt, by the founders of the new thrust in methods research, to establish a <u>necessary</u> separation between methods of science, engineering, and mathematics, and those of design and planning.

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(10) Unpublished lecture notes prepared by Prof. Bruce Dexter following the visit to the University of Manitoba of Jean Pierre Protzen, March 22-25, 1977. p. 2.

Assumptions and Premises

While it is only one of the many facets of architecture, the justification for concentration upon the design activity is assumed to be the crucial role it plays in architecture.

It is recognized that designing is an activity common to many fields. This investigation is premised upon an acceptance of the potential relevance to each field of observations concerning the design activity within the others.

Clarification of Terms

"Design", when the term is used in this work, has a meaning substantially in accord with the following description proposed by Horst Rittel:

> " . . . a ubiquitous human activity. A man designs whenever he has a purpose in mind and devises a scheme to accomplish the purpose. The outcome of designing is, not the accomplishment of the purpose, but a plan for its accomplishment . . . the execution of the plan is exptected to produce a situation with desired characteristics: this situation ought to contain what was to be accomplished, and besides this, it should not incorporate undesirable and unforseen side effects." (11)

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(11) Horst W. J. Rittel, "Some Principles for the Design of an Educational System for Design - Part One," D.M.G. Newsletter, IV (December, 1970) p. 7.

"Planning" is a similar, if not identical activity, perhaps characterized by an increased time span between implementation and assessment, and thereby increased uncertainty: "Planning is long-range thinking affecting action in the present." (12)

"Method" is intended to be synonymous with "systematic procedure", and, following Bonsiepe, indicates a selection of actions aimed at eliminating, as much as possible, arbitrary actions, leading to a result. The question: how is something done? can be replaced by: what method is used? (13)

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(12) Erich Jantsch, Technological Planning and Social Futures (New York, 1972) p. 4.

(13) Gui Bonsiepe, "Arabesques of Rationality - Notes on the Methodology of Design," Kommunikation, Vol. 3 (1967) p. 143.

Development of Design Methods

Sources of Contemporary Methodology

Much of the work in design methodology has been founded in developments of this century whose effects upon the fundamentals of science have not yet been thoroughly investigated (14). The so-called "system sciences" stemmed from studies of body temperature regulation conducted by W. B. Cannon (15). Of specific interest to design methodologists have been the general systems theory of von Bertalanffy (16), and the cybernetics of Wiener (17) and Ashby (18). Related to these fields in their approach, has been the mathematical theory of communication (19) and several mathematical techniques, including the game theory of John von Neuman (20).

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(14) Ervin Laszlo, The Systems View of the World (New York, 1972) Ch.'s 1, 2.

(15) E. Nagel, "A Formalization of Functionalism", Systems Thinking, ed. F. E. Emery (Harmondsworth, 1969).

(16) Ludwig von Bertalanffy, General Systems Theory (New York, 1968).

(17) Norbert Wiener, Cybernetics (Cambridge, 1961).

(18) W. Ross Ashby, An Introduction to Cybernetics (London, 1956).

(19) Claude E. Shannon and Warren Weaver, The Mathematical Theory of Communication (Urbana, 1949).

(20) Leonid Hurwicz, "The Theory of Economic Behavior" in The World of Mathematics, ed. James R. Newman, Vol. 2 (New York, 1956).

The demands of wartime production, together with a shortage of trained people generated a need for problem solving personnel. The talents of persons of backgrounds varying widely from that of the problem area were used to meet this need. The success of various kinds of scientists in solving complex technical and logistical problems in fields unconnected with their specialties lead to the emergence in the postwar period of the field of "operations research". An early definition of the field proposed by Morse and Kimball described operations research as " . . . a scientific method of providing executive departments with a qualitative basis for decisions regarding the operations under their control." (21)

Operations research was further developed by, amongst others, C. W. Churchman during the early 1950's. A methodology was proposed which emphasized the establishment of a mathematical model for the problem situation, from which a "solution" could be derived (22).

Historial Development

The development of such techniques, and their success in application, had become, by the late 1950's, of considerable interest to design methodologists. Morris Asimow's seminal work, Introduction to Design, described design as "the gathering, handling, and creative organizing of

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(21) Philip M. Morse and George E. Kimball, Methods of Operations Research (New York, 1951) p. 1.

(22) C. West Churchman, R. L. Ackoff, and E. C. Arnoff, Introduction to Operations Research (New York, 1957).

information relevant to the problem situation; it prescribes the derivation of decisions which are optimized, communicated and tested or otherwise evaluated . . . " (23).

By 1962, interest was large enough to support an international conference of design methodologists at Imperial College, London (24). The aim of the conference was to explore the application of scientific methods and knowledge to the solution of problems in other fields (25). A theme which characterized much of the work presented was that of the separation of logical analysis and creative thought (26). If this separation could be achieved, it was widely held that methods existed to resolve problems of considerable complexity.

In this regard, a notable paper presented at the conference was that given by Christopher Alexander (27). This work was later incorporated into his Notes on the Synthesis of Form (28). Alexander was concerned with the interrelationships amongst the definable subproblems of a design task. The apparent complexity of these interrelationships

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(23) Morris Asimow, Introduction to Design (New Jersey, 1962).

(24) J. C. Jones and D. G. Thornley, eds., Conference on Design Methods, (London, 1963).

(25) P. A. Slann, "Forward," in Conference on Design Methods, eds. J. C. Jones and D. G. Thornley (London, 1963).

(26) J. C. Jones, "A Method of Systematic Design," in Conference on Design Methods, eds. J. C. Jones and D. G. Thornley (London, 1963).

