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Conducting and publishing design science research
Inaugural essay of the design science department of the Journal of Operations Management

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ABSTRACT

The new Design Science department at the Journal of Operations Management invites submissions using a design science research strategy for operations management (OM) issues. The objective of this strategy is to develop knowledge that can be used in a direct and specific way to design and implement actions, processes or systems aimed at achieving desired outcomes. This knowledge is developed by engaging with real-life OM problems or opportunities. Manuscripts submitted to this department will be evaluated on pragmatic validity and practical relevance. Because design science research (DSR) differs in some important aspects from other OM research strategies, this essay examines in some depth its challenges and possible solutions.

1. Introduction

The operations management (OM) community is widely regarded as a problem-solving discipline, seeking to create knowledge by interacting with the real world (McCutcheon and Meredith, 1993; Lewis, 1998). OM scholars have consistently echoed this sentiment and urged researchers to develop valid and relevant knowledge that can directly or indirectly support managers' problem-solving efforts (Tang, 2015; Boyer and Swink, 2008). Van Mieghem (2013) calls for OM research to increase its relevancy dimensions and urges scholars to move away from the quintessential "ivory tower" syndrome.

1.1. DSR as a research strategy for OM

The new Design Science department at the *Journal of Operations Management* intends to contribute to this objective by publishing original, high-quality and practice-based OM articles using a design science research (DSR) strategy. Inspired by Herbert Simon (1996), DSR is conceptualized as a research strategy, aimed at knowledge that can be used in an instrumental[1] way to design and implement actions, processes or systems to achieve desired outcomes in practice. DSR is driven by field problems or opportunities; instrumental knowledge is developed by deep engagement with these real-life OM problems or opportunities.

DSR's core research products are well-tested, well-understood and well-documented innovative generic designs, dealing with authentic field problems or opportunities. DSR posits that such generic designs have significant practical relevance. In the OM context, they can take a variety of forms, from a highly responsive scheduling system to account for strong demand variations to an approach to manage power conflicts in a supply chain or a model for patient-centered hospital care delivery.

The assessment criteria for Design Science department submissions will be discussed in detail later in this essay. Key criteria, however, cover questions of validity and relevance: (1) How strong is the evidence that the design will produce the desired results (i.e. pragmatic validity)?; and (2) In what way does the design make a valuable contribution to addressing a significant field problem or

[1] The concept of instrumental knowledge use draws on Pelz (1978): it is use of knowledge in a specific and direct way for action or design. This is in contrast to conceptual use, the use of knowledge for general enlightenment on the subject in question.

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exploiting a promising opportunity (i.e. practical relevance)?

DSR can be unfamiliar territory for social science researchers, less so those with a background in practice. For them, DSR presents a natural approach: analyze the problem, design a solution and develop it further in cycles of testing and redesign. DSR, moreover, is widely used in other academic disciplines. As defined above, it is the main research strategy in engineering and medicine and is gaining ground in areas such as information systems (see e.g. Hevner et al., 2004).

1.2. DSR can be regarded as an engineering approach to OM

DSR in operations management can be regarded as a conscientious transfer of the strategy used in engineering research, taking into account the fundamental differences between designing and building a material artifact and designing and realizing a socio-technical system.

Generally OM-systems are socio-technical systems, having both technical and social components. Those with minimal social components (e.g. a fully automated assembly line) largely can be treated as technical systems with a smooth engineering-OM DSR transfer. Other OM systems such as professional services, however, may be almost entirely social systems. The engineering-OM transfer here involves specific and important issues, including establishing the pragmatic validity of designs, generalizing the design, and examining the (social) mechanisms producing system performance. Most OM systems lie between these two, thus a key OM research issue for DSR is dealing with the social components. A key objective of this essay is discussing ways to do so.

1.3. Essay structure

The remainder of this essay flows as follows. In Section 2, we discuss the differences between DSR and explanatory research in terms of research paradigms. In Section 3, we illustrate basic DSR ideas using two OM examples we also will discuss later: the first is predominantly composed of technical components (an assembly line manufacturing setting) and the second predominantly composed of social components (in a hospital health-care delivery setting). In Section 4, we detail DSR's core research product, the *generic design*, together with the *design proposition*, which gives information on where and how the generic design is to be used in practice. In Section 5, we discuss the impact of *human agency* on the design, realization and performance of OM systems and *experiential learning* as a strategy to deal with it. Establishing the *pragmatic validity* of generic designs is discussed in Section 6, the *generalization* issue in Section 7. In Section 8, we discuss *operational issues* when conducting DSR, followed by a look in Section 9 at the *'DSR-add-on'*, the use of a design science approach as an addition to a largely explanatory research project. We conclude the essay with a discussion on the required *documentation* of the design and how it has been tested along with the *criteria* on which Design Science department submissions will be assessed.

