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ABSTRACT

Academic management theory has a serious utilization problem. This article argues that it stands a better chance of being adopted for instrumental use if the theory is based on the paradigm of the "design sciences", like medicine or engineering. Most academic management research is based on the paradigm of the "explanatory sciences", like physics. The mission of these sciences is to describe, explain and predict, while the core mission of the design sciences is to develop "tested and grounded technological rules". The paradigm of the design sciences is applied to management research and I discuss the potential of solving its utility problem by combining both types of research.

INTRODUCTION

In virtually all academic disciplines research is undertaken to create valid and reliable knowledge to pass on to students and to share with other interested parties. This also applies to research done in Business Schools. As most students of Business Schools aspire to careers outside academia, the use of research results for the practice of management should be a major issue.

Yet there are serious doubts about the actual relevance of present-day management theory as developed by the academic community. As far back as 1982, Beyer and Trice remarked, "Recently (....) scholars have expressed concern about why organisational research is not more widely used" (Beyer and Trice, 1982, p. 591). More recently, in his Presidential Address to the American Academy of Management, Hambrick (1994) sketched a dismal picture of the Academy's impact and concluded that it might have mattered to the world of organisations and business, but that it did not.

Essentially, the solution Hambrick proposes is to improve the presentation of academic management research results to the outside world, in order to "open up the incestuous, closed loop of the Academy's conferences" (Hambrick, 1994, p. 13). This may help. My thesis, however, is that the relevance problem of academic management theory is not caused primarily by poor presentation but by its very *nature*. Compare Kurt Lewin's well-known adage, "nothing is quite so practical as a good theory" (Lewin, 1945, p.129). Assuming that "good" means something like "scientifically valid and reliable" rather than "practical," this article intends to qualify the adage: all good theories are practical, but some are more practical than others.

The nature of the products of a given research programme (in Lakatos' sense, 1991) or "school of thought" (McKinley, Mone and Moon, 1999) is largely determined by its research paradigm. By "research paradigm" I mean the combination of research questions asked, the research methodologies allowed to answer them and the nature of the intended research products. Most academic research in management is based on the notion that the mission of all science[1] is to understand, i.e. to describe, explain and possibly predict (see e.g. Nagel, 1979; Emory, 1985). Some even state that "the essence of science is explanation by law" (Seth and Zinkhan, 1991, p35). But, also many non-positivists hold that the mission of all science is to create shared understanding, i.e. understanding of a certain phenomenon shared between the researcher and an informed audience, his scientific community (Peirce, 1960).

However, understanding a problem is only halfway to solving it. The second step is to develop (alternative) solutions. Understanding the sources of resistance to certain organisational changes, still leaves undone the task of developing sound change programmes. Understanding the reasons for delays in New Product Development still leaves undone the task of developing effective product development systems. Understanding the changes on certain markets still leaves undone the task of developing successful strategies. Thus, besides description-driven research programmes in management one also needs prescription-driven research programmes in order to develop research products which can be used in designing solutions for management problems. By this I do *not* mean the actual application of scientific knowledge to solve a specific managerial problem - this is the domain of practitioners - but the development of scientific knowledge to solve a class of managerial problems, in other words, the development of abstract knowledge. Nor is it a plea to develop recipes, but rather a plea for the development of *tested and grounded technological rules to be used as design exemplars* of managerial problem solving.

The classics in our field like Taylor, Fayol and Barnard, did not shrink from prescription, but the subsequent scientisation of our field has greatly diminished the academic respectability of prescriptions. In this article I use analogies with various other disciplines, like medicine and engineering (which I call "design sciences"), to analyse the nature of the academic research products used in problem solving and the nature of academic research producing these products. Furthermore, I use these analogies to show that prescription-driven academic research can indeed claim academic respectability. Subsequently, I discuss the nature of research in management if based on the paradigm of the design sciences and how this may help to solve the utilisation problem of academic management theory.

THE UTILISATION PROBLEM OF ACADEMIC MANAGEMENT THEORY

In the social sciences the utilisation problem is a well-known one (see e.g. the 1982 and 1983 Special Issues of Administrative Science Quarterly on the utilisation of social science). In management theory it is sometimes seen as a dilemma: the rigour-relevance dilemma (see e.g. Schön, 1983). Management theory is either scientifically proven, but then too reductionistic and hence too broad or too trivial to be of much practical relevance, or relevant to practice but then lacking sufficient rigorous justification. March and Sutton (1997) remark that in other disciplines this dilemma is sometimes solved by separating the two contexts. However, in and around business schools “the soldiers of organisational performance and the priests of research purity often occupy not only the same halls but also the same bodies” (March and Sutton, 1997, p. 703).

In the natural sciences the utilisation problem is of quite a different order. Some tension may exist between basic and applied research including a possible difference in social status and competition for research resources. In general, however, two very effective partnerships are in place. There is the one between the natural sciences and applied fields like medicine and engineering and the other between researchers in any given field and the professionals of that field (often occupying the same bodies).

In the field of management the utilisation problem is both a well-discussed and thorny issue (Miner, 1984; Whitley, 1988). Researchers in this field operate within two reputation systems (Whitley, 1988; March and Sutton, 1997): the academic reputation system, which rewards rigorous research and the professional reputation system, which rewards relevant research outcomes and the professional training of prospective managers.

The priorities given to each system vary over time and sometimes resemble a pendulum. Prior to the Ford and Carnegie Foundation reports on American Business Schools (Gordon and Howell, 1959; Pierson and Others, 1959), priority was given to professional training, to the professional reputation system. At the time, the academic community regarded the field more or less as a practice-based craft. This was largely caused by the scant attention given to descriptive research and to the justification of the prescriptions given. Examples are the prescriptions on rational decision-making in organisations and the concept of top managers as rational, long-range planners.