(27) Christopher Alexander, "Determination of the Components for an Indian Village," in Conference on Design Methods, eds. J. C. Jones and D. G. Thornley (London, 1963).

(28) Christopher Alexander, Notes on the Synthesis of Form (Cambridge, 1964).

seemed to deny the amenability of the task as a whole to resolution by solution of its constituant problems.

By its application of scientific knowledge (graph theory) and technique (computer analysis) the "Synthesis of Form Method" may be seen to have been exemplary of the thrust of methods research of its time.

Major contributions to the understanding of the potential usefulness of scientific and mathematical technique to the designer were made at the "Hochschule für Gestaltung" at Ulm, West Germany. In their 1964 survey article "Science and Design", Tomas Maldonado and Gui Bonsiepe outlined the extent to which both scientific knowledge and method were incorporated into the curriculum of the Hochschule (29).

Included in their survey were topology, information theory, systematic methods, psychology, ergonometrics, and heuristic techniques.

The approach in evidence at the 1967 Portsmouth conference showed a strong orientation towards systems sciences (30). Bruce Archer, in particular, outlined what he believed to be the basis of a science of design. He drew heavily upon the techniques of operations research, game theory and cybernetics, as well as general systems theory (31).

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(29) Tomas Maldonado, and Gui Bonsiepe, "Science and Design," Ulm No. 10/11 (May 1964) pp. 10-29.

(30) Geoffrey H. Broadbent and A. Ward, eds., Design Methods in Architecture (New York, 1969).

(31) L. Bruce Archer, "The Structure of the Design Process," in Design Methods in Architecture, eds. G. H. Broadbent and A. Ward (New York, 1969).

Papers delivered by Amos Rapoport (32) and Gordon Best (33) further axamined the potential of systems theory and cybernetics. Rapoport's work was concerned with the extent to which research had concentrated upon an objective approach to design models which, he argued, was not required within the systems paradigm he investigated. Gordon Best presented a view of architectural design as a cybernetic variety reducing process.

The first international conference of the Design Methods Group was held in Cambridge, Massachusetts in June of 1968 (proceedings published as <u>Emerging Methods in Environmental Design and Planning</u> (34)). Papers were presented covering a wide range of topics, including thought processes in design, computer-aided design, problem structure identification, automated space planning, evaluation systems, applications of systems engineering, and form/behavior relationships. The essential dependence of design methods upon scientific techniques was, evidently, largely unchallenged.

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(32) Amos Rapoport, "Facts and Models," in <u>Design Methods in Architecture</u>, eds. G. H. Broadbent and A. Ward (New York, 1969).

(33) Gordon Best, "Methods and Intention in Architectural Design," in <u>Design Methods in Architecture</u>, eds. G. H. Broadbent and A. Ward (New York, 1969).

(34) Gary T. Moore, ed., <u>Emerging Methods in Environmental Design and Planning</u> (Cambridge, 1970).

Nicholas Negroponte presented a paper describing a computer system which was intended as a simulation of an interactive urban design tool (35). Negroponte later developed his approach in The Architecture Machine (36).

The presentation of methods founded in the techniques of sociology and behavioral psychology represented a substantially new approach. One such paper (37), together with that of Alexander and Poyner (38), outlined an approach then developing at the Berkeley Centre for Environmental Structure, which was eventually to lead to the development of the "pattern language" (39).

In his two-part article of 1970-71 concerning design education, Horst Rittel elaborated upon recurrent difficulties in design. He introduced the term "ill behaved" to describe the behavior of design

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(35) Nicholas Negroponte and Leon Groisser, "Urban 5: A Machine That Discusses Urban Design," in Emerging Methods in Environmental Design and Planning, ed. G. T. Moore (Cambridge, 1970) pp. 105-114.

(36) Nicholas Negroponte, The Architecture Machine: Toward a More Human Environment (Cambridge, 1970).

(37) Francis Duffy and John Torrey, "A Progress Report on the Pattern Language," in Emerging Methods in Environmental Design and Planning, ed. G. T. Moore (Cambridge, 1970) pp. 261-277.

(38) Christopher Alexander and Barry Poyner, "The Atoms of Environmental Structure," in Emerging Methods in Environmental Design and Planning, ed. G. T. Moore (Cambridge, 1970) pp. 308-321.

(39) Christopher Alexander et al., A Pattern Language: Towns, Buildings, Construction (New York, 1977).

problems when approached from the orientation of scientific methodology (40)(41). In a 1974 paper, Rittel, with Melvin Webber presented a further development of their investigations concerning the differences between problems of science, engineering and mathematics and those of design and planning (42). In his 1972 description of the state of the art in design methods, Rittel stated that such difficulties required a reorientation towards a second generation of methods (43).

The growth of methods designed to elicit the participation of those for whom the design or plan is intended was a necessary part of the approach of second generation methods. The participatory thrust within design methods was the subject of a conference sponsored by the Design Research Society in Manchester in 1971 (44).

Amongst the conference participants, Reyner Banham argued that the principle responsibility of a professional was to eliminate the need for

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(40) Horst Rittel, "Some Principles for the Design of an Educational System for Design - Part One," in <u>D.M.G. Newsletter</u> (December, 1970) pp. 3-10.

(41) Horst Rittel, "Some Principles for the Design of an Educational System for Design - Part Two," in <u>D.M.G. Newsletter</u> (January, 1971) pp. 2-11.

(42) Horst Rittel and Melvin Webber, "Dilemmas in a General Theory of Planning," in <u>DMG-DRS Journal</u>, Vol. 8, No. 1 (1974), pp. 31-39.

(43) Horst Rittel, "The State of the Art in Design Methods," in <u>The D.M.G. Fifth Anniversary Report</u> (Berkeley, 1972) pp. 5-10.