2. Research paradigms: DSR and explanatory research

2.1. Two paradigms compared

Most management sciences research, including OM research, is based on the paradigm of explanatory research, the iconic example of which is physics. When using this paradigm, the mission of research is to describe and explain the present (or past) from the perspective of a detached observer. Research according to this approach is a quest for understanding what is, the causal model being the iconic research product. This type of research tends to be a *'science of the average'* focusing on average relations between causes and outcomes and its outcomes are justified on the basis of descriptive and explanatory validity.

DSR, on the other hand, focuses on improving the present. The main stream research strategies of engineering and medicine are the iconic examples of the DSR strategy. DSR takes the perspective of involved actors seeking to improve matters – a doctor needing to deal with a certain medical disorder or an engineer designing a bridge (see van Aken, 2004 on the paradigms issue).

As said, the core research product of DSR is a generic design. The justification of a generic design is based on pragmatic validity, or whether its implementation produces desired outcomes. For instance, does a drug proposed for a disorder lead to the desired recovery, or does an OM system produce the desired performance in practice? Ultimately, DSR is a science of the average (e.g. by developing a certain *type* of bridge) *as well* as a science of the particular, giving knowledge on how to deal with specific contextual issues (such as in designing an instantiation of a bridge over a river with unstable shores). See Section 7 to explore this topic further.

While based on different research strategies, explanatory and DSR are not to be regarded as opposites, rather as complements. DSR projects, in fact, consist of two components, respectively descriptive/explanatory and design/testing. The first provides a solid foundation for the second by cultivating a deep understanding of the field problem for which the second component produces improvement-oriented knowledge.

2.2. The logic of justification in DSR

In explanatory research on the present (or past), justification is about truth, moving from question to answer using logical deduction: this is the research question, this is the research design, and its execution produced these answers. The explanatory validity of these answers is to be proven on the basis of the way outcomes have been obtained.

Logical deduction is possible, when dealing with what *is*, an attribute of explanatory research. Design-oriented research, however, makes a creative jump to what *can be*. A design, therefore, cannot logically be deduced from the problem it is to solve, nor from extant theory or from problem solution specifications.

The justification of a generic design concerns not truth but effectiveness. Justification in DSR goes from answer to question: this is our design (an answer to a design problem), this is how we have tested it in various contexts, and this is how the design solves the problem or satisfies given specifications. The validity of a generic design is, unlike an explanation, not justified on the basis of how it has been made but by proving that it "works."

2.3. Research strategies sharing characteristics with DSR

There are other well-known research strategies, used in OM-research, that share several characteristics with DSR for the social domain. One of them is Action Research (see e.g. Eden and Huxham, 1996; Reason and Bradbury, 2001; Nair et al., 2011; Netland et al., 2015). We must, however, note important differences, mainly that most action research projects aim for case-specific improvements. DSR, by contrast, seeks to develop generic knowledge to support organizational improvement actions.

Another strategy similar to DSR is evaluation research (see e.g. Powell, 2006). This stream is important for DSR because of its contributions to field testing approaches. However, evaluation research normally tests the effectiveness of a given system or process, while field testing in DSR also has a crucial function in optimizing and generalizing a design. For DSR the book *Realistic*

Evaluation (Pawson and Tilley, 1997) is especially informative, because in this book evaluation research has objectives comparable with the ones of DSR.

3. Two examples of DSR in OM

To illustrate this rather abstract discussion on DSR, we give two examples. First, we discuss a fictitious DSR project in a predominantly technical context inspired by an article by Trovinger and Bohn (2005) on PCB assembly. The second example concerns research by Senot et al. (2016) in a largely social context on doctor-nurse collaboration.

3.1. Designing an OM-system with minimal social components

The Trovinger and Bohn article is based on deep engagement in an authentic field problem: the large loss of capacity in PCB assembly due to set-up times that can consume up to 50% of total effective capacity. To reduce set-up times, researchers applied to the process the Single Minute Exchange of Dies (SMED) approach of Shingo (1985). This can be regarded as a contextualization of the generic SMED approach developed for the manufacturing of metal components to the very different PCB assembly process. To handle the vast complexity of the setup procedures, researchers added modern information technology tools such as wireless terminals, barcodes, and a relational database.

Our discussion is fictitious to the extent that we imagine the research project producing this article, which focuses on the design, underlying theory and technical context but details little about the research project itself. A close read on the scant detail there is nonetheless shows the researchers' engagement with the problem and their expertise in solving it with the collaboration of local engineers.

A DSR project typically is driven by a type of field problem, in this case production capacity loss, or an opportunity such as new technology. A context is chosen where this problem is important (or the opportunity has potential) and where its management and other stakeholders are prepared to engage with it in cooperation with researchers in order to develop a solution. After an intake process an improvement project is started. The problem, its context and causes are analyzed, a solution is designed (typically in collaboration with local stakeholders[2]) and tested in the field. The solution is further developed locally, drawing on increasing insights through redesign and testing cycles. In the next stage the design is generalized by using it as a model for making and field-testing similar designs in other contexts (see Section 7 for more information on generalization of designs).