The above-mentioned reports started a process of “scientisation”, resulting in a “New Look” for the American Business Schools (Schlossman, Sedlak and Kechsler, 1997; see also Whitley, 1988), which also had a strong impact elsewhere. This process of scientisation could have followed the example of the breakthrough of the engineering sciences in the nineteenth century: their assimilation of the laws and especially of the methods of the natural sciences to test solutions, transformed them from practice-based crafts to solid sciences. However, the Business Schools followed this example only halfway through. The insights and methods of the natural sciences and especially those of the social sciences were used to develop description-driven research programmes, while the interest in prescription atrophied. Gaining recognition in the academic reputation system became the main emphasis. In time, this led to reactions like the Harvard Business Review papers ‘The myth of the well-educated manager’ (Sterling Livingstone, 1971) or ‘Managing our way to economic decline’ (Hayes and Abernathy, 1988).

Tensions between the two reputation systems are not typically American. In the Netherlands, for instance, the field of business economics has known fierce debates between the Amsterdam School, primarily interested in the academic reputation system and the Rotterdam School, more interested in the professional reputation system (Van Baalen, 1995)[2]. In France one finds a somewhat similar competition between the more professional Grandes Ecoles and the more academic Universities. Recently in Britain Tranfield and Starkey (1998) voiced concerns with respect to the relevance and application of management research results, advocating more emphasis on mode 2 knowledge production (using the distinction Gibbons et al. (1994) make between mode 1 knowledge production, predominantly driven by academic concerns, and mode 2 knowledge production, trans-disciplinary with intensive interaction between knowledge production and knowledge dissemination and application). Such tensions between academia and professional application may have stimulated the idea of the rigour-relevance dilemma. However, this article is not based on the idea that there is a dilemma (in which case no satisfactory solution exists), but rather on the idea of Pettigrew's double hurdle: management theory should meet criteria of scholarly quality *and* managerial relevance (Pettigrew, 1996). Understandably, academics tend to worry more about the scholarly hurdle than about the relevance hurdle[3].

The utilisation problem discussed here concerns management theory as developed by the academic community. There is an abundance of management literature, which is widely read by managers but which does not meet scientific standards. This type of literature is dubbed “Heathrow-literature” by Burrell (1989) or, more kindly, Literature on Principles (of management) by Whitley (1988). There are *craftsman-like* publications, based predominantly on first-hand experience (or on the experience of people one knows), that have a generalisation problem: what can be learnt from this experience for other contexts? Then there are *metaphysical* publications by management gurus (nomen est omen), that have a justification problem: on which observations and which logical reasoning are the recommendations based? These publications may perhaps succeed in taking Pettigrew's second hurdle, but fail at his first one. Improving the utility of academic management theory should make it a powerful competitor for these two types of management literature.

Beyer and Trice (1982) give an in-depth analysis of the process of utilising management research results. Among others, they distinguish between adoption, i.e. the decision by decision-makers within the user system to use certain research results, and implementation, i.e. the actual use of the research results by members of the user system. Another distinction is between instrumental and conceptual use of scientific knowledge (Pelz, 1978, cited in Beyer and Trice, 1982)[4]. Instrumental use involves acting on research results in specific and direct ways, while in case of conceptual use the results are used for general enlightenment on the subject in question.

The primary interest of this article is the *adoption* of management research results and management theory for *instrumental use.* The problems of subsequent implementation are not very different from other problems of organisational change and implementation and are well-researched. I agree with Beyer and Trice’s statement, “The predominant use of organisational research probably occurs through graduate seepage's into organisations of new ideas, metaphors, and rationales for explaining human behaviour” (Beyer and Trice, 1982, p. 615). The conceptual use of management research results is indeed an important outcome. However, I fear that academic management research will retain its utilisation problem if this remains its only ambition. If the field takes its mission seriously, it should also aim for the more ambitious objective of adoption for instrumental use in order to produce theory relevant for management students and other interested parties.

THE PARADIGM OF THE DESIGN SCIENCES

My thesis is that a major inhibition for adopting academic management theory for instrumental use lies in the very nature of this theory, which is strongly influenced by the paradigm used for developing it. Kuhn's (1962) term "paradigm" as used by him has many different meanings. Here it is used in its sociological sense (Masterman, 1970): a system of "scientific habits" used by a group of scientists for the solution of scientific problems. More specifically, as stated in the introduction, by research paradigm I mean the combination of research questions asked, the research methodologies allowed to answer these questions and the nature of the intended research products.

Formal, Explanatory and Design Sciences

On the basis of the paradigms used, I distinguish three categories of scientific disciplines:

1. the *formal* sciences, such as philosophy and mathematics
2. the *explanatory* sciences, such as the natural sciences and major sections of the social sciences
3. the *design* sciences, such as the engineering sciences, medical science and modern psychotherapy.

The formal sciences are "empirically void". Their mission is to build systems of propositions whose main test is their internal logical consistency.

The mission of an explanatory science is to describe, explain and possibly predict observable phenomena within its field. Research should lead to "true" propositions, i.e. propositions which are accepted by the scientific forum as true on the basis of the proof provided. The typical research product of an explanatory science is the causal model, preferably expressed in quantitative terms.

The mission of a design science is to develop knowledge for the design and realisation of artefacts, i.e. to solve *construction problems*, or to be used in the improvement of the performance of existing entities, i.e. to solve *improvement problems***.** Architects and civil engineers deal predominantly with construction problems while medical doctors and psychotherapists deal mainly with improvement problems. Research aims at developing knowledge and its application should lead to the intended results. I use the term "design sciences" because the ultimate objective of research in these sciences is to develop valid and reliable knowledge to be used in designing solutions to problems. I prefer to avoid the term "applied sciences", as this term suggests that the mission of these sciences is merely to apply the basic laws of the explanatory sciences, thus disregarding the impressive body of knowledge developed by the design sciences themselves.

The idea to distinguish between explanatory and design sciences is strongly inspired by Simon's *The Sciences of the Artificial* (Simon, 1969)[5]. Much research within the design sciences is based on the explanatory paradigm, i.e. research aimed at describing, explaining and predicting in order to understand the setting of construction or improvement problems and to know the properties of the "materials" to be used. However, understanding alone is not enough. The ultimate mission is to develop design knowledge, i.e. *knowledge that can be used in designing solutions to problems* in the field in question. It is important to teach a civil engineer subjects like physics and mechanics, but in designing a bridge he or she needs the design knowledge developed by his or her discipline, like for instance the properties of different types of bridges. In the same way a medical doctor should have a working knowledge of physics and biology, but for medical problem solving he or she predominantly uses the results of clinical research.