(44) Nigel Cross, ed., <u>Design Participation</u> (London, 1972).

his services (45). Charles Eastman (46) and Sean Wellesley-Miller (47) emphasized the changing nature of the requirements to which a building must repond over its life. Thomas Maver recognized a similar problem, and stressed the potential of participatory planning to deal with ongoing problems in the theory of methods (48).

During the most recent international conference of the Design Methods Group (Berkeley, 1975), papers were presented representing both the more conventional lines and the emergent second generation (49). Much interest was shown by the participants in the participatory approaches investigated by Hanno Webber and others (50)(51)(52)(53).

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(45) Reyner Banham, "Alternative Networks for the Alternative Culture," in Design Participation, ed. N. Cross (London, 1972) pp. 15-18.

(46) Charles Eastman, "Adaptive-Conditional Architecture," in Design Participation, ed. N. Cross (London, 1972) pp. 51-57.

(47) Sean Wellesley-Miller, "Self-Organizing Environments," in Design Participation, ed. N. Cross (London, 1972) pp. 58-62.

(48) Thomas Maver, "Simulation and Solution Teams in Architectural Design," in Design Participation, ed. N. Cross (London, 1972) pp. 79-83.

(49) Donald P. Grant, ed., "D.M.G. 3 (1975) Conference Proceedings," DMG-DRS Journal, Vol. 9, No.'s 2 and 3, 1975.

(50) Hanno Webber, "A Contextual Dwelling Cell Morphology: Discourse for Participation in Design," DMG-DRS Journal, Vol. 9, No. 2, 1975, pp. 171-176.

(51) Hanno Webber and Michael Pyatok, "A Playground: Participation in Design," DMJ-DRS Journal, Vol. 9, No. 3, 1975, pp. 214-278.

(52) Edward Robbins, Michael Pyatok, and Hanno Webber, "Who Minds What Matters? and Epilogue," DMG 3, ed. D. P. Grant (Berkeley, 1975) pp. 377-383.

(53) Thomas L. Thompson, "Treking Through a Participatory Wilderness: Procedural Traps in Design," DMJ-DRS Journal, Vol. 9, No. 2, 1975, pp. 159-165.

Although some criticism of Rittel's work was offered (54), support for the second generation approach was much in evidence. Andrzej Pinno presented a paper which paralled Rittel's criticism of the positivist tradition in methods (55). Kenneth Stevens investigated the role of teams in executing second generation methods (56). Tom Heath elaborated upon his concern regarding the role of the design brief or program in the argumentative structure of such methods (57).

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(54) Herman Neuckermans, "The Relevance of Systematic Methods for Architectural Design," DMG-DRS Journal, Vol. 9, No 2, 1975, pp. 140-144.

(55) Andrzej Pinno, "Beyond Scientific Methods in Architecture," DMG 3, ed. D. P. Grant (Berkeley, 1975) pp. 340-347.

(56) Kenneth V. Stephens, "Systematic Methods: The Implications for Project Teams," DMG-DRS Journal, Vol. 9, No. 2, 1975, pp. 145-152.

(57) Tom Heath, "Getting Started: Is Your Programme Really Necessary," DMG-DRS Journal, Vol. 9, No. 2, 1975, pp. 196-199.

Distinguishing Characteristics of Design Problems

Methodologists have recognized a limit to the degree to which the scientific approach, which they have investigated, can be applied to design problems. Maldonado and Bonsiepe (58) argued that creative thought in both science and design could not be totally reduced to algorithm. Bruce Archer, whose attempt to establish a science of design was perhaps the most fervent in the field, thought that the efficiency of a design method would be increased when the rationality of the method was augmented with an appropriate amount of intuitive technique (59).

The limits established by the work of Horst Rittel and others in the early 1970's were of quite a different order, however. This work has been seen by many as establishing a distinction between, in Rittel's words, a first and second generation of design methods (60).

In their 1974 paper, Rittel and Webber described the technique toward which the first generation of methods appeared to be moving:

> " . . . an ongoing cybernetic process of governance, incorporating systematic procedures for continuously searching out goals; identifying problems; forecasting uncontrollable contextual changes; inventing

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(58) Tomas Maldonado and Gui Bonsiepe, "Science and Design," <u>Ulm</u>, No. 10/11 (May, 1964) pp. 10-29.

(59) Bruce Archer, "An Overview of the Structure of the Design Process," in <u>Emerging Methods in Environmental Design and Planning</u>, ed. G. T. Moore (Cambridge, 1973) p. 307.

(60) Horst Rittel, "The State of the Art in Design Methods," in <u>The D.M.G. Fifth Anniversary Report</u> (Berkeley, 1972) pp. 5-10.

> alternative strategies, tactics, and time sequenced actions; simulating alternative and plausible action sets and their consequences; evaluating alternatively forecasted outcomes; statistically monitoring those conditions of the publics and of systems that are judged to be germane; feeding back information to the simulation and decision channels so that errors can be corrected - all in a simultaneously functioning governing process." (61)

While the authors did not consider this goal attainable, their rejection of it was deeper seated. It was claimed that methods derived from scientific and engineering sources were inappropriate for the solution of planning and design problems. Rittel and Webber theorized that the problems facing designers and planners were of a fundamentally different type than those dealt with by scientists.

Rittel has used the terms "ill behaved" (62) and "wicked" to distinguish design and planning problems from the "benign" or "tame" problems of science and engineering. Such problems, although often extremely difficult, tend to have clear objectives. Any proposed solution can be readily verified. Suggested examples included the solution of a

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(61) Horst Rittel and Melvin Webber, "Dilemmas in a General Theory of Planning," DMG-DRS Journal, Vol. 8, No. 1, 1974, p. 33.

