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Rethinking Management of Technology

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Abstract

This paper discusess how management of technology can be made more critical and a new method of reasoning is incorporated into this dicsipline to stimulate more widely application. Management of technology is found as a discipline that practitioners or academics need to have in order to be able to manage and improve technology. It relies on two streams of reasoning called deduction and induction. These two reasoning methods tends to neglect the human need to make sense and therefore fails to stimulate critical thinking of how to extract meaning from complex reality surrounding technology. It is suggested that abduction is the missing link in managemet of technology which is capable to combine the predominant strands of induction and deduction. Based on abductive thinking, TechnoValue is developed as a methodology to gain understanding the general statements when and how new technology creates value to all related stakeholders. Future research is also presented in this paper.

Keywords: management of technology, induction, deduction, abduction, information technology

Introduction

Companies are progressively experiencing a quantum leap of technological innovation. The impact of the most technological developments is profound on the way companies work The spread of technology is also increasing at an ever-growing rate to invade companies' lives not only at an economic level but

also in psychological terms. Companies have to watch technological developments and plan technological adoption in order to take advantage from the flood of technological innovation.

Management of Technology (MOT) has thus received a great deal of attention from practitioners and scholars. Researchers have reported that companies implementing a MOT approach may gain a number of positive benefits, including increased profitability, reduced costs, service quality, and product innovation. MOT has recently grown as a distinctive body of knowledge (Lowe, 1995). It primarily accumulates its body of knowledge based on inductive and deductive reasoning. However, MOT literature focuses almost exclusively on the knowledge of technology consisting of formalised and practical knowledge. Very little attention has been paid to consider human as a main reason for technological innovation, especially the human need for sense making.

MOT provides a relatively unexamined setting for the influence of human on the adoption of technology. The traditional conceptualization of MOT encompassess both commitment to apply formalized knowledge into solving technological problems and to draw new insights from practical knowledge of managing new technology. Given these two streams of reasoning, MOT almost neglects the way people making sense of their organizational settings in the presence of technology. MOT tends to provide formalized knowledge which are not able to assist people in coping with ill-defined problems. Practical knowledge is also limited to past experience and often costly to experiment with early alternative teachnology that help them understand the current problems. Deduction from formalized knowledge and induction based on practical knowledge are not sufficient in the information age. A new approach is required to incorporate ways to deal with ill-defined problems and unorganized information, real world phenomena, and complex human knowledge which go beyond prevalent formal induction and deduction.

Therefore, this study proposes to examine MOT as a discipline that needs abductive reasoning as a basis for tools that help in the derivation of new knowledge. Abductive reasoning enables people in organizations to make sense the integration of technology and organizational rules which influence how people behave in adopting and employing technology.

Definition of technology

The word technology stems from the Greek 'tekhnologia' which means the systematic treatment of an art or craft (i.e., techne is an art or skill and logia is science or study). Relating to this definition, *the Oxford English Dictionary* considers technology as “the scientific study of the practical or industrial arts”. This definition is limited to the historical usage of technology. Public views technology as the practical way of doing things to accomplish objectives. Technology can be the knowledge, products, processes, tools, methods, and system employed in the creation of goods or in providing services.

Many definitions have been proposed to describe technology for the purpose of analysis (Lowe, 1995). People define technology ranging from the stock and application of scientific knowledge, processes, instruments and equipment, and computer software. For example, Dosi (1984) defines technology as a set of pieces of knowledge, both practical and theoretical, know-how, methods, procedures and physical devices which incorporate such knowledge. In an attempt to resolve the explicit boundary's problem of technology, Lowe (1995) proposes a working definition of technology as “the structured application of scientific principles and practical knowledge to physical entities and systems”. He also identifies that the constituents of specific technology consists of know-how, techniques, scientific principles, equipment, and organization.

In a more succinct definition, Zeleny (1986) argues that any technology consists of three interdependent, codetermining, and equally important elements:

- Hardware: the physical structure and logical layout of the equipment or machinery that is used to carry out the required tasks.
- Software: the knowledge of how to use the hardware in order to carry out the required tasks.
- Brainware: the reasons for using the technology in a particular way. This may also be referred to as the know-why.