In English the term "science" is often equated with "natural science", which leads to the idea that the mission of *all* sciences is to merely describe, explain and predict and that such descriptive knowledge is sufficient for practitioners to solve their problems. Science, then, occupies Schön's (1983) "high ground of theory," while practitioners operate "in the swamp of practice". In the present article the focus is on the development of design knowledge, which occupies the middle ground between descriptive theory and actual application. In design sciences like engineering and medicine a significant part of this knowledge is produced by academic research, which scores high in both the academic and in the professional reputation system.

Design Knowledge and its Instrumental Use

A design science does not develop knowledge for the layman, but rather for the professionals in its field. This means that design knowledge is to be applied by individuals who have received formal education in that field.

A professional, such as a medical doctor, architect, psychotherapist, mechanical engineer, lawyer or accountant, can be defined as a member of a well-defined group who solves real-world problems with the help of skills, creativity and scientific design knowledge (Freidson, 1973; Klegon, 1978, Schön, 1983, Abbott, 1996, Becher, 1999).

Each time a professional sets out to solve a unique and specific problem for a client, or in conjunction with a client, he or she does so by using the *problem solving cycle*, also called the regulative cycle (Van Strien, 1997). This cycle consists roughly of: defining the problem out of its "messy" context (Schön's, 1983, "naming and framing"), planning the intervention (diagnosis, design of alternative solutions, selection), applying the intervention and evaluating.

The essence of professional work is designing, planning an action in advance or during the action ("reflection-in-action", Schön, 1983). The outcome of this process is a design, which can be defined as a representation of a system or process to be realised. In general, a professional will make three designs (Van Aken, 1994): an *object-design*, the design of the intervention or of the artefact, a *realisation-design*, i.e. the plan for the implementation of the intervention or for the actual building of the artefact, and a *process-design*, i.e. the professional's own plan for the problem solving cycle; or, put differently, the method to be used to design the solution to the problem.

The term "design science" is used here to indicate that the mission of the academics involved is to develop scientific knowledge to support the design of interventions or artefacts by professionals and to emphasise its knowledge-orientation: a design-science is not concerned with action itself, but with *knowledge to be used in designing solutions, followed by design-based action.*

The Repertoire of Design Knowledge

In order to be able to make these designs, professionals have a repertoire of design knowledge at their disposal (Schön, 1983). This includes their own experience and that of their teachers, and the body of scientific design knowledge of their design science acquired during their training and continuing education. This design knowledge is general, i.e. valid for *classes* of cases. The problem of the professional, however, is always unique and specific. Therefore, general knowledge must be translated to the unique and specific case at hand. In this way, lawyers use jurisprudence from similar cases when dealing with their specific case and doctors use general descriptions of symptoms, diseases and therapies applied previously, when designing a therapy for a specific patient.

Design-repertoires contain three types of design knowledge, according to the three types of designs discussed above. The repertoire of a professional typically contains predominantly object knowledge, i.e. knowledge on the settings and properties of the artefacts or interventions to be designed. For a mechanical engineer this may be the properties of different types of bearings and for a medical doctor the effects of alternative therapies for a given disease. It may also contain realisation knowledge, e.g. knowledge on manufacturing technologies for a mechanical engineer and knowledge on various types of surgery for a surgeon. Finally, a design repertoire typically contains only a fairly limited amount of explicit process knowledge, i.e. knowledge on how to tackle the actual design process itself. Most professionals obtain their process knowledge in a craftsman-like manner, i.e. by their own experience and by imitating their teachers and peers. Process-knowledge tends to remain largely tacit; professionals often find it difficult to express their approach to design problems[6].

The design repertoires of well-educated and experienced professionals contain a large variety of knowledge. Within each of the three types of design knowledge discussed above, prescriptions are an important category. The logic of a prescription is "if you want to achieve Y in situation Z, then perform action X." There are algorithmic prescriptions which operate like a recipe and which typically have a quantitative format and whose effects can be proven conclusively on the basis of observations through deterministic or statistical generalisation. However, many prescriptions in a design science are of a heuristic nature. They can rather be described as "if you want to achieve Y in situation Z, then something like action X could help". "Something like action X", means that the prescription is to be used as a *design exemplar*. It is a general prescription which has to be translated to the specific problem at hand; in solving that problem, one has to design a specific variant of that design exemplar. Such a prescription typically has a qualitative format. The underlying logic is as stated above, but the actual formulation can use various formats. An example of an algorithmic technological rule is: in order to cure disorder Y, you follow a course of treatment consisting of taking 0.3 milligrams of medicine X during 14 days. An example of a heuristic technological rule is: in order to cure disorder Y, you follow a course of treatment consisting of rest, exercising and a fat-free diet. The indeterminate nature of a design exemplar makes it impossible to prove its effects conclusively, but it can be tested in context, which in turn can lead to sufficient supporting evidence.

Tested and Grounded Technological Rules

In the explanatory sciences, the research object is an "*explanandum*" (Van Strien, 1997) and the typical research product is the causal model: one or more dependent variables are explained in terms of one or more independent variables. Knowledge about the values of these variables can be used to predict the behaviour of the dependent variables.

In the design sciences the research object is a "*mutandum*" (Van Strien, 1997); these sciences are not too much interested in what *is*, but more in what *can be*. The typical research product is the prescription discussed above, or in terms of Bunge's (1967) philosophy of technology, the *technological rule*. A technological rule is "an instruction to perform a finite number of acts in a given order and with a given aim" (Bunge, 1967, p. 132).

Mankind has a long tradition of developing technological rules. Primitive societies not only developed technological rules to manufacture artefacts, but also to make rain, to pacify the gods, to increase fertility, to avoid natural disasters, and so on. So both the know-how of making a bow and arrow and the rain dance are examples of ancient (heuristic) technological rules. A major breakthrough occurred with the systematic testing of technological rules. A tested technological rule is one whose effectiveness has been systematically tested within the context of its intended use. The system of interest is treated as a black box, but under certain conditions specific interventions give the desired results (deterministically or stochastically). Traditional Chinese medicine is an example of a system of very powerful, tested technological rules.