(62) Horst Rittel, "Some Principles for the Design of an Educational System for Design - Part One," DMG Newsletter, Vol. 4 (December, 1970) p. 8.

mathematical equation, the chemical analysis of the structure of an unknown compound, and a five-move checkmate problem (63).

In the paper entitled "Dilemmas in a General Theory of Planning," Rittel and Webber suggest ten distinguishing characteristics of wicked problems:

" 1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no stopping rule.
3. Solutions to wicked problems are not true-or-false, but good-or-bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a "one shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
6. Wicked problems do not have an enumerable (or exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique.

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(63) Horst Rittel and Melvin Webber, "Dilemmas in a General Theory of Planning," DMG-DRS Journal, Vol. 8, No. 1, 1974, p. 34.

" 8. Every wicked problem can be considered to be a symptom of another problem.

9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.

10. The planner has no right to be wrong." (64)(65)

These characteristics appear to fall within three general categories: those dealing with the proliferating nature of design problems (numbers 1, 6, 8 and 9); those concerned with the identification and testing of proposed solutions (numbers 2, 3 and 4); and those addressing the problems inherant to the nonrepeatability of design and planning situations (numbers 5, 7 and 10).

Statement of Hypothesis

It is the contention of this thesis that the characteristics which Horst Rittel has posited are limited in their ability to distinguish the class of design and planning problems from those amenable to techniques derived from science, mathematics, or engineering.

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(64) Horst Rittel and Melvin Webber, "Dilemmas in a General Theory of Planning," DMG-DRS Journal, Vol. 8, No. 1 (1974) pp. 34-37.

(65) For an alternative formulation, see W. J. Mitchell, Computer Aided Architectural Design (New York, 1977) p. 60.

This contention will be supported by considering research in problem solving techniques, and by examining each of the three groups of distinguishing characteristics in the light of work in algorithmic theory, computing science, cognitive psychology, and system theory.

Problem Solving

An initial doubt concerning the lack of applicability of methods derived from science may be established by a study of work in cognitive psychology concerning human problem solving. Herbert Simon and Allen Newell (66) studied the behavior of human problem solvers dealing with cryptarithmetic problems such as that shown below. The objective is to find a consistent substitution of numbers for the letters given which will translate the problem into a true arithmetic statement:

$$\begin{array}{r} \text{C R O S S} \\ +\ \text{R O A D S} \\ \hline \text{D A N G E R} \end{array}$$

While such problems are hardly wicked, they do allow subjects to exhibit search, trial, and reasoning.

The researchers gathered behavioral data from the observations of subjects solving such problems. The data consisted of records of the subjects' verbalizations, and, in trials where these were allowed, written records. The data allowed inferences to be made concerning

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(66) Allen Newell and Herbert Simon, Human Problem Solving (Englewood Cliffs, 1972)

both the final outcome of the solution process, and the state of knowledge of the subject at many intermediate points. Simon and Newell were able to show that their subjects moved through the possible states of knowledge concerning the problem guided by operators which, while not part of the problem statement, arose consistantly amongst the subjects. The operators were seen as transforming the subjects' knowledge of the problem from one state to another. The researchers concluded that the selection of a particular operator to move from one state of knowledge to another was governed by a fairly simple system of rules dependent largely upon the state of knowledge at the time of selection (67).

In the view which has emerged from works such as these, the problem solver appears to possess a repertoire of relatively simple methods which he applies recursively to a problem, transforming it to another problem, until a solution is reached.

Researchers in this field have recognized that most of their work has been concentrated upon well defined problems, with clearly identifiable goals. However, several have addressed directly the issue of ill-structured problems, which appear similar to Rittel's ill-behaved or wicked problems.

The work of W. Reitman (68) characterized ill-structured problems as those in which at least some of the constraints are not specified

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(67) This description follows the summary presented by Allen Newell in "Artificial Intelligence and the Concept of Mind" in Roger Schank and Kenneth Colby, eds., Computer Models of Thought and Language (San Francisco, 1973) pp. 28-35.

(68) Allen Newell, "Artificial Intelligence and the Concept of Mind," in Computer Models of Thought and Language, eds. R. Schank and K. Colby (San Francisco, 1973) p. 56.

in the problem statement. It is incumbent upon the problem solver to "close" these "open" constraints by reference to his general knowledge.

While such a description does recognize the dependence of problem solution upon "background" information, Newell has criticized the concept of open constraints due to the fact that no substantial domain of such problems has yet been described (69).

Newell suggests another approach to ill-structuredness. He hypothesizes that a problem solver will call a problem ill-structured whenever he does not have a method capable of dealing with it (70). This conjecture arises from his presentation of general problem solving as the application in sequence of relatively "weak" methods. In this view, a problem may be ill-structured from one point of view, or for a particular problem solver, and not for another. There are no special features of such problems which make them necessarily ill-defined; with the development of more "weak" methods, a solution may be found.

Another approach to ill-structuredness has been developed within the architectural context. In a paper presented at the Design Methods Group conference of 1968, Charles Eastman reported the results of an application of the investigative techniques then being developed by

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(69) Allen Newell, "Artificial Intelligence and the Concept of Mind," in Computer Models of Thought and Language, eds. R. Schank and K. Colby (San Francisco, 1973) p. 57.

(70) ibid., p. 57.

