Which kind of science is construction management?

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WHICH KIND OF SCIENCE IS CONSTRUCTION MANAGEMENT?

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ABSTRACT

It is argued that the mainstream views on the nature of construction management are insufficient, and as one consequence of this, the relevance of construction management has been questioned. As a solution to this situation, construction management is suggested to be repositioned as a design science, rather than as an explanatory science. A historical consideration reveals that design science equals to one of the sciences proposed by Aristotle, however, the suggestion of Aristotle has been forgotten. Thus, there has been a long-standing neglect of the design science, which explains the present fragmentation of this field. It is argued that this redefinition of construction management will solve several problems plaguing this discipline, including the problem of relevance.

KEY WORDS

construction management, natural science, social science, science of production, design science, constructive research

INTRODUCTION

The question on which kind of science construction management is, or should be, ignites from time to time among construction management scholars and researchers; the discussion launched by a paper by Seymour and Rooke (1995), and the recent discussion in the CNBR email list are illustrative examples. Such a discussion would seem, at first sight, purely academic, in the pejorative sense of this word. It is argued here that this is not the case. Rather, an appropriate understanding of the character of a given science is contended to be highly significant for the success of that science and for the esteem it enjoys. The question is about the research questions tackled, methodologies used and outcomes produced.

The objective of this paper is to justify a new understanding of the discipline of construction management. For doing this, first, the mainstream views of the nature of construction management are examined. Then, an alternative view on the nature of construction management as a design science is presented. The present uptake, historical roots and character of the design science is also discussed. Next, the implications for the discipline from the adoption of this alternative view are discussed. Finally, conclusions are drawn from the analyses made.

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THE MAINSTREAM VIEWS: CRITICAL EVALUATION

Presently, there seems to be three popular understandings on the character of construction management: first, as a social science, second, as a mixture of social and natural science, and third, as a technical science.

The view of construction management as a social science was usefully exposed in an email debate among construction management scholars by Bon (2002):

Construction management falls in the domain of social sciences. The emphasis is on management, a sui generis discipline. The other two disciplines that contribute to construction management are economics and law. Engineering is more or less incidental to what we do, just as film development is incidental to what a film director does.

The origin of this view is probably the notion of construction management as a subcategory of (general) management, which often is seen as a social science[1]. Indeed, construction is a human and social activity, and social science has much to contribute. However, there are theoretical grounds to argue that the explanatory power of social science is limited in construction management. The notion of construction management as social science tends[2] to lead to analyses where on the one hand, physical reality, and on the other hand, the technical phenomenon of production are abstracted away, i.e. creation of artefacts (as proposed by Bon). Arguably, social behaviour analyzed in construction management is always embedded in physical and production contexts, which follow their own laws – they are not incidental: the flow of work is determined by the queueing theory; for getting all work done, there must be a work breakdown structure. Social phenomena in construction can be orderly understood only in connection to their context. Thus, construction management cannot usefully be seen as falling solely into social sciences.

If construction management does not fall into social science, where then is its disciplinary home? The alternative view is to see construction management as part of production/operations management, which conventionally is seen covering also social science focus and approach, even if the core focus is on understanding production in the physical world. In a seminal paper on theory in operations management, Schmenner and Swink (1998) state: “Operations management can arguably be viewed as a mongrel mixture of natural and behavioral science.” In a similar way, Love et al. (2002) contend that research in construction management can be categorized as at the intersection of natural science and social science.

This view on construction management rectifies some of the problems of seeing construction management as social science, but not all. Both natural and social science are explanatory sciences: they explain describe and explain phenomena. Such knowledge may be useful in practice,

[1] This view of management has recently been contested (van Aken 2004, Boland & Collopy 2004, Hatchuel 2005).

[2] This general tendency is shared by social sciences in general, but there are signs towards a changed attitude. Thus, Barley and Kunda (2001) call for a reintroduction of work studies into organizational theory. Orlikowski (2007) calls for taking account of the material in organizational studies.

but it is still (at least) one step away from a solution to a practical problem. Indeed, similarly to the discussion in the discipline of management (Davies 2006), the question about the relevance of construction management research results has often been raised.

Lastly, there is the view on construction management as a technical science. It is cultivated especially in those countries where the education and research of construction management is located in engineering departments of universities. The noteworthy merit of this approach is that it endeavours to solve practical problems. However, this view has suffered from a non-reflective and implicit methodological basis. In technical research, the instinctive way of proceeding is to design and build a model, tool or system and then evaluate it for showing that it is superior in comparison with earlier solutions. This methodological approach has not convinced[3] those who subscribe to the sophisticated methodologies of explanatory sciences.