The real breakthrough came when tested technological rules could be grounded on scientific knowledge (Bunge, 1967), including law-like relationships from the natural sciences. For instance, one can design an aeroplane wing on the basis of tested, technological (black box) rules, but such wings can be designed much more efficiently on the basis of tested *and* grounded technological rules, grounded on the laws and insights of aerodynamics and mechanics. The stunning progress of the design sciences since the first Industrial Revolution is based on the effective partnership between the explanatory natural sciences and the design sciences, which leads to systems of tested and grounded technological rules. Whereas the typical research product of the explanatory sciences is the causal model, the typical research product of the modern design sciences is the tested and grounded technological rule.

Clinical Research and the Reflective Cycle

If the tested and grounded technological rule is the typical research product of a design science, the typical research strategy is clinical research, i.e. research on the performance of interventions or artefacts, executed within their context.

The causal model of the explanatory sciences is developed, typically, within a closed system (like a laboratory) in order to exclude (or control) the influences on the dependent variables from other sources than the independent variables of interest. A causal model may be partial, explaining only certain elements or aspects of the phenomenon of interest.

The technological rule, on the other hand, is typically studied within its intended context in order to be as sure as possible of its effectiveness, also under the influence of less well-known factors. Grounding a technological rule on explanatory laws does not necessarily mean that every aspect of it (and of its relations with the context) is understood. Typically, several aspects keep their “black box” character and testing within the context is still very necessary to account for its effectiveness[7].

The typical research design to study and test technological rules is the multiple case: a series of problems of the same class is solved, each by applying the problem solving cycle. Design knowledge is built up through the reflective cycle (Van Aken, 1994): choosing a case, planning and implementing interventions (on the basis of the problem solving cycle), reflecting on the results and developing design knowledge to be tested and refined in subsequent cases.

In developing and testing a technological rule through the multiple case and in analysing its effectiveness through the cross-case analysis during the reflective cycle, one can gain insight in the indications and contra-indications for the application of that rule and hence also in its application-domain. A technological rule is typically not totally general, but applicable to a certain application-domain, a class of problems.

By borrowing concepts from software development (see e.g. Dolan and Matthews, 1993) one can say that research on technological rules typically goes through a stage of *α-testing*, i.e. testing and further development by the originator of the rule, to be followed by a stage of *β-testing*, i.e. the testing of the rule by third parties.

TECHNOLOGICAL RULES IN THE FIELD OF MANAGEMENT

Academic research in design sciences combines description-driven and prescription-driven research. However, the paradigm of these sciences holds that its ultimate goal is the development of tested and grounded technological rules to be used by the professionals in their field. My thesis is that in the field of management the development of more prescription-driven research programmes, i.e. research on the basis of the paradigm of the design sciences, would contribute markedly to the solution of its utilisation problem. The use of this paradigm would lead to different research products, i.e. technological rules[8] rather than causal models, and would lead to different research strategies.

Technological rules derived from description-driven research

This is not to say that the rich results of present description-driven research programmes would not contribute. Many available research results can be used to derive technological rules, like:

- if you want to realise a large-scale, complex strategic change, use a process of logical incrementalism (Quinn, 1980)
- if you want effective realization of the outcomes of strategic decision-making, promote perceived procedural fairness (Korsgaard, Schweiger and Sapienza, 1995) and active participation of middle management (Woolridge and Floyd, 1990)
- if you want to manage the activities within the operational core of a professional organisation, use standardisation of skills rather than direct supervision (Mintzberg, 1983).

Such technological rules are to be used as design exemplars as they do not give a specific course of action. However, the original research results were not formulated as technological rules. In description-driven research management implications tend to be treated more or less as an afterthought of the analysis and are not tested as such. As will be discussed below, in research based on the paradigm of the design sciences, ß-testing of technological rules is a key element of its research strategy.

Research products, based on the paradigm of the design sciences

There are significant differences between the causal models of description-driven research and the technological rules of prescription-driven research. Their causal logic is comparable: one or more dependent variables are caused, deterministically or stochastically, by one or more independent ones. However, one difference lies in the nature of the independent variables: in the case of the causal model these are elements already present in reality (and not always manipulable), while in the case of the rule it is a newly designed intervention or artefact. Often the dependent variables are also different. For causal models in the field of management the “bottom line” (or organisational effectiveness) is a much used result variable (see e.g. Lewin and Minton, 1986; March and Sutton, 1997). March and Sutton show that the mechanisms causing variation in overall organisational performance are unstable. To this one may add that overall performance is typically not only influenced by the independent variables of interest, but by many more organisational and contextual variables as well. So the impact of the independent variables tends to “drown in noise”, forcing the researcher to restrict himself or herself to analyse only those independent variables that have a real strong impact on the bottom line. On the other hand, when testing technological rules one tends to investigate short causal chains. The dependent variable is not the ultimate overall organisational performance, but rather one or more operational variables, like the question whether an intended change is indeed realised.

Causal models can be and often are partial and so explain only certain aspects of the phenomenon of interest. If they are quantitative, they tend also to be strongly reductionistic, forced by the need for quantification. Technological rules, on the other hand, are holistic. A given intervention is applied in a certain context and all organisational and contextual factors have an impact on its outcome. Some of the mechanisms determining its effectiveness will be analysed to ground the technological rule, but other factors will retain their "black box" character. The description of rule, context and outcome need not be reductionistic, but can use "thick" qualitative text (Geertz, 1973).

Research strategies, based on the paradigm of the design sciences

Not only the intended research products are different, so too are the research strategies. Prescription-driven research is solution-focused, rather than problem-focused. Of course the problem is analysed, but the emphasis of analysis is on those aspects which determine the choice and effectiveness of the solution. This means, among other things, that already after an initial scan of the problem some possible solutions are explored, the results of which guide further problem analysis.