Allen Newell (71). In Eastman's study, subjects were given a rather less well defined problem than those of cryptarithmetic:

> "The accompanying plan and photograph represent an existing bathroom plan for one model of a home sold by Pearson Developers in California. This model of house has not sold well. The sales personnel have heard prospective buyers remark on the poor design of the bath. Several comments are remembered: 'that sink wastes space'; 'I was hoping to find a more luxurious bath.' You are hired to remodel the existing baths and propose changes for all future ones (these should be the same).
>
> "The house is the cheapest model of a group of models selling between $23,000 and $35,000. It is two stories with a ranch style exterior. The bath is at the end of a hall serving two bedrooms and guests.
>
> "You are to come up with a total design concept. The developer is willing to spend more for the design--up to fifty dollars. For all other questions, Mr. Eastman will serve as client. He will answer other questions." (72)

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(71) Charles M. Eastman, "On the Analysis of Intuitive Design Processes," in Emerging Methods in Environmental Design and Planning, ed. G. T. Moore (Cambridge, 1970) pp. 21-37.

(72) ibid., p. 25.

Observations of subjects (architectural students) indicated that the problem solving methods employed by the designers were very similar to those evidenced during the cryptarithmetic experiments. Although the problem is much less well structured in its initial statement than the arithmetic puzzle, subjects continued to structure it throughout its solution. Problem solving and problem definition were seen to emerge together from the solvers' activities.

Proliferating Problems

The first category of distinguishing characteristics proposed by Rittel and Webber is concerned with the proliferating nature of design and planning problems. Wicked problems can not be definitely formulated, as can, for instance, mathematical problems. There can be many formulations of a wicked problem each dependent upon a particular point of view. Each formulation tends to be both a solution to the problem from the point of view from which it was formulated, and a problem from another point of view. Thus, a seemingly endless chain of problems is generated. Similarly, an attempt to formulate the problem may proliferate a chain of problems in search of an elusive "root" problem.

Evidently, at least some seemingly endless chains of problems have been brought to resolution. While the problem of landing men on the moon may seem, initially, to be a technological problem, and relatively "tame"; in its context, the American space program may be seen as a "solution" to the problem posed by cultural shock resulting from early Soviet success in space. The problem, which had broad political and cultural implications, exhibited many characteristics of "wickedness".

A growing body of work exists within the theory of algorithms which may be useful in the analysis of solution methods appropriate to problems which increase in scope when solution is attempted.

An algorithm may be defined as "an exact prescription, defining a computational process, leading from various initial data to the desired result" (73). Broadbent has suggested that such methods constitute the most rational end of a spectrum of design activities which ranges onward toward pure chance (74).

Problems which are solvable by algorithm are evidently not "wicked", since they must be well defined, and have recognizable goals. It is, therefore, reasonable to expect that a limit to wicked problem areas could be established by delimiting the class of problems capable of algorithmic solution.

A British mathematition, A. M. Turing, investigated the mathematical nature of algorithms in the 1930's (75). Turing imagined a simple but carefully conceived machine and studied the nature of the problems which his machine could solve (76). He was able to demonstate that the "Turing

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(73) A. A. Markov, quoted in Geoffrey Broadbent, <u>Design in Architecture</u> (New York, 1973) p. 326.

(74) Geoffrey Broadbent, <u>Design in Architecture</u> (New York, 1973) Ch. 16.

(75) Hao Wang, "Games, Logic and Computers," in <u>Computers and Computation</u> (San Francisco, 1971) p. 136.

(76) For a lucid description of a "Turing machine", see Joseph Weizembaum, <u>Computer Power and Human Reason</u> (San Francisco, 1976) pp. 51-63.

machine" could, given enough time and paper, solve any problem for which a solution algorithm could be written (77). This work has been of great interest to computer scientists, because it established that any problem which is capable of algorithmic solution may be solved by computer.

Of greater significance to the current study, Turing also established that there are problems which are not solvable by algorithm. Algorithmic insolubility is interpreted as meaning that it is logically impossible to determine whether or not a proposed solution is, in fact, an answer to a given problem. Turing was able to demonstrate that, even amongst problems which can be definitively formulated (definitely enough to justify the search for a solution algorithm) there exists a class for which no algorithm can be devised (78).

A class of wicked problems is therefore guaranteed, in that there do exist problems for which no scientific or mathematical solution methodology exists. This particular distinction can not, however, justify a separation of design and planning problems from the scientific or mathematical, since the problems investigated by Turing were within these fields. Although it seems contradictory, some of the problems of science and mathematics are apparently wicked (79).

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(77) Hao Wang, "Games, Logic and Computers," in Computers and Computation (San Francisco, 1971) p. 142.

(78) This contention was also established in another context by Alonzo Church. See Howard DeLong, "Unsolved Problems in Arithmetic," Scientific American, Vol. 224, No. 3 (March, 1971) pp. 50-60.

(79) Similar issues of apparently contradictory statements in the foundations of science are discussed in Wesley C. Salmon, "Confirmation," Scientific American, Vol. 228, No. 5 (May, 1973) pp. 75-83.

More recent work in the theory of algorithms may be of relevance to the issue of proliferating problems. If it can be demonstrated that a problem does not belong to the class of those which are algorithmically unsolvable, then it follows that there exists an algorithm for its solution. However, the theory does not guarantee that such an algorithm, once found, can be practically executed.

Practical executability is a function of the time which is required to carry through the steps of the algorithm to solution. This is an issue of concern within computer science, where advances in technology have altered the speed of execution, and thus the limits of practicality.

If it is possible to prepare a list of all possible solutions to a problem, then it may also be possible to choose the correct answer from the list by examining each candidate in turn. This is the method of "exhaustive search", and is the only method guaranteed to exist for a problem which does not lie within the class of those which are algorithmically unsolvable (80).