Khalil (2000) adds the fourth element of technology called know-how which must be considered independently. Know-how is technical skill regarding how to do things well. A result of experience, transfer of knowledge, or hands-on practice may be the source of know-how. People acquire know-how by receiving formal and informal training, conducting internships with experts, and involving in transfer of knowledge.

Management of technology

Technology alone is not sufficient to enable companies to reap potential benefits. Many companies have begun to realize that management of technology (MOT) is critical in tapping the advantage of technology. Although, the field of MOT is continuing to evolve, there is a difficulty to conceptualise its idea and characteristics. Noori (1990) contends that this difficulty stems from the nature of MOT as cross-functional and problem-driven. He refers to the Task Force on Management of Technology to describe that MOT links engineering, science, and management disciplines to address the planning, development, and implementation of technological capabilities to shape and accomplish the strategic and operational objectives of an organization.

MOT is about dealing with technological change and management functions. MOT thus consists of a wide range of isses concerning the development, acquisition, and implementation of technological skills (Noori, 1990). It fills the gap between the field of management and the field of engineering and science. Its focus is on the strategic importance of technology and its mission is to synergise technical and nontechnical resources of companies to enable them to improve the quality of the worklife.

The key to MOT is the ability of companies to identification and solving of technological problems. An organizational problem requiring technological touch is not a trivial task. The task is particularly challenging in the case of complex processes which relate to many different aspects of technological problems including actors, hardware, software, and brainware that have to be integrated in the MOT process. The success of MOT in solving problems typically depends on two factors: a strong scientific background and experience in technological application.

As a consequence, the knowledge of MOT can be distinguished into two components: formalized knowledge based on a set of rational ideas or theories and practical kowledge based on generalizations of empirical world. During the accumulation process of its body of knowledge, MOT has been approached from two perspectives: deduction which promotes application and testing of the MOT theories and induction which endorses the generalization of new understanding from experiential processes (Hammer and Champy, 1993). The notion of deduction is defined as the pattern of theorems or laws that help individuals understand technological reality and thus provide them with reasoning tools in applying those theorems to solve technological problems. Theories are defined as a simplified explanatory framework for undestanding complex phenomena. On the other hand, induction is concentrated on the insights from experience which is held in the form of practical knowledge.

Deduction results in a loop of theory application and induction results in a loop of theory building when a new technology is adopted. Figure 1 depicts the loop of deduction and induction to contribute to the body of knowledge of MOT. The loop describes that MOT develops theories through inductive logic and then tests theories by generating predictions through deductive logic and veryfying empirically those predictions. A typical way of exercising this loop is by making use of experimentation which is the systematic testing of ideas. The trial and error process triggered by experimentation greatly contributes to finding new solutions to the typical problems encountered by technologists during a MOT process. Experimentation also allows prople to anticipate many additional observations and breakthrough solutions. The implications of aplying the loop of theory application and building is the development of MOT in enabling organizations to tap tachnology for better and more innovative products and services and reduced costs.

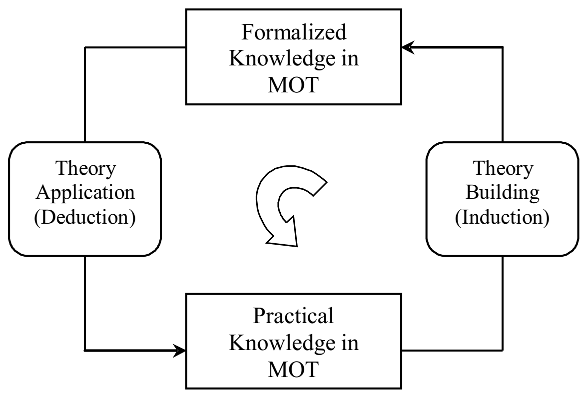

Figure 1. The loop of theory building and testing in MOT

Proponents of MOT employ the loop of Figure 1 by adopting the argumentative logic in terms of a deductive form (exposing a reasoning) and an inductive form (giving examples and models to be imitated). Deduction can be interpreted as applying knowledge held in a general form, for instance of general theories, to specific instances (Newman, 2003). Deductive theories at least initially may have only minimal empirical support. These later are solved by understanding which general knowledge is available about specific problems, which laws govern them, and by applying this general knowledge to the specific case. Based on the general law, one can form a prediction of what is most likely to happen. From assumptions, implications are derived in an analytical and logical way. For example, one infers from the general assumption that all balls in the box are black, the particular implication that the next ball taken from the box will be black as well. Assumptions within deduction already contain all information that there is available. Generally spoken, deduction sustains the information contained already in the assumption but does not create new one. If A = B and B = C (assumptions), then A = C (implication).