Research to develop and test technological rules in management will be "clinical research", i.e. the rules will be tested in context, typically using a multiple-case design. It can first go through a stage of "α-testing", i.e. analysis of the effectiveness of a certain rule in the original context (like Quinn's, 1980, research into logical incrementalism). But invaluable insight can be gained by subsequent "β-testing" (see Dolan and Matthews, 1993), i.e. translating the rule to other contexts, having third parties use it, assess its effectiveness and make final improvements. One might compare β-testing with replication research, advocated by Tsang and Kwan (1999) for description-driven management research. It is this β-testing, which can provide further insight into the indications and contra-indications for the rule and hence in its application-domain. In principle, much material is already available from some form of testing, since many top academic researchers also have consultancy practices. These practices are, in essence, the translation of their research results to other contexts and both the successes, and especially the less than successful applications, should provide much insight. Unfortunately, such material is too little published. Nevertheless, such testing is still not full β-testing. An essential element of β-testing is that testing is conducted by a third party to counteract the "unrecognized defenses" of the originator of the rule, which may blind him or her to possible flaws in its use (Argyris, 1996).

The testing of managerial technological rules has much in common with evaluation research of social programmes, like crime prevention or schooling programmes (see, e.g. Cook and Campell, 1979; Guba and Lincoln, 1989 and especially Pawson and Tilly, 1997). Such evaluation research is by its very nature testing-in-context. Following Pawson and Tilly (1997), the key question is not so much whether 'it' works, but what is it about the programme that makes it work in terms of explaining mechanisms. Their starting point is what they call the basic realist formula: *mechanism + context = outcome*. These mechanisms may include both impersonal, material factors and personal interpretations and discourses of the actors involved. So such testing does not make a paradigmatic choice between a structure and an agency-view. Like Schulz and Hatch

(1996) we do not accept Burrell and Morgan's incommensurability argument with respect to paradigm diversity in organization theory.

A managerial technological rule will not usually be grounded in terms of general laws, as may be the case in engineering, but rather in terms of explaining mechanisms. An example of the use of impersonal factors as explaining mechanisms is Goldratt's Theory-of-Constraints (Goldratt and Cox, 1986). The rule is that in managing a factory one should focus on optimising the use of the constraining capacity group. The explaining mechanism is that it is this group that determines the output of the factory as a whole. An example of the use of more personal factors can be found in Tichy's TPC-model. One rule is that if a given strategic change hurts the real interests of a certain subgroup, one should use political interventions rather than technical or cultural ones. The explaining mechanism is that technical, i.e. content-oriented interventions will demonstrate even more clearly to that group that their interests will be hurt, which will not help to overcome their resistance to the change, that cultural interventions, i.e. inviting participation, will give them the opportunity to organise a coalition against the change, while political, i.e. power interventions can be accepted as being the duty of top management to act in the interests of the organisation as a whole.

ß-testing of managerial technological rules is interested in both driving and in blocking explaining mechanisms (instances where the rule fails are also highly interesting). It is especially this grounding in driving and blocking explaining mechanisms which will support the translation of the rule to other contexts.

A key criterion for distinguishing academic research results from the prescriptions found in "Heathrow-literature", is justification. The effectiveness of an algorithmic technological rule (applied as recipe) can be proven conclusively in deterministic or stochastic terms. But the indeterminate nature of heuristic rules - and most technological rules in the field of management will be heuristic - makes it impossible to provide such conclusive proof. However, through multiple case-studies one can accumulate supporting evidence which can continue until "theoretical saturation" (Eisenhardt, 1989) has been obtained.

In the case of algorithmic rules, the evidence can be left out after it has been assessed. Application and further research can be based on the rules themselves. In the case of heuristic rules, the evidence remains part of the results. In order to use the results for application or for further research, one keeps needing the evidence - either as it is or in condensed form - to forecast the effectiveness of the application and for translation into the new context.

The argument is summarised in Table 1, showing the main differences between description-driven and prescription-driven research programmes.

characteristic	*Description-driven research programmes*	*Prescription-driven research programmes*
dominant paradigm	explanatory sciences	design sciences
focus	problem focused	solution focused
typical research question	explanation	alternative solutions for a class of problems
typical research product	causal model; quantitative law	tested and grounded technological rule
nature of research product	algorithm	heuristic
justification	proof	saturated evidence

Table 1. The main differences between description-driven and prescription-driven research programmes.

Description and prescription in functional management fields

The tensions between description-driven and prescription-driven research and between the academic and the professional reputation systems do not only exist in the field of organisation and management theory in general, but also in functional areas like Operations Management, Management of Technology, Marketing Management and Human Resources Management. The situation in these areas is somewhat different, because here professional associations, which publish journals and organise conferences, bring together practitioners and academics. These conferences tend to suffer less from what Hambrick calls the "incestuous, closed loop" of the American Academy of Management conferences (Hambrick, 1994, p. 13). Furthermore, in these fields one finds more academics with mixed academic/professional backgrounds as opposed to academics with purely academic backgrounds. This causes some more interest in the utility of research products and in the professional reputation system.

However, the forces of the academic reputation system are also felt strongly in these fields as is illustrated by the following two examples. In the field of Operations Management Meredith, Raturi, Amoake-Gyampath and Kaplan (1989) bemoan the dominance in their field of Operations Research - high in academic prestige - at the expense of research products more relevant for real-life problems (see also Whitley, 1988, on the clash between the two reputation systems in this field). In Management of Technology Ottosson castigates the "terror of statistical investigations", "concentrating on measurable numbers to get nice tables processed with advanced computer programs", which are "well received in scientific society", but leave "managers and entrepreneurs, seeking useful theories for their every-day businesses" in the cold (Ottosson, 1998, p. 236).

Nevertheless, because of its more instrumental nature, the literature in these functional fields *does* give practitioners, like marketing managers and logistic managers, essential knowledge without which they would perform suboptimally. One may compare this with our field of management-in-general, which as yet provides fairly little instrumental knowledge (exceptions being e.g. psychological theories on motivation, which score high on both utility and validity according to Miner, 1984, and research on organisational change management, which often has a strong instrumental component).

THE UTILITY OF TECHNOLOGICAL RULES IN THE FIELD OF MANAGEMENT

The quest for prescriptions in the field of management is as old as the field itself and was not invented here. It is older than the tradition of description-driven research based on the trinity of description, explanation and prediction. My proposition, therefore, is not the invention of the idea of prescription, but to take prescription-driven management research serious academically by rigorous testing and grounding.