[3] In their book on research methods in construction, Fellows and Liu (2008) come nearest to technical research in their description of "instrumental research": "Instrumental – to construct/calibrate research instruments, whether physical measuring equipment or as test/data collection (e.g. questionnaires, rating-scales). In such situations the construction etc. of the instrument is a technological exercise; it is the evaluation of the instrument and data measurement in terms of meaning which renders the activity scientific research. The evaluation will be based on theory." It can be concluded that Fellows and Liu do not see the stage of designing and building of artefacts falling into scientific research. In addition, they have an extremely narrow view on the notion of instrument, and accept thus only the evaluation of research instruments falling into scientific research.

Thus, we have found that all three mainstream views on the character of construction management wanting. What is the way forward?

CONSTRUCTION MANAGEMENT AS A NORMATIVE SCIENCE

It is argued here that the solution to the unsatisfactory situation regarding the nature of construction management is to view it as comparable to clinical research in medicine. The objective of clinical research is to create and test new drugs and treatments, based among other things, on the knowledge gained in physiology, biochemistry etc. In the same way, construction management can best be seen as an instrumental and normative science, which provides solutions to the managerial problems in construction. These solutions are informed by or based on, among other things, the knowledge gained in explanatory sciences, such as organization theory and economics.

In this view, construction management is seen to fall into the production science or (more or less equivalently) the design science or (again more or less equivalently) constructive research. Already this multiplicity of terms reveals that the production science suffers from fragmentation – however, there is unity behind this current fragmentation. Next, we turn to discuss the present state of the production science, and its antecedents.

CONSTRUCTIVE RESEARCH, DESIGN SCIENCE, PRODUCTION SCIENCE

THE DESIGN SCIENCE/CONSTRUCTIVE RESEARCH VIEW

Obviously, the methodology of natural and social science addressing how things are is not fit to answer the question of how things ought to be. In several research fields (outside the traditional technical fields), the need for research, the goal of which is not to describe and explain the world but to change it and to create something new to it, has been felt. Thus, calls for constructive research in accounting (Kasanen & al. 1993), for design science research on information systems (March & Smith 1995, Hevner & al. 2004) and management in general (van Aken 2004, Boland & Colloby 2004) have been presented. The common feature in these calls is that the end result of research is seen to be a new artefact.

In the last 10 – 15 years, the uptake of this kind of research has been rapid and enthusiastic especially in accounting, information system and management research[4]. It is cogent that the first international conference on design science research in information systems and technology was held in Claremont, California, in 2006. In the Netherlands, an association for design science research has been established.

JUSTIFICATION FOR THE SCIENTIFIC STATUS OF DESIGN SCIENCE

But why should we see the development of an artefact as scientific research? The seminal authors take differing starting points in this regard. Kasanen & al. (1993) ground their discussion on constructive research on the fact that it is comparable to technical research carried out in engineering departments or technical universities. The scientific status of that kind of research is well established. However, most other seminal authors, for example van Aken, Hevner and others, refer to Simon (1969) when justifying the scientific status of the type of research they promote. It is thus opportune to consider this influential initiative, widely seen as seminal, in design science in more detail.

Simon (1969) writes:

Natural science is knowledge about natural objects and phenomena. We ask whether there cannot also be "artificial science" - knowledge about artificial objects and phenomena.

Simon (1969) continues by explaining that a science of the artificial will be closely akin to a science of engineering: it is concerned with how things ought to be, in order to attain goals, and to function. The core of that science would be provided by ”a science of design, a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process”. He presents engineering, architecture, business, education, law and medicine – as well as music - as examples of professional fields where this science applies. According to Simon, this science of the artificial has been sidetracked in universities during the 20th century in pursuit of academically more respectable topics, falling into descriptive (in the terminology of this paper, explanatory) sciences.

[4] The database SCIRUS gave in November 2007 hits as follows: 789 for "constructive research"and 929 for "design science research". Note that all hits are not necessarily in the meaning purported here.

DESIGN SCIENCE VIEW IN HISTORICAL PERSPECTIVE

However, the commonly held view of Simon as the seminal contributor to design science is wrong. Aristotle made a similar, sophisticated call for a science of production 2300 years earlier. Unfortunately, it has been forgotten, misunderstood or it has run out of fashion. This is in stark contrast to many other calls of Aristotle, which are now considered seminal.