A difficulty is often encountered in the application of exhaustive search techniques. When dealing with problems whose variables range over relatively few possibilities, the number of possible solutions to be examined may be manageable. However, when the range or number of these variables grows, the number of solution candidates may quickly become too large for examination in any reasonable length of time.

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(80) Harry R. Lewis and Christos H. Papadimitriou, "The Efficiency of Algorithms," Scientific American, Vol. 238, No. 1 (January, 1978) p. 102.

The practical executability of an algorithm, and, therefore, its effective solvability, depends upon the rate at which the number of possible solutions grows when the number or range of the problem's variables increase (81).

It has been demonstrated that there are problems for which, while algorithms for their solutions must exist, these are necessarily not practically executable (82). Members of this class may also be described as wicked problems, in the sense that they are not solvable by the methods of science or mathematics without an outrageous and exhorbitant expenditure of time and effort.

Again, hwoever, the lack of such solution methods cannot be meaningfully claimed as a distinction of design problems.

Perhaps the most interesting class of problems currently under investigation within the theory of algorithms is that which includes problems for which there is neither a known practically executable algorithm, nor a proof that none can exist. It has been shown that a requisite for membership in this class is that, when a solution is known,

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(81) More specifically a problem is said to be effectively solvable if an algorithm exists for its solution having an execution time which is a polynomial function of the complexity of its variables. If the execution time is an exponential function of the input complexity, then the problem is effectively unsolvable. See Harry R. Lewis and Christos H. Papadimitriou, "The Efficiency of Algorithms," Scientific American, Vol. 238, No. 1 (January, 1978) p. 99.

(82) Harry R. Lewis and Christos H. Papadimitriou, "The Efficiency of Algorithms," Scientific American, Vol. 238, No. 1 (January, 1978) p. 102.

there will be a short and convincing argument of proof (83). Many problems which have been of interest to design theoreticians, have been shown to be in this class. These include long standing problems in graph theory, which Maldonado and Bonsiepe argued was of " . . . considerable instrumental value in the design of buildings . . . " (84).

Lewis and Papadimitriou also described a further subclass of this last group. Apparently, there exists a group of problems for which no known practically executable algorithm exists, but if a practical algorithm does exist for any one problem in this class, then a practical algorithm necessarily exists for all such problems (85). That this group of problems may be of interest to designers and planners is suggested by the fact that it includes both packing and scheduling problems (86).

This investigation into algorithmic theory has shown that effective solvability is evidently dependent on the rate with which a set of solution prospects grows, rather than on the rate at which the number of problems increases. For the planner or designer, this could mean that, in a problem situation in which the issues to be addressed proliferate

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(83) Harry R. Lewis and Christos H. Papadimitriou, "The Efficiency of Algorithms," <u>Scientific American</u>, Vol. 238, No. 1 (January, 1978) p. 102.

(84) Tomas Maldonado and Gui Bonsiepe, "Science and Design," <u>Ulm</u>, No. 10/11 (May, 1964) p. 14.

(85) Lewis and Papadimitriou, p. 103.

(86) Ronald L. Graham, "The Combinatorial Mathematics of Scheduling," <u>Scientific American</u>, Vol. 238, No. 3 (March, 1978) pp. 124-132.

upon examination, his concern might lie more appropriately with what options are available to him to pursue. In a given situation does the proliferation of problems imply a proliferation of choice of action? Evidently, the term "wicked problem" need necessarily apply only to issues for which the answer to this question is in the affirmative.

In their attempt to deal with tasks facing human problem solvers, computer scientists have explored another area of technique which seems relevant to the problem of dealing with rapidly increasing choice in problem chains. These explorations have lead to the development of heuristic techniques.

"Heuristic", in this context has the meaning of "aiding in discovery", and is derived from the Greek "eureka", or "I have found it". Heuristic problem solving was explored by George Polya in his influential book How to Solve It (87). Polya was concerned with heuristics as "rules of thumb" which might lead to the solution of a problem but do not guarantee such a solution. He argued that heuristic problem solving methods must be based on experience in solving problems, and on observation of others solving problems.

The heuristic method is based on a search procedure which orders elements within a problem according to their likelihood of resulting in a satisfactory solution. The required order is achieved by applying a reasonable preevaluative tool (the heuristic) to the problem elements.

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(87) George Polya, How to Solve It (New York, 1957).

The order achieved may tend to minimize the length of search by eliminating many of the unsatisfactory options which would otherwise impede the discovery of a satisfactory solution (88).

The pre-evaluative tool, or heuristic, may be a rule of thumb, as Polya's "let the end suggest the means", or a complex procedure such as that used by Hart, Nilsson, and Duda involving exact time-dependent specification of known quantities and rigorously defined estimates of unknowns (89). In any case, the effect is to exclude from the search whole areas which might otherwise be considered.

Because of the power of heuristic methods to deal with proliferating problem areas, they may be of interest to designers and planners faced with problems characterized by the first of Rittel's distinctions. Indeed, heuristic methods have been successfully applied to space planning problems (90)(91).

Certain heuristic devices can be shown to be "perfect" to the extent that searches which they guide will always result in correct solutions. However, this approach may not be the most useful for application to design and planning problems, since, in the plausable case in which the

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(88) Michael Arbib, The Metaphorical Brain (New York, 1972) pp. 94-107.

(89) ibid., p. 99.

(90) Charles M. Eastman, Spatial Synthesis in Computer Aided Building Design (New York, 1975).

(91) William J. Mitchell, Computer Aided Architectural Design (New York, 1977) pp. 453-468.

heuristic device provides no help in ordering the search, it may reduce (or extend) to the method of exhaustive search (92). As the investigation of the theory of algorithms has shown, this situation may preclude practical execution.