By their very nature technological rules are much more application-oriented than the causal models of description-driven research. I discuss here the utility of technological rules by examining the extent to which they fulfil the five key user-needs of practitioners regarding (academic) management theory as developed by Thomas and Tymon (1982) on the basis of various criticisms of such theory.

- *Descriptive relevance* or external validity: the raison d'être of a technological rule is its external validity as established by the multiple case-studies discussed above.
- *Goal relevance* or the extent to which research results refer to matters the practitioner wishes to influence: in a prescription-driven research programme goal relevance is a key criterion for the choice of rules to be developed, tested and grounded.
- *Operational validity* or the extent to which the practitioner is able to control the independent variables in the model: the very nature of a technological rule assures its operational validity.
- *Non-obviousness*: because a technological rule is not forced into a reductionistic format as quantitative causal models are, there is little danger of overly obvious research results.
- *Timeliness*: a practitioner need arising from the "incredible long periods of time" required to adequately assess organisational phenomena and the scientists' reluctance to make recommendations before all the facts are in (Thomas and Tymon, 1982, p. 349): in this respect the technological rule has no advantage over the causal model; for classes of management problems for which timeliness is a real issue, the practitioner will have to deal with consultants rather than with academic researchers.

This brings me to the overall conclusion that on the basis of the Thomas and Tymon criteria, generally speaking, the utility of the technological rule is significantly higher than that of the traditional causal model.

CONCLUSION AND DISCUSSION

The main thesis advanced here is that by and large the utilisation problem of academic management theory is caused by its very nature. Predominantly, such theory is the result of description-driven research, with the causal model as the typical output. This is a plea to combine description-driven research programmes with prescription-driven ones, which can lead to more instrumental knowledge in the form of tested and grounded technological rules.

Both types of programmes could well operate in a profitable partnership: the former providing causal models to be used by the latter to ground technological rules, the latter providing further insight into the nature of managerial processes and generating new research questions. Such an approach would meet Dewey's (1929) criticisms on the traditional separation of knowledge and action and follow Starbuck and Nyström's (1981) adage, "if you want to understand a system, try to change it".

I used analogies with design sciences like medicine and engineering to show the potential of such a partnership for academic research in the field of management. This is not to say that I expect that its results will obtain the privileged status of the foremost source of knowledge for practitioners as is the case in these disciplines. Although in the heady days of the scientisation of Business Schools, Andrews (1969) did argue that management should be regarded as a profession, there are also reasons not to do so (see, e.g. Realin, 1990)[9]. One is that formal managerial knowledge, i.e. formal knowledge on management-in-general, is not as central to managerial success as such knowledge is in "strong" professions. Managers will continue to be inspired by a range of sources of knowledge. However, in my opinion, academic management research should at least strive to be one of the more important of these sources.

Several authors, like Koontz (1961; 1980) and Pfeffer (1993), argue that the variety of approaches advocated in organisation and management literature is a sign of immaturity of the field. On the contrary, variety can be a source of inspiration for practitioners. In my opinion, variety is an expression of the richness of the field. Besides, it is doubtful whether practitioners expect the field to develop one Grand and Unified Management Theory. What *is* possibly a sign of immaturity is the plethora of *unopposed* so-called management fads (Byrne, 1986; Pascale, 1990, p. 20). It could be a rewarding task for prescription-driven research to do some weeding here with the help of some rigorous testing and grounding.

An increasing interest in prescription-driven management research could lead – in terms of McKinley et al. – to a certain "school of thought" , i.e. an integrated theoretical framework that provides a distinct view on organizations and that is associated with an active stream of empirical research (McKinley, Mone and Moon, 1999, p. 635). However, a more ambitious result would be an effective partnership of description-driven and prescription-driven research in many schools of thought, thus giving our field the character of a technology more than that of a basic science, or – in terms of Gibbons et al. (1994) – increasing the use of mode 2 knowledge production in our field.

Whether that will happen, will ultimately be a matter of values. Academics may consider it unacademic to be much concerned with praxis, rather like Roman senators who were not supposed to be involved in craft or trade. A quest for tested and grounded technological rules, which in the field of management will be predominantly qualitative and heuristic by nature, means trading the priestly beauty of truth for the soldiery glory of performance (to paraphrase March and Sutton, 1997) and that may be too high a price. Some may fear that a stronger praxis-orientation will cause the field to relapse into a "practice-based craft". In medieval times, the medical doctor did not soil his hands, but left the butchery to the chirurgeon. In modern times, this barber-surgeon emancipated and became an academically respectable surgeon. Ultimately, I expect this to happen to utility-conscious academic management researchers too, as long as they focus on rigorous testing and grounding of their technological rules.

Notes

1. In this article I use the term "scientific" like the German "wissenschaftlich" or the Dutch "wetenschappelijk", meaning "according to sound academic standards"; thus, its meaning is not confined to the natural sciences.
2. Some authors, like Child (1995) and Koza and Thoenig (1995), suggest that in our field one might contrast a European tradition, which is concerned more with the academic reputation system, with an American one, which is concerned more with the professional reputation system. This may be true for European scholars with a background predominantly in sociology, but not necessarily so for organisation and management scholars with a different background.
3. In a discussion on the quality of research products in the field of strategic management, Montgomery, Wernerfelt and Balakrishnan admit that "sciences should be undertaken for the sake of ultimate application" (Montgomery et al., 1989, p.191), but then proceed to stress the "ultimate" in their statement, urging editors of academic journals not to demand *direct* application of the research products presented (as if they always do), thus leaving more room for the fine tuning of (descriptive) theory. In a reaction Seth and Zinkhan (1991) take it a step further and complain that Montgomery et al. are too application-oriented [sic] and propose that "if strategic management is to become a science it must strive towards "explaining by law" the phenomena of interest (Seth and Zinkhan, 1991, p.80), thus forcing their causal models into a reductionistic, quantitative format.
4. Pelz (1978) also discussed a third type of use, viz. *symbolic* use of scientific knowledge: the use of that knowledge to legitimate predetermined positions. This type of utilisation is, however, less relevant for the present discussion.
5. In the context of the design sciences, Simon primarily discusses construction problems, while in this article the design sciences may also deal with improvement problems.
6. It is the mission of Design Research and Design Theory (see, e.g. Cross, 1993; Evbuomwan, Sivaloganathan and Jebb, 1996; Hubka and Eder, 1996) to contribute to the process knowledge of the designer. However, the gap between design theory and design practice is at least as large as the gap between management theory and practice, see, e.g. Norman (1996), Dorst (1997) and Van Handenhoven and Trassaert (1999). It is with respect to *object knowledge* that (academic) research in the design sciences is so successful, not with respect to process knowledge.