What did Aristotle mean by the science of production? We can try to sketch the nature of productive sciences in his system of science. Aristotle classified knowledge into theoretical, productive or practical (Barnes 2000). Theoretical knowledge is pursued for the sake of truth. The practical sciences are concerned with how we should act in various situations. In turn, the science of production is oriented towards the making of useful or beautiful objects. Poetry, medicine, and house-building are given as examples of fields covered by the productive sciences. Thus, the science of production is instrumental by nature: it considers how action contributes to productive goals.

What does the science of production cover? In Metaphysics, Aristotle says:

Now the healthy is generated when a man thinks as follows: since health is so-and-so, if the subject is to be healthy it must have such-and-such, let us say uniformity, and if uniformity, then warmth; and he always thinks in this manner until he arrives at something final which he himself can produce. Then the motion from this instant onward, which here is a motion towards health, is called "production" [poiesis]. [….]

Of the generations and motions just considered, one of them is called "thinking" [noesis] and the other "production" [poiesis]; thinking occurs from the principle or the form, production from the end of thinking and thereafter. (Metaphysics 1032b15-20)

Thus, we can conclude that the Aristotelian science of production covers both the thinking preceding production – which we today call designing and planning – as well as the physical act of producing.

What else does Aristotle say about the science of production? Only a fifth of Aristotle's literary works have survived (Barnes 2000). In what is available to us, he considers production only to a modest extent. However, it has been argued that in Nicomachean Ethics, Aristotle reveals, almost in passing, his theoretical stand for the science of production (Koskela & Kagioglou 2005). He suggests that in production, comprising thus both of designing and making, the method of geometrical analysis is applicable. As geometry was the most developed science of the time (Barnes 2000), and the method of analysis had evolved into a sophisticated procedure, this connection is highly significant. In (Koskela & Kagioglou 2006), it is contended at more length that the ancient method of analysis and synthesis provides a proto-theory of design, which unfortunately has largely been forgotten in the modern period. To justify this claim, six central features of the method of analysis and synthesis are discussed and compared to recent developments in design theory and methodology. It is shown that various issues covered by the method of analysis and synthesis have recently been rediscovered in the design science, but without any connection to it. Indeed, it has been claimed that the Aristotelian proto-theory of design (and production), as reconstructed, is both deeper and broader than present candidates of design theory (Koskela et al. 2008).

However, we encounter here the problem of the partial loss of the scientific legacy of the antiquity. Even if geometrical treatises have survived, only one account of how ancient geometers analysed figures has remained, and it is from a somewhat later period. Thus, it is no wonder that, after Aristotle, the idea of a science of production and its core content have almost fallen into oblivion.

It is interesting to compare Simon's call for a science of the artificial to Aristotle's call for a science of production (Table 1). The similarity is obvious – in fact, Simon is reinventing the very idea of the science of production of Aristotle, obviously without knowing about these antecedents. Neither has this similarity been discussed in other literature, as far as it is known. Aristotle is mentioned once in the book (Simon 1969), but only in connection to his view that it is not natural for heavy things to rise or light ones to fall.

Table 1. Comparison of Aristotle's science of production to Simon's science of the artificial.

	Aristotle	*Simon*
Name of the science	Science of production	Science of the artificial
Purpose of the science	Making useful or beautiful objects	How things ought to be, in order to function
Exemplary fields	House-building, medicine, poetry	Engineering, architecture, business, medicine, education, law, music
Core	The method of analysis as used in geometry	A science of design, a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process

It is instructive to compare the fate of production science to that of natural science (treated in Aristotle's Physics). Although there have been quiet periods in the time line of natural science, there has been a continuity in the scientific activities on the different fronts of natural science, especially physics, after Aristotle. Especially physics has experienced two major upheavals, initiated by Newton and Einstein, and its progress has been remarkable. In contrast to the natural sciences, production science has experienced a long silence after the seminal contribution as well as lack of continuity (spectacularly evidenced by the re-introduction of the science of production under the term science of the artificial by Simon). The scientific progress of the science of production, when measured with conceptual and empirical gains, has been modest in comparison to the seminal contribution, and has occurred in recent years. Thus, we can speak about a long-standing neglect of the science of production. This also implies that we cannot expect the production science being mature and fully established regarding its philosophy, methods and paradigms. Nevertheless, the present methodology has already proved useful, especially in comparison to a situation with no clear guidelines.

