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Editorial

Introduction to risk and uncertainty management in technological innovation

This special issue presents papers addressing the role of risk management in the important field of technological innovation. Technological innovation is a manifestation of human progress, but efforts in this direction have yielded many issues. For example, in the energy field, nuclear power was considered the solution to electrical supply 50 years ago. While it has proven to be a viable source of energy in France and other European countries, it has had problems in the US (Three Mile Island) and in the former Soviet Union (Chernobyl). There is a reticence on the part of citizens to nuclear power, and the issue of waste disposal defies solution. The Federal Government in the US did not license new plants for decades, despite technological advances developed by national laboratories. Coal remains a major source of electrical energy fuel, although there are very strong questions concerning the need to replace it for carbon footprint reasons. Natural gas is one alternative. Wind power is another. Solar energy has been proposed. All of these alternatives can be seen to work physically. The question of energy was further complicated with the recent large-scale adoption of *fracking*. This technique introduces risk and uncertainty not only to itself, but its inclusion changes decision-making regarding all sectors of energy.

The question of economic practicality remains, and each solution seems to create new negative impacts. In the field of transportation, petroleum continues to be the dominant fuel, although technological progress has been made with respect to electrical power for vehicles. Systemic issues such as practical resupply on the road remain. Ethanol is an intermediate solution, although the complexities of using corn for ethanol seem dubious when viewed from a life-cycle perspective. Practically everything we do involves a complex system with unexpected (unintended) consequences (Perrow, 1999).

An example of these complexities is the proposed Keystone Pipeline, intended to move crude oil from Alberta Province in Canada to refineries in the southern US. The NIMBY phenomenon (Wildavsky, 1995) has risen, with strong supporters of environmental cleanup contending massive risks from burning carbon-rich Canadian oil, as well as the possibility of spills contaminating land on the pipeline route (ecological system). Supporters of the pipeline counter that pipelines are much safer than train and truck shipping of oil, and that the oil in question is going to be processed somewhere regardless of the pipeline being built (economic system). The US Federal government has taken the attitude that it should be carefully studied (at least until after the next election – political system). This is just one example of why we need to study risk related to technological innovation.

As the example of energy illustrates, risk can involve both positive and negative outcomes. However, when the term risk is used there is a tendency to focus on negative outcomes. It is critical to consider not only whether risk is symmetric (similar distribution of uncertain positive and negative outcomes), but the nature of the distribution. Different questions and approaches are appropriate to deal with incremental technical change versus sudden low likelihood high impact risk such as an oil spill. While differences in the nature of innovation and its impact has been considered in both the innovation literature (Abernathy and Clark, 1985) and the adoption/diffusion literature (Rogers, 2003), the focus has not been on uncertainty/risk and its management. Uncertainty and unanticipated consequences work both for and against the adoption and development of technology.

While there are thousands of studies on diffusion, and certainty/uncertainty is often mentioned as a critical factor (Rogers, 2003), there is relatively little work in the area. Most existing research focuses on the development of new products. More specifically project selection (Michnik, 2013; Nishimura, 2011; Graves and Ringuest, 2009; Wu and Ong, 2008; Irani et al., 2005; Jacob and Kwak, 2003), techniques to better predict (Richter, 2013; Fuglsang and Mattsson, 2011; Song et al., 2007; Kwak and Stoddard, 2004; Benaroch, 2001; Lambert et al., 2001, Jägle, 1999), and to mitigate and manage uncertainty (Amer et al., 2011; Heim et al., 2012; Tan et al., 2011; Lùthje and Herstatt, 2004; Comican and O'Sullivan, 2004; Hinnant and O'Looney, 2003; Magnusson and Berggren, 2001; Nightingale, 2000; Sicotte and Langley, 2000). However, there is a recognition of the importance of risk and uncertainty in the integration of new technology into an organization (Stock and Tatikonda, 2008; Tatikonda and Stock, 2003; McGaughey et al., 1994) – often with a focus on information technology. Risk associated with information technology includes a range of unintended uses and threats both internal to the organization (D'Arcy and Devaraj, 2012; Volpentesta et al., 2011) and along its supply chain (Von Solms and Von Solms, 2005; Gerber and Von Solms, 2005; Von Solms, 2001). Uncertainty and risk linked to technological innovation calls for consideration of functional areas like marketing (Chang and Park, 2013; Becker an Lillemark, 2006), supply chain partners (Stanko and Calantone, 2011; Hoecht and Trott, 2006; Hoetker, 2005; Sivadas and Dwyer, 2000; Littler et al., 1995) and other stakeholders (Hall and Martin, 2005). Other important insights, include:

1) Role of rapid learning and unlearning (Caravannis, 1999).
2) Technology as a defense against uncertainty (Wang et al., 2006).

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3) Difference in approach if managing commercialization of sustaining versus disruptive innovation (Kassicieh et al., 2002).
4) Uncertainty is a key contingency for both managerial and organization structure for innovation (Tidd, 2001).
5) Metrics suggest risk differs as a function of industry and new product development process (Unger and Eppinger, 2009).
6) Tools can be useful to illustrate technology risk (Hansen et al., 2009).