7 This is not to say that *all* technological rules have to be tested within their context. In the engineering sciences in particular, it is possible to isolate certain research subjects from their context without losing essential characteristics.

8 "Action theories", as discussed by Argyris, Putnam and McLain Smith (1985, chapter 3), can be seen as technological rules in the field of management.
9 Or see the balanced discussion of this issue by Squires (2001, pp. 483-485), who concludes that management may not be a "strong" profession, but still has several important characteristics of it.

REFERENCES

ARGYRIS, C., PUTNAM, R. and McLAIN SMITH, D. (1985). *Action Science, Concepts, Methods, and Skills for Research and Intervention*. San Francisco: Jossey-Bass Publishers.

ARGYRIS, C. (1996). 'Unrecognized Defenses of Scholars: Impact on Theory and Research.' *Organization Science* **7**, 79-87.

ABBOTT, A. (1996). *The system of Professions. An Essay on the Division of Expert Labor*. Chicago: The University of Chicago Press.

Academy of Management, (1995). 'Academy of Management Code of Ethical Conduct.' *Academy of Management Journal* **38**, 573-577.

ANDREWS, K.R. (1969). 'Towards professionalism in business management.' *Harvard Business Review* **50**(2), 49-60.

BECHER, T. (1999). *Professional Practices.* New Brunswick: Transaction.

BEYER, J.M. and TRICE, H.M. (1982). 'The Utilisation Process: a Conceptual Framework and Synthesis of Empirical Findings.' *Administrative Science Quarterly* **27**, 591-622.

BUNGE, M. (1967). *Scientific Research II: The Search for Truth*. Berlin: Springer Verlag.

BURRELL, G. (1989) 'The absent centre: The neglect of Philosophy in Anglo-American Management Theory.' *Human Systems Management* **8**, 307-312.

BYRNE, J.P. (1986). 'Business Fads: what is in and out.' *Business Week*, January 20.

CHILD, J. (1995). 'Guest Editorial.' *Organisation Science* **6**, 117-118.

COOK, T.D. and CAMPBELL, D.T. (1979). *Quasi-experimentation*. Chicago: Rand McNally.

CROSS, N. (1993). 'Science and Design Methodology: a review.' *Research in*

Engineering Design **5**(2), 63-69.

DEWEY, J. (1929). *The Quest for Certainty***,** New York: Minton Balch.

DOLAN, R.J. and MATTHEWS, J.M. (1993). 'Maximizing the Utility of Customer Product Testing: Beta Test Design and Management'. *Journal of Product Innovation Management* **10**, 318-330.

DORST, K. (1997). *Describing Design: A comparison of Paradigms*. Rotterdam: Vormgeving Rotterdam.

EMORY, W.C. (1985). *Business Research Methods*. Homewood(Ill): Irwin.

EISENHARDT, K.M. (1989). 'Building Theories from case study Research.' *Academy of Management Review* **14**, 532-550.

EVBUOMWAN, N., SIVALOGANATHAN, S. and JEBB, A. (1996). 'A survey of Design Philosophies, Models, Methods and Systems.' *Journal of Engineering Manufacture* **210**, 301-319.

FREIDSON, E. (Ed) (1973). *The Professions and their Prospects*. Beverly Hills: Sage.

GEERTZ, C. (1973). *The interpretation of culture.* New York: Basic Books.

GIBBONS, M., LIMOGES, C., NOWOTNY, H., SCHWARTZMAN, S., SCOTT, P., and TROW, M. (1994) *The New Production of Knowledge: the Dynamics of Science and Research in Contemporary Societies.* London: Sage

GOLDRATT, E.M. and COX, J. (1986). *The Goal, a Process of Ongoing Improvement.* Croton-on-Hudson: North River Press.

GORDON, R.A. and HOWELL, J.H. (1959). *Higher Education for Business*. New York

GUBA, Y. and LINCOLN, E. (1989). *Fourth Generation Evaluation*. London: Sage.

HAMBRICK, D.C. (1994). 'What if the Academy Actually Mattered?' *Academy of Management Review* **19**, 11-16.

HAYES, R.H. and ABERNATHY, W.J. (1980). 'Managing our way to economic decline.' *Harvard Business Review* **61**(4), 67-77.

HUBKA, V. and EDER, W. (1996). *Design Science: Introduction to the Needs, Scope and Organisation of Engineering Design Knowledge*. London: Springer.

KLEGON, D.G. (1978). 'The Sociology of Professions, an emerging perspective.'

Sociology of Work and Occupations **5**, 259-283.

KOONTZ, H. (1961). ‘The management theory jungle.’ *Academy of Management Journal* **4**, 174-188.

KOONTZ, H. (1980) ‘The Management Theory Jungle Revisited.’ *Academy of Management Review* **5**, 175-187

KORSGAARD, M.A., SCHWEIGER, D.M. and SAPIENZA, H.J. ‘Building commitment, attachment, and trust in strategic decision making teams: the role of procedural justice’. *Academy of Management Journal* **38**, 60-84.

KOZA, M.P. and THOENIG, J.C. (1995). ‘Organizational Theory at the Crossroads. Some Reflections on European and United States Approaches to Organizational Research.’ *Organizational Science* **6**, 108.

KUHN, T.S. (1962). *The Structure of Scientific Revolution*. Chicago: The University of Chicago Press.

LAKATOS, A. (1991). Falsification and the Methodology of Scientific Research Programmes. In Lakatos, I. and Musgrave, A. (eds) *Criticism and the Growth of Knowledge.* Cambridge: Cambridge University Press.

LEWIN, K. (1945). The research centre for group dynamics at Massachusetts Institute of Technology. *Sociometry,*:126-136.

LEWIN, A.Y. and MILTON, J.W. (1986). ‘Determining Organizational Effectiveness: Another look, and an Agenda for Research.’ *Management Science* **32**, 514-539.