3.2. Designing an OM-system with significant social components

Senot et al. (2016) is based on a multiple-case study on doctor-nurse collaboration at five acute-care U.S. hospitals. While not developed as a design science article, it can be regarded as such *avant la lettre* because it addresses a serious problem – suboptimal doctor-nurse collaboration – then analyzes its nature and causes and presents a promising design for improvement[3]. Physicians and nurses operate in different domains, are driven by different objectives and regulations, have different roles and responsibilities, yet execute interdependent tasks and share a commitment to patient welfare. The design involved a combination of "physician-led cross-level collaboration" and "nurse-led cross-level collaboration" wherein higher-level physician leaders communicate via formal and informal mechanisms with front-line nurses on various issues, including upcoming changes and care-process innovations. Higher-ranking nursing leaders act similarly with front-line physicians. Establishing such connections across disciplinary and hierarchical boundaries, the researchers find, is a simple but potentially powerful approach.

The proposed design needs further elaboration and field testing, but the article still illustrates important aspects of social system design. By itself, this is not fundamentally different from material system design (van Aken, 2014) in that one makes a model of a to-be-realized process or system on the basis of certain analyses and design requirements in a process of synthesis-evaluation cycles. The fundamental differences are the testing of the design "on paper", the actual building of the system, and the degree to which the design determines system behavior and performance. A material system such as a machine or building can be built by a workshop or a contractor more or less exactly as designed. Design-based realization of social systems, however, follows a process of planned change, communicating design contents to the "recipients of change" and motivating them to learn to operate accordingly. The design describes only the formal system, whereas actual system behavior is the result of the informal system, emerging on the basis of the interpretations of the formal system by the recipients of change and their mutual interactions and learning processes (van Aken, 2007).

This evolution process from a designed formal system to a working real life social system makes that social system designs tend to be much less detailed than material system designs (inessential details do not survive this social evolution process) and, furthermore, makes that system behavior and performance strongly depend on the quality of implementation. A generic social system design may simply focus on the core ideas of the design, like the Senot et al. design for cross-level collaboration, leaving much room for practitioners to make their case-specific designs (i.e. by developing case-specific practices).

4. The core product of DSR: the generic design supported by a design proposition

DSR aims to improve, like also consultancy does. However, consultancy aims to improve a local context through case-specific designs, while academic research aims for generic knowledge that can be transferred to various contexts within a specified application domain. Generic knowledge, as we will see, is not transferred as-is; transfer of such knowledge to a given context involves contextualization.

4.1. The generic design and the design proposition

The core product of DSR is the well-tested, well-understood and well-documented innovative generic design that has been field tested to establish pragmatic validity. Logic, extant theory and these field tests have produced an understanding of the (material and social) mechanisms producing the outcomes, while the generic design is well-documented enough to enable practitioners to use it as a model for making case-specific designs.

The generic design is supported by a design proposition, producing insight on where and how the generic design is to be used in the field. The design proposition follows the basic pragmatic logic of:

[2] Another way to develop effective generic designs is to analyze and compare the various designs already made in different contexts to deal with a given type of field problem. In this approach the researchers are not involved in the actual design process. Their contribution, then, is to develop a validated *generic* design.

[3] Senot et al. distilled this design from effective approaches in two of their hospitals.

"if you want to achieve Y in situation Z, then use the generic design X (or perform the action type X): Y = X(Z)".[4]

Design propositions can be formulated using the so-called CIMO-logic (Denyer et al., 2008), which is as follows: For this problem-in-***C***ontext it is useful to use this ***I***ntervention, which will produce through these ***M***echanisms this ***O***utcome. The intervention in OM typically is the implementation of a generic OM system design.

This pragmatic logic, which underpins a DSR article, need not be formulated as a one-liner. The Trovinger and Bohn article can be regarded as a design proposition, even if the authors have not made explicit its basic pragmatic logic, which is: If PCB assembly setup times are regarded as being too long (the field problem in context), our system (the generic design) can be used as a model for you own setup procedures, which will produce significantly shorter setup times. The authors further detail the mechanisms to reduce setup times. Similar logic can be found in Senot et al.

The design proposition, with its action/outcome relation and explanatory mechanisms, can together — with its specified application domain — be regarded as mid-range theory, positioned between the case-specific and the universal.

Beyond the generic design and the design proposition, several other DSR outcomes are possible. A DSR project can explore fundamentally new approaches to a certain issue without producing well-defined generic designs. A DSR article also can present a methodological innovation, e.g. approaches for field testing generic designs in volatile environments.

4.2. The use of generic designs in the swamp of practice

The generic design can be regarded as a product from the "high ground of theory" to be used in the ever-changing, underdetermined and insecure "swamp of practice" (terms, coined by Schön, 1983).

Designing seldom is fully radical, producing a totally new product. Most designing produces a variant of a design model that fits the given assignment. For example, a civil engineer seldom designs a radically new bridge, but in most cases uses a carefully selected and well-documented type of bridge as a design model for a context-specific instantiation. A generic design for OM systems is to be used as a *design model* by well-trained and experienced designers to make their own context-specific designs. In this contextualization they take into account the nature of their own "swamp," something that never can be done from the high ground of theory.