Induction is often summarised as inferring from the specific instance to general concepts and laws (Newman, 2003). Inductive theory builds on strong data base and tends to stay close to data. Patterns of examples can be used to draw inferences which build a bridge between many specific instances and more general relationships. Its assumptions describe a part of a larger population and then infer conclusions about the characteristics of this larger population. For example, the case is that these balls from the box and the assumptions of the particular observation that these balls are black and infer from this the general implication that all balls in the box are black.

What is wrong with the management of technology?

The loop of deduction and induction in MOT obviously helps practitioners and scholars to advance their knowledge in managing different facets of technology. However, this loop has given little attention to address the human need for sensemaking in explaining why technology fails or succeeds in creating value and therefore diminishing the ability of a company to realize potential benefits of technology. Althouh people need to learn in order to engage effectively in managing technology, their compeling orientation to meaningful activity continually undermines the motivation to spend time and effort just learning MOT. Lack of attention to sense making could explain a variety of problems in the adoption or development of new technology. This also means that the loop of knowledge in MOT is using today to navigate value creation do not correspond with how value actually created. The loop of knowledge is supposed to help analysis to be made, decisions to be taken, work to be organized, and managerial actions to be undertaken. The basic question becomes how to enhance the loop of knowledge in ensuring the process of sense making for emerging and more widespread forms of value creation due to the presence of a new technology, especially in the era of information intensive.

The second shortcoming stems from the limitation in dealing with information overload. MOT does not provide practitioners with systematic attempts to think and reason to get something meaningful from the ocean of information. They did not seem to be getting appropriate guidance and feedback from the systems and documentation they were using, even though they were being presented with a huge amount of information. For example, technologists often face unprecedented problems during the implementation of new technology and often make a number of errors, their training materials did not support the process of error recognition, diagnosis, and recovery. As a result, although they get training with hips of knowledge but very little impact on transforming the knowledge into action and error still taken place. There is no learning because they make the same mistake again and again such as late delivery of product launch. The trational MOT ignore learning motivation to rapidly undertake realistic tasks of problem solving.

Deductive and inductive methods have been critisised for various limitations such as their tendency to explain away details that should be better understood and their incapability of gererating new knowledge. Deduction and induction require the problem at hand to be structured. For induction, the minimum structural requirement is that the instances used to induce a regularity are in some respect similar to each other. For deduction, one needs to be able to map the different elements in the law to elements of the problems. The usual way to define inductive reasoning is as the generalization from cases which were observed to cases which have not seen, but in order to do that one must have identifies an underlying pattern in the seen cases.

The statement that induction creates new information when reasoning from particular to general is doubtful. The inductive reasoning says something not contained in the assumptions. If the reasoning arguments are strong it is probable that the claims made about the generalizations hold. Inductive inference is based on data. However, even if the number of observations in the data set is huge it is in principle impossible to have all observations available, not the last because future events cannot observed. This means that the implications derived from data are uncertain. In the future, the same will only happen with an unknown probability. This proability is impossible to gain, because future observations can by definition not be made.

In deduction assumptions contain all possible elements of models like e.g. premises, definitions or causal relationship. Therefore, it is often claimed that inference in deduction is necessary in the sense that the conclusions stemming from the assumptions are corrent. In formal sciences like methematics this holds, because assumptions are often provided in the form of axioms, i.e. they are self-evident and need be proven. In MOT such self-evident assumptions do not exists because the social setting. Implications drawn from premises are in general true but only in the sense that they are logically derived. In MOT without self-evident premises available it is virtually impossible to derive implications that are true in the sense of correctly describing and explaining reality.

Abductive reasoning

Once people believe the traditional loop of knowledge in MOT, it is difficult to change it. If the facts are wrong, then people rely on the loop that is insufficient to make sense the confronted situation. It is too often found that this loop of knowledge acts like blinkers rather than guides which prevent people from acting creatively. The answer to this difficulty is to to find an inovative way of reasoning which is called abduction.

