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Opportunities for developing the science of operations and supply-chain management

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ABSTRACT

In a separate paper (Singhal and Singhal, 2011b), we identified two sets of opportunities for radical innovations in operations and supply-chain management (O&SCM): pursuing all phases of science and pursuing multiple perspectives. In this paper, we propose and analyze ways to accomplish this task. A network of research teams can be effective in obtaining multiple perspectives and discovering radical innovation if it conducts intensive research over an extended period. Outliers are a source of multiple perspectives and innovative ideas and can help in identifying and addressing risks. Similarly, meta-analyses and syntheses of published works can provide multiple perspectives and lead to radical innovations.

1. Introduction

1.1. The need to pursue all phases of science and multiple perspectives

In a separate paper (Singhal and Singhal, 2011b), we identified two major opportunities in academic research in O&SCM: First, there is an opportunity to pursue all phases of science, including exploratory and qualitative research, developing theories, causation and internal validity, and testing models and theories for external validity (the ability to generalize knowledge to other situations). Second, there is an opportunity to pursue multiple perspectives because a scientific conclusion valid for a narrow domain may prove to be partially true or false if one obtains multiple perspectives. Multiple perspectives can be obtained by investigating different parts of the system, by employing different methods of analysis, by using different sources of data, or by using different subsets of the same data. Multiple perspectives also have the potential for obtaining new insights and for finding a new paradigm (or a new punctuated equilibrium) in research, in the system being investigated, or in both.

In this paper, we describe specific approaches for pursuing all phases of science and multiple perspectives. The paper is organized as follows: In Section 2, we describe various phases of science from exploratory research to verification of models and theories. We also address the role of fundamental tools and instruments and the role of knowledge drawn from other fields and from multiple countries in developing any science. In Section 3, we describe three situations for organizing networks of research teams to pursue radical innovation in individual topics, supply networks, and multiple industries. In Section 4, we outline the roles of outliers in radical innovation and risk management, and we emphasize the importance of analyzing such outliers as industries with unusual characteristics. In Section 5, we describe the roles of meta-analysis and synthesis of published works. In Section 6, we highlight some points covered in the paper, outline the steps needed to implement our proposals, and offer a long-term perspective.

2. The phases and the facilitators of the science of O&SCM

Academic research in O&SCM is currently dominated by mathematical models and by hypothesis testing based on mail surveys in spite of new areas like behavioral operations. The academic community has an opportunity to cover all phases of science: exploratory and qualitative research, development of theories, causation and internal validity, and external validity with model testing and with multiple perspectives. It can also expand the role of other research paradigms, fundamental tools and instruments, and knowledge from other fields and other countries in development of the science of O&SCM.

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2.1. Exploratory and qualitative research

Exploratory research is usually qualitative and, in some cases, qualitative research in itself can be a new theoretical development. Langley et al. (1987, p. 195) remind us that the "discovery of quantitative laws has generally been preceded by the discovery of qualitative relations. Early physicists noted that colliding objects tended to change velocities before they determined the exact form of the relation, and plant and animal breeders knew that certain traits were passed on to offspring long before Gregor Mendel formulated the quantitative principles of inheritance. . . . (In chemistry), qualitative laws of reaction were discovered decades before numerical relations were determined." On the history of the theories of acids and bases, they add that during the 17th and 18th centuries, "chemists made considerable progress in classifying substances on the basis of qualitative properties (Partington, 1961–1962). Researchers focused on such features as the tastes and textures of substances as well as on their interactions with other substances."

In a journal-article length account of research, particularly research performed by one individual or a small team, it is almost impossible to make a contribution that covers all phases of science from exploration to theory and data (or data and theory) to empirical testing. A new topic can rarely be developed without some exploratory study, and descriptions of exploratory studies do not meet the current editorial requirements, which seek some "scientific adulthood" (or "normal science" in Kuhnian terms) in such forms as models or testing of hypotheses. Once the early development of new topics is ruled out as a subject for publication, thus eliminating any radical innovations they could contain, the "normal science" consists mostly of (a) marginal extensions of what has been published or (b) induction models based on a single case in the real world. Relying on a single data point from the real world to develop a model or framework rarely provides much supporting evidence of scientific validity. Albert Einstein asserted (Hanson, 1965, p. 119), "There is no inductive method which could lead to fundamental concepts of physics."