5. Dealing in DSR with human agency impact

Many OM systems have significant social components, e.g. the doctor-nurse collaboration from Senot et al. However, OM systems of a largely technical nature may also have social components, for example if they need frequent interventions from operators, while maintenance, learning and continuous improvement can cause further human agency impact. As a result, system behavior and performance cannot be predicted with full certainty, thus applying DSR to OM system research may present a number of issues not present or less important in the engineering world. These include the gathering of evidence on pragmatic validity of the design, the generalization of the design and the determination of the (social) mechanisms producing performance.

5.1. Strong mechanisms versus weak ones

These issues are not present, or less important, in the design of material systems because in the material domain there are invariant, universal, individual behavior-determining mechanisms linking cause with effect, action with outcome. These will be called *"strong mechanisms"* (van Aken, 2014). Galileo, for example, needed only one drop test to prove that light balls fall equally fast as big ones. The moon has no freedom to deviate from its orbit; its behavior can be predicted with certainty.

Because of human agency, there are no comparable strong mechanisms in the social domain. There exist regularities and patterns in human behavior, yet it is governed by "weak mechanisms" that are neither invariant nor universal, which influence, but do not determine, human behavior (Pajunen, 2008; Hedström and Ylikoski, 2010). System behavior and performance, therefore, cannot be predicted with the same degree of certainty as material systems, making establishing a design's pragmatic validity more difficult. Furthermore, as human behavior is strongly influenced by context and human relations, OM systems with significant human agency impact tend to be much more context-dependent than technical systems. This makes the generalization of a design more difficult. Finally, the social mechanisms producing performance are less tangible than material mechanisms and, therefore, may be harder to establish.

5.2. Experiential learning as a strategy to deal with human agency impact

The weak mechanisms of the social domain still enable the prediction of social behavior, be it with less certainty than possible with strong mechanisms. In fact, the prediction of the behavior of others in response to one's own actions is an almost universal human competence — without it, intentional social behavior would be impossible. The extent to which this competence is universal can be seen in people, lacking this competence because of an autistic disorder.

Personal social experiential learning develops this ability, i.e. learning from personal experiences (see Kolb, 1984; Kolb and Kolb, 2005). It is subsequently applied through case-based reasoning wherein the present setting is compared — typically unconsciously — with similar prior experiences and a line of action is chosen on the basis of prior outcomes.

Personal learning is limited by the scope of one's personal experiences, yet experiential learning also can be the basis of a research design: *systematic and methodical experiential social learning*. Research as experiential learning entails learning on the basis of a series of case studies centered on a specific type of field problem, producing "thick" descriptions and analyses of problem, context, interventions and outcomes. Subsequent thorough cross-case analyses produce insight in what is case-specific and what is generic, i.e. what also can be used successfully in other contexts.

If the human agency impact on a given OM system is limited, structured data gathering and mathematical modeling can be powerful approaches to analyze and test designs "on paper". If human agency impact is significant a learning strategy, using multiple case studies, may be more appropriate.

6. Establishing pragmatic validity

In any research effort, outcome validity is a key issue (Maxwell, 1992). In explanatory research this validity issue centers on truth: Is

[4] One can also have design propositions as general recommendations, like "never marry your first design idea." Design propositions supporting generic designs, as discussed here, however, are formulated on the basis of a concept from the philosophy of technology viz. The *technological rule*. This is "an instruction to perform a finite number of acts in a given order and with a given aim" (Bunge, 1967, p. 132).

the given explanation true, or at least credible? In DSR, validity centers on effectiveness: Does the realized design "work?" Does it produce the desired outcome or performance[5]? In the explanatory component of a DSR project, the issue also is truth (revisiting the Senot et al. article, is the analysis of the causes impeding doctor-nurse collaboration true?). In the design science component, however, the issue is the future effectiveness of a system or process (Can the proposed cross-level communication indeed improve doctor-nurse collaboration?).

The impact of human agency on the behavior of some OM systems can be small. If the technical context dependency is as well, quantitative modeling can provide important contributions to the body of evidence on performance. (Even then, it will be interesting to know how operators, managers and other stakeholders regard the system and how this may influence its performance). However, when human agency impact is significant or technical context dependency difficult to model, system performance prediction is not straightforward and future performance cannot be proven in the traditional sense. Here, the pragmatic validity of a generic design is to be justified on the basis of a strong body of evidence.

This body of evidence is to be compiled through field testing a number of instantiations of the design within the intended application domain. In most cases, this involves rigorous case-studies using methods such as controlled observations, triangulation, "thick" descriptions, careful cross-case analyses and member checks. In DSR, field testing is key, often beginning with alpha testing (testing by the designers themselves) followed by beta testing (testing by third-party stakeholders). Field testing may be complemented by "peer reviews" or focus group discussions with experts, operators and other stakeholders. Both can produce valuable additional information on pragmatic validity and practical relevance.