MARCH, J.G. and SUTTON, R.I. (1997). ‘Organisational Performance as a Dependent Variable.’ *Organisation Science* **8**, 698-706.

MASTERMAN, M. (1970). The Nature of Paradigm. In Lakatos, I. and Musgrave, A. (Eds) *Criticism and the Growth of Knowledge*. Cambridge: Cambridge University Press.

McKINLEY, W., MONE, M.A. and MOON, G. (1999). ‘Determinants and Development of Schools in Organization Theory’. *Academy of Management Review* 24, 634-648

MEREDITH, J.R., RATURI, A., AMOAKO-GYAMPAH, K. and KAPLAN, B. (1989). ‘Alternative Research Paradigms in Operations.’ *Journal of Operations Management* **8**(4), 297-326.

MINER, J.B. (1984). ‘The Validity and Usefulness of Theories in an Emerging Organizational Science.’ *Academy of Management Review* **9**, 296-306.

MINTZBERG, H. (1983). *Structure in fives, designing effective organisations***.** Englewood Cliffs: Prentice Hall.

MONTGOMERY, C.A., WERNERFELT, B. and BALAKRISHNAN, S. (1989). 'Strategy content and the research process: a critique and commentary.' *Strategic Management Journal*, **10**, 189-197.

NAGEL, E. (1979). *The Structure of Science*, Indianapolis: Hackett.

NORMAN, D. (1996). Design as Practiced. In Winograd, T. (ed) *Bringing Design to Software*. New York: ACM Press.

OTTOSSON, S. (1998). 'Strategic considerations in the interplay between R&D and M&S' *Technovation* **18**(4), 235-245.

PASCALE, R.T. (1990). *Managing on the Edge: how the smartest companies use conflict to stay ahead.* New York.

PAWSON, R. and TILLEY, N. (1997). *Realistic Evaluation.* London: Sage.

PEIRCE, C.S. (1960). The Rules of Philosophy. In Konvitz, M. and Kennedy, G. (Eds) *The American Pragmatists*, New York: New American Library (originally published in 1868).

PELZ, D.S. (1978). Some expanded perspectives on the use of social science in public policy. In Yinger, M. and Cutler, S.J. (Eds.) *Major Social Issues: A Multidisciplinary view*: 346-357 New York: Free Press.

PETTIGREW, A. (1996). Interview by M.S. Kraatz for the *OMT-Newsletter* of the Academy of Management, Winter: 1-4.

PFEFFER, J. (1993). 'Barriers to the Advance of Organisational Science: Paradigm Development as a Dependent Variable.' *Academy of Management Review* **18**, 599-620.

PIERSON, F.C. and others. (1959). *The education of American business men. A study of university-college programs in business administration*. New York.

QUINN, J.B. (1980). *Strategies for Change, Logical Incrementalism*. Homewood (Ill): Irwin.

RAELIN, J.A. (1990). Let's not teach management as if it were a profession. *Business Horizons*: 23-28.

SCHLOSSMANN, S., SEDLAK, M. and WECHSLER, H. (1987). The 'New Look': The Ford Foundation and the Revolution in Business Education. *Selections, The Magazine of* *the Graduate Management Admission Council*, (Winter): 11-13.

SCHÖN, D.A. (1983). *The Reflective Practitioner*. London: Temple Smith.

SCHULZ, M. and HATCH, M.J. (1996). ‘Living with multiple paradigms: the case of paradigm interplay in organizational culture studies’. *Academy of Management review* **21**, 529-557.

SETH, A. and ZINKHAN, G. (1991). ‘Strategy and the Research Process: A Comment.’ *Strategic Management Journal* **12**, 75-82.

SIMON, H.A. (1969). *The Sciences of the Artificial*. Cambridge (Mass.): the MIT Press.

SQUIRES, G. (2001). ‘Management as a professional discipline’. *Journal of Management Studies* 38, 473-486.

STARBUCK, W.H. and NYSTRÖM, P.C. (1981). Designing and understanding organizations. In Nyström, P.C. and Starbuck, W.H. (Eds) *Handbook of Organisation Design*, vol 1. Oxford: Oxford University Press.

STERLING LIVINGSTONE, J. (1971). ‘The myth of well-educated manager.’ *Harvard Business Review* **52**(1), 79-89.

THOMAS, K.W. and TYMON, W.G. (1992). ‘Necessary Properties of Relevant Research: Lessons from Recent Criticisms of the Organizational Sciences.’ *Academy of Management Review* **17**, 345-352.

TICHY, N.M. (1983). *Managing Strategic Change, Technical, Political and Cultural dynamics*. Chichester: Wiley.

TRANFIELD, D. and STARKEY, K. (1998). ‘The nature, social organization and promotion of management research: Towards policy’. *British Journal of Management* **9**, 341-353.

TSANG, E.W.K. and KWAN, K.-M. (1999). ‘Replication and Theory Development in Organizational Science: a Critical Realist Perspective’. *Academy of Management Review* **24**, 759-780.

VAN AKEN, J.E. (1994). ‘Bedrijfskunde als Ontwerpwetenschap (Business Administration as a Design Science, in Dutch).’ *Bedrijfskunde* **66**, 16-22.

VAN BAALEN, P.J. (1995). *Management en Hoger Onderwijs: de geschiedenis van het academisch management-onderwijs in Nederland*. (Management and Higher Education: the history of academic management teaching in the Netherlands, in Dutch), Delft: Eburon.

VAN HANDENHOVEN, E. and TRASSAERT, P. (1999). Design Knowledge and design skills. In Lindeman et al. (Eds) *Proceedings of the 12th International Conference on Engineering Design*. München: Technische Universität München ,153-158.

VAN STRIEN, P.J. (1997). ‘Towards a Methodology of Psychological Practice, the regulative cycle.’ *Theory and Psychology* **7**(5), 683-700.

WOOLRIDGE, B. and FLOYD, S.W. (1990). ‘The strategy process, middle management involvement, and organizational performance’. *Strategic Management Journal* **11**, 231-241.

WHITLEY, R. (1988). ‘The Management Sciences and Managerial Skills.’ *Organization Studies* **9**(1), 47-68.

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