The notion of abduction has been introduced by Charles S. Peirce (1838-1914) as a reasoning step from a fact, to the action of the state that caused it which is different from induction and deduction. Abduction is to closely look for a pattern in a phenomenon and suggest a plausible hypothesis which can be illustrated with symbols for simplication as follows.

> The surprising phenomenon, X, is observed.
> Among hypotheses A, B, and C, A is capable of explaining X.
> Hence, there is a reason to pursue A.

Abduction can be seen as reflecting inductive processes but within a context, either existing or asumed to exist. Creativity processes can be identified here as abduction attempts to link a local pattern to a general including negation in the analysis so that by placing the pattern of an observed phenomenon in real or imagined contexts, it can lead to innovative ideas in which an unexpected link is made.The basic dissimilarity between abduction and induction is that induction does not assume meaning to exist, there is no initial distinction until the inductive process moves from the particular to the general where the general is the formation of an hypothesis, a law, or a principle.

The similarity between abduction and deduction is that they both assume meaning. Deduction attempts to move from a given general, in the form of a theory, a principle, or a law to a particular and this process reduces appreciation in the general. For abduction, it suggests to move from a particular to a general and in doing so also validate the general because the objective of abduction is to determine which plausible hypothesis to test not which one to adopt. Deduction cannot lead to the discovery of new knowledge because the conclusion has already been implanted in the premise.

Abduction enables practitioners and scholars to identify underlying structural elements which explain facts from observations and to develop a theory of part of the investigated world. This provides a substantial step further than pure deduction or induction, because abduction helps people to meet theory and data in a creative way. By using the principle of abduction, practitioners of MOT are able to create new information. Figure 2 illustrates the use of abduction in MOT to integrate the process of induction and deduction. The starting point is to reveal facts from observation. By using induction process and proposing assumptions about the phenomena, plausible hyphothesis is created. Deduction process is used to verify whether the hypothesis is able to explain the phenomena. If the hypothesis fails to explain the phenomena, then one invalidates the previous assumption and find other assumptions untill the hypothesis can be proved to explain the observed phenomena.

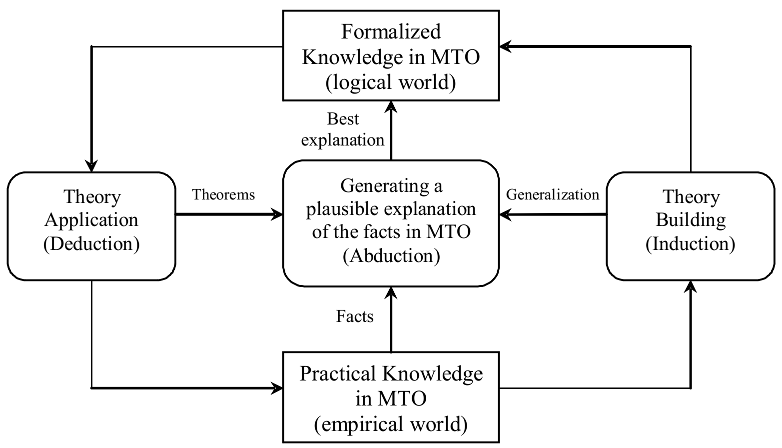

Figure 2. An explanation reasoning in MOT

If abductive reasoning is defined as reasoning in which explanatory hyphotesis are formed and evaluated, then to some extent abductive reasoning ability can be seen as part of inductive reasoning because no valid abduction can be made if no pattern has been observed. Abduction classifies particular events into general patterns. It is important to notice that abduction requires much more data based on substantial and detailed observations to infer implications that are likely to hold when confronted with a phenomenon. The more relevant details are known about the phenomenon the more precisely they can be classified to a general pattern. Only then is it possible to find meaningful and sensible underlying mechanisms to infer from the assumptions to the implications. Consider a a case that all balls in the box are black. One starts from a particular observation such as "that these balls are black" and try to undercover the underlying mechanisms about what is "disposing balls to be black". It might suggest to look for other balls that are black and study what they have in common. The explanation becomes "that these balls are from the box".