Pragmatic validity and practical relevance do *not* present a trade-off; more relevance does not imply less validity. In explanatory research, increasing the practical relevance of a quantitative causal model by aiming for a broader explanation may decrease its explanatory validity (the truth of the explanation of a phenomenon somewhere in the past). However, in DSR, the pragmatic validity of a generic design refers to the outcomes of its future use. One may aim to increase the practical relevance of a generic design by giving more details on it or on its possible implementation process, yet absent a "mechanistic" link between the generic design and specific instantiations, more information does not decrease pragmatic validity. Researchers can strive for maximum relevance as far as they can.

The pragmatic validity of a generic design refers to the question of whether it will work after contextualization and implementation. If there is no human agency impact on performance, one may be able to "clone" the generic design for use in other contexts and obtain full proof on future performance. In the case of significant human impact on performance, however, the pragmatic validity of a generic design is to be shown on the basis of "saturated" evidence (see Section 8) supporting the claim that experienced professionals are able to use it and implement systems with the desired performance. This evidence mostly is collected through a number of case studies in which the generic design is contextualized and tested.

[5] In this essay the "effectiveness" of a realized design is used as a container concept, covering all design requirements designers (or their principals) may want to use, such as a required functionality or system performance or effectiveness plus efficiency.

7. Generalizing designs

Both explanatory research and DSR aim at generic, rather than case-specific, research outcomes. In explanatory research, a generalization typically is founded on analyses of random samples from well-defined populations. Generalization, then, means generalizing a finding in a sample *as it is* to the whole population. This is a simple step in a logical argument, possible if the sample has been drawn correctly.

7.1. Generalization in DSR

In DSR, generalization works differently. A generic design is a design that can be transferred (within a certain application domain) to contexts other than the ones in which it has been made and tested without losing its basic effectiveness. Transfer is done using the generic model as a design model for making context-specific designs. For instance, a claim on generality for the Trovinger and Bohn (2005) design could be that setup times can be significantly reduced when experienced designers use it as a design model for making case-specific designs for all (or certain types of) PCB assembly operation setup systems.

The difficulty of generalizing a design depends on the impact of context variations on system performance. For OM systems with minimal social components, experienced designers may handle context dependency without much further support from research. This is chiefly because technical factors causing context dependency tend to be more tangible than social ones (indeed, this seems to be the case for the Trovinger and Bohn design). Human agency impact on system performance, meanwhile, may be limited once its operators have been sufficiently trained in the new procedures. Furthermore, one may expect that their design gives experienced professionals sufficient information to use it as a model for their own efforts in reducing set-up times in PCB-assembly. Trovinger and Bohn even provide an example of design transfer from one context to another: The authors transferred and translated Shingo's SMED approach from metal component manufacturing to PCB assembly.

For OM systems with significant social components, design generalization requires serious effort, as is the case for the Senot et al. design. Their alpha and beta design testing in a number of other hospitals will produce valuable knowledge for the further articulation of a generic design to promote doctor-nurse collaboration. This testing also will produce a body of evidence on pragmatic validity as well as context dependency. Generally speaking, in case context variations cause significant variations in system performance, a design can be generalized by testing it in a number of cases representative of the intended application domain. Results are subsequently used for conscientious cross-case analyses in order to strip the design down to its generic essentials: what is specific to the context of the specific instantiation and what is generic and transferrable. Practitioners can use the resulting generic design as a model to make context-specific instantiations, mirroring the use of the SMED approach for the PCB assembly procedure design.

7.2. Generalization in DSR produces a need for the science of the particular

Cross-case analyses are not only useful to develop "science of the average", in this case a generic design. They also can yield "science of the particular" by shedding insight on the nature and causes of deviations from the average. Indeed, professionals typically need results from both. Explanatory research, however, tends to produce the former, focusing on average relations between causes and outcomes. This may be sufficient for detached observers, but practitioners focus on expected outcomes in their specific case. Average outcomes nonetheless may be informative enough if their contextual variance is limited and if the practitioner has sufficient "clinical" experience to properly contextualize the average intervention or system. In medicine, for example, Random Controlled Trials (RCTs) are regarded as the gold standard for determining the effectiveness of certain medical interventions despite only providing average outcomes; physicians are left to contextualize these average outcomes for particular patients.

OM designs with significant context dependency, by contrast, require information on context-driven deviations from average outcomes in addition to information on the average behavior and performance of the generic design. For DSR, a science of the average as well as the particular, knowledge on the particular comes from testing the design in various contexts, followed by analyzing the deviations from the average. Information on contextual deviations from average outcomes may be given in the form of "if –then" instructions, yet this is not always possible or necessary. General "user instructions" on context dependency may be enough for experienced professionals.

8. Operational issues when conducting DSR

Because DSR is as yet an uncommon research strategy, we will now discuss a number of operational issues in conducting DSR.

8.1. The two components of a DSR-project

As stated in Section 2, every DSR project has an explanatory and design component. By the former, the chosen problem type, its causes and contexts are analyzed. By the latter, a generic design for addressing the problem is developed in design-testing-redesign cycles. These two components are unequal in length and effort. If the field problem in question (or nature of the new opportunity) is well-studied, the explanatory component may be limited. If not, it requires significant effort, which may limit ambitions for the design component, maybe even to a "DSR add-on" (see Section 9).