These investigations suggest that the designer or planner, when faced with proliferating problem areas, could ask if there exists an effective heuristic which he can use to reduce the area of inquiry to that which he can manage. Such heuristics have been suggested as constituents of second generation design methods. J. P. Protzen has presented certain value based precepts which guide the actions of designers. These include:

> Bentham's principle: greatest good for the greatest number.
>
> Bentham's principle modified: minimize misery.
>
> Pareto's principle: only choose plans in which no one is worse off.
>
> Pareto's principle modified: bring up the worse off first without taking away from the better off.
>
> "Robinhood": take from the rich to give to the poor.
>
> General Motors principle: what's good for me is good for everybody.

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(92) Michael Arbib, <u>The Metaphorical Brain</u> (New York, 1972) p. 99.

> Kantian imperative: act as if the principal upon which the action is based were to apply to everyone's action (93).

From the foregoing, it is evident that at least some of the characteristics of design and planning problems are shared by those of science and mathematics. Further, it appears that there exist, within these fields, areas of inquiry which may yet prove fruitful sources of knowledge for investigators in design methods.

Identification and Testing of Proposed Solutions

The second group of distinguishing characteristics which Rittel elaborated arise from the difficulty of determining when a design or planning problem is "solved".

The difficulty arises from two sources. The first follows from the previously discussed group of distinguishing characteristics; since the problem cannot be clearly formulated, its solution may not be clearly recognizable. The second source lies in the indeterminate nature of adjudicated assessments (94).

The search for solutions to wicked problems, then, is likely to end because of a lack of time or resource, and with a judgement of "good enough", or "as much as we can do".

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(93) Unpublished lecture notes prepared by Prof. B. Dexter, following the visit to the University of Manitoba of J. P. Protzen, March 22-25, 1977. pp. 3-4.

(94) Horst Rittel and Melvin Webber, "Dilemmas In a General Theory of Planning," in <u>DMG-DRS Journal</u>, Vol. 8, No. 1 (1974) p. 35.

Do these characteristics distinguish wicked problems from those of science and engineering? Certainly, in many problems of the second type, solution criteria are logical consequences of the problem statement. Such is the case in solving an equation or dealing with a chess problem.

The view of science which emerges from the work of Karl Popper, however, is not one in which a scientific solution need be seen as necessarily definitive. Popper has suggested that the method of establishing fact in science is a continual debate in which conjectures are put forward which stand only until a refutation can be found (95). Thus, a widely accepted scientific truth assumes much of the character of "the best we can do".

The indeterminate nature of proposed solutions is encountered directly in certain methods which attempt to find the optimal solution to a problem. These methods are applicable when it is possible to judge an improvement (or the opposite) in a proposed solution when some controllable element of the solution is altered. The strategy of the method is to continually alter the element as long as the solution continues to improve. When no further improvement is noted, the current state of the solution is said to be optimum.

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(95) Karl R. Popper, Conjectures and Refutations: The Growth of Scientific Knowledge (New York, 1968)

This particular optimization method is known as "hill climbing" (96), since its application to an imaginary machine able to survey only the ground immediately about it, and to relocate itself to the highest location surveyed, would eventually bring the machine to the top of a hill upon which it was situated.

The hill climbing method may be described as an heuristic procedure. It is discussed separately in order to exemplify the problem of determining an optimum with some scientific and mathematical techniques.

A difficulty of the hill climbing method bears some relation to the characteristics of design and planning problems which Rittel has noted. Without additional information acquired outside of the scope of the method itself, it is not possible to guarantee that the "optimum" found is the optimum over all possible solutions. Since the method relies on limited information concerning alternative solutions differing only slightly from each other, it may not uncover a potentially superior solution which differs widely from those under consideration. In the metaphor adopted, the imaginary machine will climb the hill, but may remain totally oblivious to the mountain beyond.

The method may be modified by requiring that other solution areas by located and "climbed". There is, however, no guarantee (short of exhaustive search) that any solution better than the original will be found, or that an extension of the search will not yield a better solution. There is no stopping rule.

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(96) Wayne A. Wickelgren, <u>How to Solve Problems</u> (San Francisco, 1974) pp. 67-90.

Only with information concerning the structure of the solution candidates within the total area of investigation can the problem solver in science or design be entirely confident that a better solution will not result from further research.

From this discussion, it is evident that the lack of a stopping rule, and therefore the need to terminate a problem solving effort on the basis of external criteria, is a consequence of a lack of perfect information concerning the solution options available.

Such total information may be more than the problem solver wishes to deal with, however. In many cases, criteria may be used to establish the characteristics of an adequate solution. A moderate search may then yield an appropriate solution. Methods such as this have been termed "satisficing" by Herbert Simon, after their characteristics of being both satisfactory and sufficient (97).

Simon indicated that the difficulty encountered in finding a "satisficing" solution to a problem is much less dependent upon the organization of solution candidates than is the case with optimization methods. Satisficing methods depend only upon the density of satisfactory solutions, and are consequently more dependent upon the specified standard of acceptability than upon the number of candidates (98).

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(97) Herbert A. Simon, The Sciences of the Artificial (Cambridge, 1969) pp. 64-65.

(98) *ibid*., pp. 64-65.

In his study of designers in action cited earlier, Charles Eastman observed that satisficing tests were frequently applied in problem solving (99).

The heuristic techniques investigated earlier may also be usefully applied to problems characterized by the second group of distinguishing characteristics. This will be particularly so when there is reason to believe that the search for solution will be terminated when a resource, such as time, is exhausted. Since the principle of the heuristic method is to explore first possible solutions most likely to be successful, there is justification for use of the "best solution to date" at the time of an arbitrary termination of the problem solving effort.