An explanation reasoning process as proposed in Figure 2 can be used to enhance the role of MOT by helping people to make sense and provide arguments to explain, defend, and challenge a theory. Practitioners and scholars need to approach the building and testing of theory by integrating inductive and deductive thinking processes. The discovery logic of abductive thinking is shown in Figure 3. One observes the initial fact 1 and generates a plausible hypothesis. The first test in proving or disproving the hypothesis is to deduce whether the hypothesis is able to explain fact 1. The second test is to deduce other facts or events from the hypothesis that can be investigated. These are shown as fact 2, fact 3, and fact 4. Data collection and can be made to find out if these facts are true. If they found to be true, they confirm the hypothesis. If they are not comfirmed the hypothesis and one must look for another explanation.

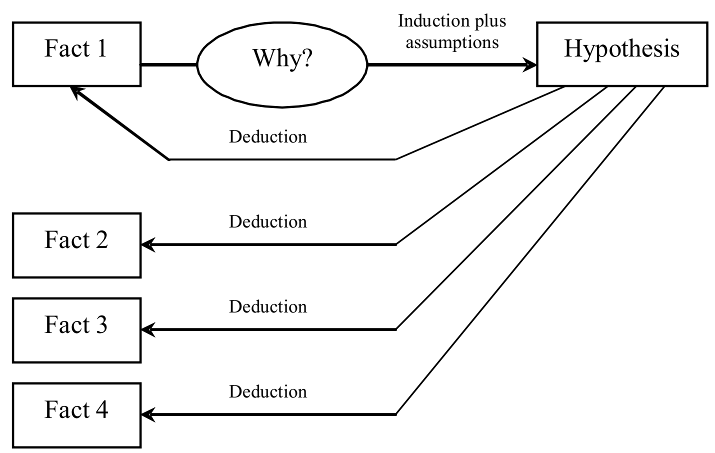

Figure 3. The discovery logic of abduction

Concept of TechnoValue

Literature has confirmed that the main reason to employ MOT is to make sure that technology brings value to stakeholders (Burgelman et al., 2001; Hammer and Champy, 1993; Khalil, 2000; Noori, 1990).

However, there is little explanation of how and when a technology brings value to stakeholders. It can be demonstrated that the discovery logic of abduction can be used to find convincing explanation of how and when technology earns value.

An interested question is that when technology brings value or why technology fails to convey value. Many alternative answers have been proposed to explain the relationship between technology and value, but they do not distinguish the fulfillment of technological prerequisites and the explanation of technological contribution because much attention is focussed on normative objective of technology (Warner, 1987). The answer to this question needs to specify whether the premise is a necessary condition or a sufficient condition of explaining the appropriate role of technology. Abductive reasoning shows that the necessary condition in explaining when technology brings value rests in the fact that people are involved in a human made system which is only make sense when one looks the system as a whole. From the systems thingking perspective, a system has a few limitations which prevent it from attaining higher performance (Dettmer, 1998). If the technology does not support people to overcome a real limitation of the system, it is difficult to expect any value of that technology. The technology only costs or burdens the system. Goldratt et al. (2000) propose that value creation only occurs when a technology surpasses the true limitation of the system. In other words:

Proposition 1. *Technology brings value if and only if it diminishes the true limitation of a system.*

In addition to aspects of technology and system's limitations, technology is developed and used by people. People thus create habits, measures, and rules to live with technology. When a new technology appears, it defines that people have lived with an existing limitation. The organizational installs the new technology to surpass the existing limitation, but people continue to work with the old rules which accommodate the existing limitation. The old rules restraint the new technolofy to diminish the limitation. Goldratt et al. (2000) contend that technology is a necessary condition, but it is not sufficient to bring value. In order to get the potential value of technology, the old rules must be changed because the new technology has replaced the existing limitation. Expectations of benefits will be deteriorated unless changes in the rules, policies, measurements, behaviors accompany changes in the adoption of new technology. Replacing oled rules and finding new rules empower or enable the people to effectively operate within them in employing technology to create real value. hus, the adoption of new technology cannot separate with changes in the rules and measures at the organization and therefore:

Proposition 2. *Renewal of the operating rules is a sufficent condition for a technology in creating value.*

The installment of technology cannot be sepatated with various stakeholders. How do various stakeholders find particular worth, benefit, or reward in exchange for their respective contributions to value creation by using the technology? This question points out that when technological solution delivers enterprise value, which parties or agents would get the portion of materialized value and how this value can be distributed amongth the participants. Understanding the value creation process from recognizing the power of technology and renewing the policies and practices underlying the new technology should be tied with value capture which encorage people to have a stake in using technology for creating real value. Hence:

Proposition 3. *Technology is a means of increating real value through integrating the loop of value creation and value capture.*

Figure 4 shows the loop of value creation and value capture which is named TechnoValue. Value creation consists of three phases starting from value exploration, value proposition, and value delivery. Exploring value means to identify existing limitations and what rules built up to accommodate such limitations. Value proposition attempts to identify what strength of a new technology adds value for the system and what kinds of rules are required to ensure value creation. Value delivery deals with how to cause the change in accordance with the value proposition, excecutes the technology adoption, gathers information and data to continue to improve enterprise processes. Value capture starts with the establishment of clear communiation of balanced expectations with all stakeholdrs and follows with recording and rewarding materialized value to all participants.

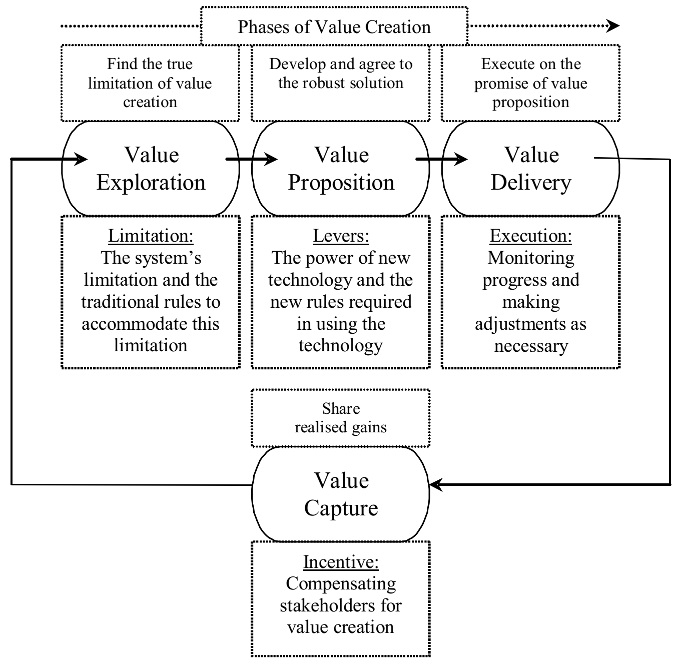

Figure 4. A TechnoValue Framework

Enterprise Resource Planning (ERP) is a relevent example to illustrate the concept of TechnoValue. This new technology provides visibility into supply chain operations (Umble et al., 2001). Prior to the existence of ERP, people have limited access to the enterprise-wide information. They thus make decisions based on local or estimated data. ERP enables people to diminish the limitation of making decision not based on all relevant information (Goldratt et al., 2000). Adopters of ERP often operate with the old rules which assume the existence of limitation. Some of the rules include local efficiency, max-min inventory policy, and product costing. These rules were important when people not having all the needed information. As a consequence, the rules prevent the enterprise from creating the value of ERP.

Conclusions

This paper shows that little attention has been paid to rethinking the underlying logics of Management of Technology. The traditional MOT emphasises on introducing new concepts and how the concepts will be applied to the current problems. This implies the use of two problem solving thinking: deduction and induction. Deductive thinking

derives logically necessary conclusions from the given premises. Inductive reasoning aims to build generalizations from cases that have been observed to infer something about a case. However, the loop of deduction and induction is not appropriate to facilitate a learning process as well as research process in understanding and explaining underlying facts of reality in MOT.

The contribution of this paper is to apply abduction to the reasoning process of MOT. Abduction is truly required not just to help in problem solving but also combining induction and deduction. Three proposition have been provided to stimulate thinking the current practice of MOT. Further research is needed to augment the three propositions in empirical settings such as their relevance within activities of MOT in companies. TechnoValue is introduced with a basic tenet to encorage proponents of MOT to see technology from value perspective and not just the technology itself.

Although the concept of TechnoValue is usefull in explaining different cases of technology adoption, it opens opportunity for further research. First, TechnoValue opens research opportunities to develop a tool kit for examining the adoption of technology from justification, implementation, and evaluation. TechnoValue can be used to guide data collection and analysis. Findings should show when technology is appropriate for the company to diminish a true limitation. When use for practitioners should be able to show the power of technology or how to lead to identifying the effectiveness of technology and concentrate on important aspects of when and where technology create and capture value.

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