These two components are not separate phases in the project timeline, requiring one to be completed before the other begins. On the contrary, it is important to begin soon after project launch with sketching rough outlines of possible alternative designs. Doing so yields insight on the descriptive and explanatory knowledge to be produced by the explanatory component of the project to enable sound designs and design choices by the design one.

8.2. Testing designs

Field testing is a key element of any DSR project. This requires the design and implementation of a number of context-variant instantiations of the OM generic system under consideration. Each instantiation is tested on effectiveness and other relevant criteria.

Testing must produce input for redesign, first to optimize and later to generalize the design. Once the design has been finalized, field testing must produce evidence of pragmatic validity. It is the quality of field testing (not design[6]) that determines the scientific rigor of the research. Field testing produces the body of evidence on the basic scientific claim of DSR: that applying the generic design will produce the desired outcomes. In field-testing documentation, it is also important to outline the role of the researcher, showing what has been done to assure the objectivity of testing procedures. Beta testing can achieve this, but even then, the researcher may influence test outcomes.

Another issue at hand is the exclusion of rival explanations for positive test results: these may not be the result of the tested interventions. Much like listing medication side effects, one also must document possible less-desirable outcomes. Unsuccessful tests must be documented as well, not only for reasons of objectivity but because they can assist practitioners in selecting design models and identifying potential implementation issues. Presentation of the generic design to focus groups consisting of OM designers and/or system users can yield important additional insight on its value.

A final issue in testing is that one should aim to test short causal relations between intervention and outcome – in other words, test for direct outcomes rather than for ultimate ones. One may, for instance, want to test a new system for managing product development, promising a significant reduction in time to market. This may be motivated by a desired sales increase, yet directly linking the new system to revenue may prove difficult because of the many other factors at play. The researcher's task is to *only* produce evidence of the direct outcome of the system – i.e. development time reduction – combined with an in-depth discussion on its possible ultimate outcome with respect to sales (which may be largely based on the literature).

Field tests are intended to produce a "saturated body of evidence" on the pragmatic validity of a generic design. "Saturation" is an instance of the law of diminishing returns.[7] Testing procedures produce "saturated evidence" on the effectiveness of a generic design if further testing no longer produces results that add value to the already obtained body of evidence. Thoroughly field testing is very important in DSR, but the assessment of the presented body of evidence ultimately is a judgment call by editors, reviewers and others in academia. Over time, a kind of case law on the "saturated body of evidence" will develop.

8.3. Establishing the mechanisms producing outcomes

An important but often difficult issue concerns the mechanisms producing outcomes. Unfortunately, no straightforward approach exists for establishing the material and social mechanisms producing the outcomes and performance of a generic design. Neither is there one for gathering evidence on how these mechanisms affect outcomes and performance. Establishing mechanisms is rather a matter of 'bricolage',[8] combining one's social and technical expertise, logic, generic explanatory theory on the phenomena in play and conscientious cross-case analyses of design instantiations. This may be enough to produce sufficient insight in the most important mechanisms. If not, it may be needed to invest additional effort in explanatory research, targeted on one or more possibly important mechanisms.

9. The design science research add-on

Developing design science can be the objective of a research project right from its start. But it may also be that one has produced

[6] The *rigor* of DSR (related to its core scientific claim concerning the effectivity of a proposed design) is not the same as the *quality* of the design. Quality depends, among other things, on the quality of the design process, its inputs and its designers, but none of these guarantees the resulting design will work – field testing does. Furthermore, a design question is an open one; there are always multiple good answers possible. One never can claim to have designed the best possible one.

[7] See e.g. Eisenhardt (1989) on saturated evidence in case-study research.

[8] See e.g. Lincoln and Denzin (2000) on bricolage as an approach for making research designs. A "bricoleur," a French word, is a handyman, doing his jobs using clever selections from his toolbox. They used this as a metaphor for qualitative research designs, using combinations of well-chosen methods depending on the nature of the research question.

valuable explanatory knowledge and now wonders how this knowledge might be used in practice. This can lead to a 'DSR add-on'. Such an add-on may be regarded as a more elaborate version of the management implications often given at the end of an article in an academic management journal.

A DSR add-on differs in at least three significant ways from the more common discussions of management implications, which can be little more than an afterthought. First, and most importantly, it provides more than understanding of the problem or the new technology, instead focusing on actions/designs in order to get desired outcomes. This action orientation is to be supported by an actor perspective: Who is to execute the action or take the initiative and responsibility for the design and implementation of a system? For the Trovinger and Bohn case, the actor perspective is clear. One expects in PCB assembly a clear managerial hierarchy where operations managers must play a key role in projects on setup time reduction, usually also involving engineering, product development and higher-level management. This might be, however, less clear in the Senot et al. design. Should the design and introduction of the new system of cross-level communication be a joint venture of doctor and nurse leadership and should higher-level hospital managers become involved to ensure sustainable success? Or on the contrary, should one try a more bottom-up approach? These issues can affect design details and system implementation, as implementation quality is crucial for the success of designed social systems. For a DSR add-on, a thorough analysis of the issues of actor perspective may not be possible, but some attention should be devoted to them.