OUTLINE OF CONSTRUCTIVE RESEARCH /DESIGN SCIENCE RESEARCH

At the outset, constructive research is characterized by its research questions and objectives. Järvinen (2004) claims that if the research question contains any of the following words, one might be doing design science research: design, build, change, improve, develop, enhance, maintain, extend, correct, adjust, introduce. However, for being different from ordinary designing, building, changing etc., the research task needs to address important and unique problems, or solve problems in a more effective way, and provide contributions to knowledge (Hevner & al. 2004).

As discussed above, the commonsense methodical approach in constructive research is ”Build and evaluate”. That is, designing and constructing an artefact (a construct, a construction) and checking that the original problem has been solved. Many more detailed models of research process have been presented. As an example, the list of steps by Kasanen et al. (1993) is given:

1. Find a practically relevant problem which also has research potential
2. Obtain a general and comprehensive understanding of the topic
3. Innovate, i.e. construct a solution idea
4. Demonstrate that the solution works
5. Show the theoretical connections and the research contribution of the solution concept
6. Examine the scope of applicability of the solution.

The outcomes of constructive research include, as discussed, artefacts (called also constructs or constructions), which comprise concepts, models, methods and instantiations (implementations) (Hevner & al. 2004). Also improvements (to artefacts or other things) are argued to be valid outcomes (van Aken 2004). In addition, better theories (Vaishnavi & Kuechler 2004) and technological rules[1] (van Aken 2004).

Finally, it is opportune to note the affinity of constructive research and action research. Järvinen (2007) contends that action research should not be classified into qualitative research methods. Rather, based on a systematic comparison of these two approaches, he claims that action research and design science should be seen as similar research approaches.

IMPLICATIONS FOR CONSTRUCTION MANAGEMENT

How, then, would the landscape of construction management seem in the proposed scheme? The suggestion is that the majority, or at least the leading part of construction management should be positioned as design science, oriented towards solving problems faced by the industry, but simultaneously contributing to knowledge. However, studies carried

[1] Theories and technological rules can be seen roughly equivalent. In terms of design science, both describe how action promotes goals.

out in the framework of explanatory sciences on construction related topics would surely be of importance, and nothing prevents positioning them into the field of "explanatory construction management", if they do not naturally fall into the domain of the respective explanatory science (for example, organization theory).

To those practicing explanatory science research, this suggestion may seem to give undue preference to design science research. However, it must be emphasized that the border is not clear-cut. In terms of design science research, methods of explanatory science are often indispensable in the first stages of research, when the problem is studied, and at the end, when the solution is evaluated.

It can be claimed that the target is not much different from the present situation: already much design science research[2] as well as explanatory science research is carried out. This is superficially true – however, a more explicit recognition of the different research types would provide several significant benefits:

- Avoiding miscategorization of research. Recently, the author has spotted two cases (of a rather limited sample) where a PhD student is doing constructive research, judging from the objectives, research questions and activities carried out, but the research has been miscategorized. Unaware of this type of research, the student has tried to apply methodologies of explanatory sciences to their research – an awkward if not impossible task.
- Strengthening the methodological basis of research falling into design science. As discussed above, the methodology in technical research falling into construction management (say on simulation, planning methods and computer applications) has traditionally not been well defined and explicit. The methodologies of design science provide an initial remedy.
- Selecting the right type of research. The recognition that explanatory and design sciences have fundamentally different objectives already helps to select a right type of research approach for the situation. This is illustrated by the common type of study on the causes of project delays. The motivation is surely practical, to solve the problem of delays. However, these studies are typically explanatory, and the studies are argued neither to contribute to knowledge nor to problem solving (Alsehaimi & Koskela 2008). Instead of explanatory delay studies, design science studies on the reduction of delays could be recommended.
- Clarifying the role of different approaches in a subfield of construction management. For example, in construction economics, the traditional approach has oriented around the methods and practices for

[2] Design science studies have been favoured, for example, in the lean construction community. The development of the Last Planner System of production control (Ballard & Howell 1998) is an archetype example of design science research.

economic management of construction projects, whereas the newer approach has endeavoured to apply economic theory to construction. It is easy to see that the debate is between design science approach and explanatory science approach.