Furthermore, most of the pioneering qualitative contributions in O&SCM during the last five decades were not published in leading research journals, but in the *Harvard Business Review*, for example, Chase (1978), Fisher (1997), Hayes and Wheelwright (1979a,b), Skinner (1969, 1974), and Starr (1965). Recently, there have been some exceptions, for example, Hayes and Pisano (1996).

In some management science cases, qualitative relationships, besides leading to promising new areas of research, can be the culmination of research and some of them have a tremendous impact. Robert Fetter's work (1991) on Diagnostic-Related Groups (DRGs), which won the 1990 INFORMS Edelman award for the best management science application, was based on the classification of various medical diagnoses similar to chemists' classification of substances on the basis of qualitative properties during the 17th and 18th centuries. It has saved "more than $50 billion in Medicare hospital payments through 1990" alone and more "than 20 countries are currently developing or have adopted DRG-based systems for managing and financing hospital care." However, an account of the original work was not published in any leading research journal in O&SCM or any other field, presumably because leading research journals in O&SCM do not welcome papers that do not include intense mathematical or statistical analyses.

2.2. Development of theories and empirical evidence

No evidence in the management science shows that theory-driven research is more effective than data-driven research or vice versa. Both are important. The current preference for empirical research expressed by leading journals in O&SCM essentially represents a backlash against the past dominance – and to some extent, the current dominance – of mathematical modeling. The development of theories and models and of their verification, have three complementary aspects.

First, a theory is more than a model and it should be empirically verified in the real world (Diesing, 1971, p. 31). Pierre Maurice Marie Duhem, a philosopher of science, wrote in 1897 (Hanson, 1965, p. 201), "The experimental verifications are not the basis of the theory, but its culmination."

Second, Hanson (1965, p. 90) looks at theories from the opposite end, "A theory is not pieced together from observed phenomena; it is rather what makes it possible to observe phenomena as being of a certain sort, and as related to another phenomena. . . . A theory is a cluster of conclusions in search of a premise." Model-based theories in O&SCM serve as effective means of observing and analyzing real-world situations.

Third, a theory can be useful even if it is not supported by evidence. Langley et al. (1987, p. 19) focus on the bright side of incompatibilities between theory and data: "Failure of data to support theories leads, in turn, to the formulation of new theories. It is generally agreed, however, that the actual sequences of events are less regular. Data may be gathered without clear theoretical preconceptions, and theories may be retained, especially in the absence of viable alternatives, even after some predictions have been disconfirmed."

2.3. Causation and internal validity

One can pursue a chain of causes, that is, the cause of the cause of the cause, and so forth, in a specific situation because one knows the context for each chain in the link. This is how fishbone diagrams are used. However, the pursuit of chains of causes is neither feasible nor necessary in academic research in the science of management because a researcher is not likely to know the various contexts for the links. Hanson (1965, Chapter 3) starts with the example of the "loss of the kingdom" "for want of a nail" and discusses the chain of causes in another example (p. 54), "The primary reason for explaining the cause of x is to explain x. There are as many causes of x as there are explanations of x. Consider how the cause of the death might have been set out by a physician as 'multiple hemorrhage', by a barrister as "negligence on the part of the driver', by a carriage-builder as 'a defect in the brakeblock construction', by a civic planner as 'the presence of tall shrubbery at that turning.'" Thus, in academic research in the social sciences and the science of management, it is sufficient to deal with only one link of causation and to explain a phenomenon in several contexts to develop a contingency theory for that link. For example, one can explain that the possible causes of x are a, b, c, and d, but going beyond that may not be possible because one might not know the four sets of contexts for determining the causes of a, b, c, and d. If indeed, academic researchers needed to explain the cause of, say, b, they could do so. Since management is an art, it is up to the manager to use these findings to decipher the chain of causes in a specific situation because she would know the exact contexts for each link in the situation she faced.

2.4. External validity: empirical testing of models and pursuit of multiple perspectives

Langley et al. (1987, p. 39) point out that the "problem of testing scientific theories for their validity is a natural descendent of the problem of deduction." Yet, most mathematical models are not tested extensively in the real world. Testing is more critical in the science of management than in physics. Physics deals with homogeneous entities and follows "the law of uniformity of nature," while many parameters in the science of management differ from