Secondly, some kind of field testing of the proposed action or design is essential. Full field testing may not be possible for a DSR add-on, but a pilot implementation on a small scale or partial field test may be possible. Additionally, discussing the proposed actions or designs with focus groups of experts and knowledgeable practitioners can be very informative and lead to better and more relevant management implications. In fact, the common process of "testing" the value and validity of an academic research contribution through peer review is a comparable process. Even limited testing can at least ensure the design deals with an authentic field problem and has a certain level of credibility.

Thirdly, a DSR add-on articulates as accurately as possible the pragmatic logic of the management implication presented: the action or design, its application domain, its desired outcomes (the specification of which often proves to be a far from trivial issue) and the mechanisms that may bring about this outcome in the intended context. These articulations can yield much additional insight; in particular, knowledge of the mechanisms involved can further inform the detailing of the proposed action. It is even possible that the work on the DSR add-on proves to be so interesting and rewarding to the researchers that they decide to pursue full DSR.

Submissions of explanatory articles on issues of significant value for practice, combining these insights with a sound add-on, also are eligible for submission.

10. Submissions to the design science department

10.1. The key elements of a DSR-article

The key element of a design science article typically is an innovative generic design for an action, process or system dealing with an authentic OM field problem or opportunity. It is preferably well-tested, well-understood and well-documented and supported by a design proposition (explicitly or only implicitly, as in Trovinger and Bohn): the problem in context, the design, expected outcomes and the material and social mechanisms producing these outcomes in the intended application domain.

The design is to be described in sufficient detail that practitioners can use it as a model in their designing. Trovinger and Bohn might have presented more details on their design but they provided enough detail to enable experienced professionals to design their own setup procedures. Of additional interest will be information on the design process, its inputs (problem and context analyses, relevant literature), possible design principles used, decision-making on design adoption, and implementation and learning curve issues. Feasible design alternatives to the design also can be of interest for both academics and practitioners as they can highlight the unique or attractive properties of the design.

10.2. The criteria to be used in assessing a DSR-submission

Generally, DSR-articles will be assessed on the following criteria:

- Provides a new and valid answer (called below the generic design) to an authentic type of OM field problem or presents sound ways to use a new technology;
- Gives a generic design that can be used as a model for designing within a given application domain;
- Is based on solid analyses of the field problem in question or of a new promising technology, uses the relevant extant literature and adds new insights;
- Produces a saturated body of evidence on the pragmatic validity of the generic design;
- Sheds insight on the material and social mechanisms producing these outcomes;
- Gives ample attention to the design, design approach and process, design process inputs, implementation, and feasible alternatives.

The department also will accept: high-quality explanatory articles combined with a sound DSR add-on; or articles only dealing with a significant issue in making sound generic designs for a type of field problem; or articles contributing to the further development of DSR methodology.

10.3. Practical and academic relevance

An article in an academic journal for a professional discipline must add to the extant literature and combine practical relevance and academic relevance. The basic idea of DSR is that new generic designs, with the properties as described above, do have significant practical relevance.

Academic relevance, in our opinion, means the article is relevant for teaching and/or research. In teaching, academics in OM want to share with their students effective and well-understood approaches to issues in the field. The generic designs discussed here support just that.

Research relevance may imply a somewhat contradictory requirement as research is inspired exactly by what is *not* yet known or understood. However, this is not a real contradiction. Like in every engineering discipline, a good and important design is a challenge for research to design better ones. A new design also may not yet be fully understood, thus follow-up research on mechanisms driving the new system's performance may be worthwhile. A good design is a pair of shoulders upon which the next generation of researchers can lean. The much-vaunted process of knowledge accumulation may be easier to realize in DSR, with its drive for improving extant generic designs, than in other areas of social science research.

11. Conclusion

DSR is a domain-independent research strategy focused on developing knowledge on generic actions, processes and systems to address field problems or to exploit promising opportunities. It aims at improvements based on a thorough understanding of these problems or opportunities. It is not a specific method with fixed rules; rather, it is a strategy that can be operationalized in various ways.

Though a strongly practice oriented research strategy, DSR as academic research differs from much practitioner work in its aim for generic designs, emphasis on establishing the (pragmatic) validity of a generic design, and a drive to understand the workings of the design, i.e. the material and social mechanisms producing outcomes and performance.

DSR is a research strategy. The differences with the more common explanatory research strategy lie at the level of strategy. There are, in principle, no differences at the tactical level of methods for data gathering and data analysis; DSR does not need specific methods at this tactical level.

Experienced researchers, for whom DSR is a new research strategy, might encounter two hurdles. The first is in seeing that a well-tested, well-understood and well-documented innovative generic design also can be a valuable product of academic research, much like in engineering and medicine. In case the design has important social components, the second hurdle is to develop effective ways to deal with the consequences of human agency for establishing the pragmatic validity of a generic design, generalizing a design, and understanding the mechanisms driving system behavior and performance.