- Lastly, but perhaps most importantly, the solution of the many acute and difficult problems faced by the construction sector seems to require design science research to harness all understanding towards candidate solutions. The work of Beamish (2008) on learning, collaboration and communication in complex organizations is especially instructive in this regard. She contends that design not only provides an overarching multidisciplinary approach that can embrace multiple approaches, but can offer practical and effective solutions through reflective and careful study of the problem. Thus, it can be expected that the relevance of construction management research can be increased through this proposed redefinition.

CONCLUSIONS

In contrast to explanatory natural and social sciences, the normative design (or productive) sciences have suffered from a long neglect. Even if the interest towards design sciences has increased in the last fifty years, they have remained too fragmented and atheoretical to have a real impact. In consequence, the many application areas of design science, such as design, construction and maintenance of the built environment, are still suffering from the underdevelopment of this science. Now, it is opportune to redefine construction management as a design science.

REFERENCES

Alsehaimi, A. & Koskela, L. (2008) What can be learned from studies on delay in construction? International Group of Lean Construction Conference, Manchester.

Aristotle (2004) Metaphysics. Book Zeta 7. In Lawson-Tancred H (2004) The Metaphysics. Penguin Books, London.

Ballard, G. & Howell, G. 1998. Shielding Production: Essential Step in Production Control. Journal of Construction Eng. and Mgmt, Vol. 124, No. 1, pp. 11 - 17.

Barley, Stephen R, Kunda, Gideon (2001) Bringing Work Back In. Organization Science, Vol. 12, No. 1, pp. 76-95.

Barnes, J. (2000) Aristotle – A Very Short Introduction. Oxford University Press.

Beamish, Anne (2008) Learning from work. Stanford University Press.

Boland R. & Collopy F. (Ed.) (2004) Managing as Designing. Stanford University Press.

Bon, R. (2002) Who's an author and who's not. E-mail message to the CNBR-list, July 3, 2002.

Davies, H. (2006) Improving the Relevance of Management Research: Evidence-Based Management: Design Science or Both? Business Leadership Review Vol. III, No. III.

Fellows, R. & Liu, A. (2008) Research Methods for Construction. Blackwell.

Hatchuel, A. (2005) Towards an epistemology of collective action: management research as a responsive and actionable discipline. European Management Review, Vol. 2, pp. 36-47.

Hevner, A.R., March, Salvatore T., Park, Jinsoo, Ram, Sudha (2004) Design Science in Information Systems Research. MIS Quarterly, Vol. 29, No. 1, pp. 75-105.

Järvinen, P. (2004) On Research Methods. Opinpajan kirja, Tampere. .

Järvinen, P. (2007) Action Research is Similar to Design Science. Quality & Quantity, Vol. 41, pp. 37-54.

Kasanen, E., Lukka, K., Siitonen, A. (1993) The Constructive Approach in Management Accounting Research. Journal of Mgmt Accounting Research.

Koskela, Lauri & Kagioglou, Mike, (2006) The Proto-Theory of Design: the method of analysis of the ancient geometers. Proceedings of the Design 2006, 9th International Design Conference.

Koskela, L., Codinhoto, R. Tzortzopoulos, P. & Kagioglou, M. (2008) The Method of Analysis of The Ancient Geometers as The Proto-Theory of Design. Manuscript submitted for publication.

Love, P. E.D., Holt, G. D., Li, H. (2002) Triangulation in construction management research. Eng., Construction and Architectural Mgmt, Vol. 9, No: 4, pp. 294-303.

March, S.T. & Smith, G.F. (1995) Design and natural science research on information technology. Decision Support Systems Vol. 15, Nr. 4, pp. 251 – 266.

Orlikowski, Wanda (2007) Sociomaterial practices: Exploring technology at work. Organization Studies, Vol. 28, No. 9, pp. 1435-1448.

Schmenner, R.W. & Swink, M.L. (1998) On theory in operations management. Journal of Operations Management Vol. 17, pp. 97-113.

Seymour, D.E. & Rooke, J. (1995) The culture of the industry and the culture of research. Construction Management and Economics, Vol. 13, pp. 511-523.

Simon, H.A. (1969) The sciences of the artificial. The M.I.T. Press, Cambridge (MA).

Vaishnavi, V. & Kuechler, B. (2004) Design Research in Information Systems. Available at http://www.isworld.org/Researchdesign/drisISworld.htm

Van Aken, J.E. (2004) Management research based on the paradigm of the design sciences: The quest for field-tested and grounded technological rules. Journal of Management Studies, Vol. 41, Nr. 2, pp. 219 – 246.