From this investigation, it appears that the lack of logical termination criteria is not unique to design and planning situations, and that there do exist methods which may be of assistance to designers and planners encountering such issues.

The Nonrepeatability of Design and Planning Situations

Rittel and Webber have argued that design and planning problems ought not to be dealt with in the same manner as scientific problems because the risks in design situations are too great to permit experimentation. Further, they reason that instances of design problems differ more substantially one from another than do those of science and

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(99) Charles M. Eastman, "On the Analysis of Intuitive Design Processes," in Emerging Methods in Environmental Design and Planning, ed. G. T. Moore (Cambridge, 1970) pp. 30.

engineering and that, consequently, inferences cannot often be made between problem situations.

It is difficult to accept arguments concerning the lack of risk in engineering design, as the authors have. In fact, the dependence of engineering design technique upon basic science and experiment can be seen as a consequence of the risk involved in being wrong. It is true, however, that there is little risk involved in proposing a solution to such problems, only in the implementation of a potentially faulty solution. Cannot a similar argument be made for design and planning problems?

In his exposition of a systems philosophy, Ervin Laszlo has indicated that contemporary science differs from classical science and natural philosophy in its assumptions concerning invariance amongst instances of the events under study. The objects of study under the classical paradigm were abstracted substances and causal interactions between abstracted substances. "New" science is oriented towards the study of organizations and the structure of sets of events in relation to their environment (100).

Because of their orientation towards organization and structure, system techniques have the potential to deal with situations which seem widely at variance.

This potential has been seen, in other contexts, as a valuable tool for planning, since it seeks an underlying stability within a dymanic

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(100) Ervin Laszlo, <u>The Systems View of the World</u> (New York, 1972) p. 20.

area exhibiting change and uncertainty. Thus, Erich Jantsch has proposed that long range planning be " . . . geared to increase uncertainty (by bringing as many options as possible into play) as well as complexity (by attempting to grasp the systemic context of a particular plan)." (101)

The British cybernetician, Sir Stafford Beer, has also presented an argument in support of the use of such techniques in planning situations. Beer's argument, paradoxically, is in partial accord with that of Rittel. Beer agrees that certain problems lie beyond the power of traditional scientific techniques to resolve; deriving this conclusion along the lines presented earlier regarding practical algorithmic solvability. He suggests, however, that such situations are very much like those studied by system science and cybernetics.

Beer also is in substantial accord with Rittel and other second generation methodologists in declaring the necessary role of widespread public participation in planning processes. In Beer's view, participation is evoked, not because a scientific technique for otherwise deciding upon a plan cannot exist, but because the technique which he believes does exist requires such participation as the only source of decision with the requisite power (102).

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(101) Erich Jantsch, Technological Planning ans Social Futures (New York, 1972) p. 2.

(102) Stafford Beer, Designing Freedom (Toronto, 1974) pp. 53-70.

Conclusions

It is the primary conclusion of this thesis that the set of characteristics posited by Horst Rittel and Melvin Webber may not definitively distinguish design and planning problems from those of science, mathematics, and engineering.

Secondarily, it appears evident that ongoing studies within these disciplines may be of continuing interest to the investigations of design methodologists.

It has not been the intention of this work to claim that all design and planning problems are solvable by the methods of science, mathematics, or engineering, nor to claim that wicked problems in the sense of Rittel and Webber do not exist. It is, however, evident that the distinction of wicked problems has not restricted problem solving investigations within other fields to any particular subset.

Although an examination of work within the "second generation" of methods lies beyond the scope of this thesis, the value of such work is not here contested.

It is proposed that design and planning problems are probably of many types, and amenable to methods derived from various sources. With regard to the present discussion regarding the methods of science, mathematics, and engineering, the following classification of problems is suggested:

1. The class of problems strictly not solvable by the methods of science, engineering and mathematics (including provably algorithmically

unsolvable problems).

2. The class of problems effectively not solvable by such methods (including problems for which methods exist, but for which satisfactory solutions cannot be generated within the limitations of resources available to the problem solver).
3. The class of problems chosen not to be solved by such methods, where they are available (including problems known to have more suitable methods).
4. The class of problems for whose solution scientific, mathematical or engineering methods are used.

It would be, then, the view of this work both that designers and planners ought to have at their disposal methods which may be developed in addition to those which Rittel and Webber's work would allow, and that designers and planners ought to be aware that new methods may emerge from ongoing investigations in the scientific disciplines.

Criticisms and Suggestions for Future Research

Criticism of this work can be directed at its inability to define precisely a role for the methods of science in design. It was argued that a justification for an interest in scientific method by designers was founded in the belief that objectivity could be socially therapeutic.

It is not denied, however, that the use of such methods provides a potential for oppression.

In commenting upon a suggestion by William Whyte that planners could eliminate the loneliness of modern life by incorporating into new housing factors which create cohesiveness, the psychologist Clark Moustakas has said:

> "Efforts of this kind result in a sick loneliness, the loneliness of fakery and pretense, the loneliness of the calculated and contrived, the loneliness of a ready-made solution replacing the satisfaction of creating with one's own talents, capacities and skills." (103)

By its assumption of a "symmetry of ignorance", the second generation of methods may evidence an ability to mediate between the instrumental knowledge of designers and the experiential knowledge of those for whom the design or plan is intended. Investigations in this direction may be expected to clarify the role of instrumental knowledge in this process, and consequently the role of methods derived from scientific problem solving approaches.

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(103) Clark E. Moustakas, Loneliness (Englewood Cliffs, 1961) p. 32.

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