DSR in the social domain is a still-developing research strategy, also in OM. Submissions accepted in the first years of the department may not meet all the criteria given above. Furthermore, the editors will support further development of promising submissions.

In engineering and medicine there exist a strong partnership between research and practice. The aim of the coming development period is to contribute to the creation of a similar partnership in OM.

References

Boyer, K.K., Swink, M.L., 2008. Empirical elephants—why multiple methods are essential to quality research in operations and supply chain management. J. Op. Manag. 26 (3), 338–344.
Bunge, M., 1967. Scientific Research II: the Search for Truth. Springer Verlag, Berlin.
Denyer, D., Tranfield, D., Van Aken, J.E., 2008. Developing design propositions through research synthesis. Organ. Stud. 29 (2), 249–269.
Denzin, N., Lincoln, Y., 2000. Handbook of Qualitative Research, second ed. Sage, Thousand Oaks, CA.
Eden, C., Huxham, C., 1996. Action research for the study of organizations. In: Clegg, S.R., Hardy, C., Nord, W.R. (Eds.), Handbook of Organization Studies. Sage, London.
Eisenhardt, K.M., 1989. Building theories from case study research. Acad. Manag. Rev. 14, 532–550.
Hedström, O., Ylikoski, P., 2010. Causal mechanisms in the social sciences. Annu. Rev. Sociol. 36, 49–67.
Hevner, A.R., March, S.T., Park, J., Ram, S., 2004. Design science in information systems research. MIS Q. 28/1, 75–105.
Kolb, D.A., 1984. Experiential Learning: Experience as the Source of Learning and Development. Prentice-Hall, Englewood Cliffs, NJ.
Kolb, A.Y., Kolb, D.A., 2005. Learning styles and learning spaces: enhanced experiential learning in higher education. Acad. Manag. Learn. Educ. 4 (2), 193–212.
Lewis, M.W., 1998. Iterative triangulation: a theory development process using existing case studies. J. Op. Manag. 16 (4), 455–469.
Maxwell, J.A., 1992. Understanding and validity in qualitative research. Harv. Educ. Rev. 62 (3), 279–300. Fall 1992.
McCutcheon, D.M., Meredith, J.R., 1993. Conducting case study research in operations management. J. Op. Manag. 11 (3), 239–256.
Nair, A., Malhotra, M.K., Ahire, S.L., 2011. Toward a theory of managing context in Six Sigma process-improvement projects: an action research investigation. J. Op. Manag. 29 (5), 529–548.
Netland, T., Ferdows, K., Sanchez, E., 2015. How company - specific production systems affect plant performance: the S - curve theory. Prod. Op. Manag. 24 (3), 362–364.
Pajunen, K., 2008. The nature of organizational mechanisms. Organ. Stud. 29/11, 1449–1468.
Pawson, R., Tilley, N., 1997. Realistic Evaluation. Sage, London.
Pelz, D.S., 1978. Some expanded perspectives on the use of social science in public policy. In: Yinger, M., Cutler, S.J. (Eds.), Major Social Issues: A Multidisciplinary View. Free Press, New York, pp. 346–357.
Powell, R.R., 2006. Evaluation research: an overview. Libr. Trends 55 (1), 102–120.
Reason, P., Bradbury, H. (Eds.), 2001. Handbook of Action Research: Participative Inquiry and Practice. Sage, London.
Schön, D.A., 1983. The Reflective Practitioner. Temple Smith, London.
Senot, C., Chandrasekaran, A., Ward, P., 2016. Collaboration between service professionals during the delivery of health care: evidence from a multiple-case study in U.S. Hospitals. J. Op. Manag. 42–43, 62–79.
Shingo, S., 1985. A Revolution in Manufacturing: the SMED System. Productivity Press, Cambridge (MA).
Simon, H.A., 1996. The Sciences of the Artificial, third ed. the MIT Press, Cambridge (MA).
Tang, C.S., 2015. OM Forum—making OM Research More Relevant: “Why?” and “How?”. Manufacturing & Service Operations Management.
Trovinger, S.C., Bohn, R.E., 2005. Setup time reduction for electronics assembly: combining simple (SMED) and it-based methods. Prod. Op. Manag. 14/2.
Van Aken, J.E., 2004. Management research on the basis of the design paradigm: the quest for field-tested and grounded technological rules. J. Manag. Stud. 41 (2), 219–246.
Van Aken, J.E., 2007. Design science and organization development interventions: aligning business and humanistic values. J. Appl. Behav. Sci. 43/1, 1–17.
Van Aken, J.E., 2014. Two hurdles to take for maximum impact of design science research in the is-field. In: Helfert, M., Donnellan, B., Kenneally, J. (Eds.), Proceedings of the European Design Science Symposium 2013. Springer, Dublin. Heidelberg.
Van Mieghem, J.A., 2013. 3Rs of OM: research, relevance and rewards. Manuf. Serv. Op. Manag. 15 (1), 2–5.