Clearly there is much to be learned and while drawing on other fields (Phan and Chambers, 2013) is helpful and should be pursued, it is insufficient. While specific areas such as commercialization (Chiesa and Frattini, 2011) are noted as being especially needed, the understanding of managing uncertainty and risk in technology is immature in all areas. This is a concern as the challenges and opportunities we face are increasingly of a Schumpeterian nature (Schumpeter, 1967) as opposed to the neo-Marshallian (Marshall, 1920) paradigm that dominated the previous century. This issue serves to increase the body of existing knowledge while acting as a call for more research.

Issue papers

This issue consists of nine insightful research papers related to technological innovation risks. Multiple research methodologies are utilized in a variety of disciplines including: physical technology, information technology, and project management. Seven of these papers deal with the process of assessing risk. The other two report simulation model results.

The consideration of risk and its influence on innovation are critical factors for strategic planning, but little research to date has focused on their interplay in this process. Ilevbare et al. (2014) examine this issue by introducting *risk-aware roadmapping* as a concept to explicitly incorporate risk and uncertainty into the roadmapping paradigm. The process expands the function of risk management to include the assessment of often overlooked risks, such as missing innovation opportunities, and provides new perspectives on innovation planning throughout an organization. Hall et al. (2014) provide a conceptual framework based on the idea that many social uncertainties are not well suited to probability models. They describe how stakeholder risk perceptions vary and change, and discuss the increase in risk when information is unclear. Thus the process calls for working with stakeholder groups, especially under conditions of high opposition in stakeholder positions. A variety of techniques to collect and understand stakeholder views, and to integrate stakeholder feedback are discussed.

Two of the risk process papers use case study methodology.

Koehler and Som (2014) report two case studies in the environmental domain. They see how early detection of risks could be obtained in emerging technologies (specifically nanotextile and smart textile development projects). Projects in these areas are reported to be undertaken without much consideration of risk prevention. While over-analysis of risks can be detrimental, and it is impossible to eliminate all risks, it is important to mitigate risks early in the innovation process. This is challenging, because at this point-in-time, knowledge is inherently incomplete. The authors emphasize the need for full product life cycle views, close governance of technology development, and accurate understanding of regulatory frameworks and standards.

Stevens (2014) provides analysis of three case studies in the technology area (semiconductor chips, telephone accessories, image processing). These were new product or service development projects. Stevens seeks means to reduce uncertainty in early development stages. Actions proposed include competency recruitment, guiding vision, and use of personal networks to reduce uncertainty.

The other three risk process papers used survey methodology.

Oehman et al. (2014) report results of a survey of new product development programs. The study finds six risk management practices to be effective. Transparency is found to be important in effective implementation. One interesting conclusion is that flexibility, transparency, and quality should be treated as non-negotiable, while cost and schedule considerations are more flexible.

Kim and Vonortas (2014) study several thousand European small businesses, all in their formative years. Their use of internal risk mitigation strategies is considered. Networks are useful in dealing with financial risk. Market risk is found to be harder to manage. Strategic alliances are suggested as an effective strategy for dealing with operational risks.

Wu and Wu (2014) report a survey of Chinese firm board involvement in risk oversight, studying the relationship between integrated risk management and success in product innovation. They find that firms benefit from such oversight as a means of developing comprehensive understanding of the risks involved in product development. They also find that use of external auditing helps control the risks that arise from product innovation.

Two of the papers report results of using tools (simulation specifically) to assess risk in technology development. The simulations were applied to project cash flow in two entirely different contexts, one in the information technology field, one in environmental monitoring technology.

Van Zee and Spinler (2014) apply simulation modeling to value public sector R&D projects. The method was demonstrated on a new sensor for large networks to track greenhouse gas fluxes. Simulation is used due to the variability in demand as well as expected unit costs. The simulation reflects highly nonlinear demand volatility, as well as nonlinear unit costs. Parametric assumptions are made to examine impact.

Miorando et al. (2014) apply simulation modeling to examining the probability distribution of the net present value of technological innovation projects. They apply their model to a case involving installation of an enterprise resource planning software. They verify that the model aided in more accurately determining cash flow, and leads to better discussion concerning opportunities and threats. It also contributes to development of potential contingency plans.

Finally a special acknowledgment and thanks is extended to Dr. Dash Wu for his interest and involvement in the special issue. Without his proposal of a Special Issue on Uncertainty and Risk and his enthusiastic efforts during the call and at the start of the review process, this special issue is unlikely to have occurred.

Conclusions

These eight papers provide useful research on risk and uncertainty management in technological innovation. There is much need for additional investigation. Ilevbare et al. (2014) considers uncertainty in road-mapping. Such considerations are also needed in other forms of forecasting, scanning, and foresight activities. Hall et al. (2014) provides a framework, that calls for validation. Case studies (Koehler and Som, 2014; Stevens, 2014) inherently call for replication in other contexts than those specifically studied. Survey results, as used in three of these studies (Kim and Vonortas, 2014; Oehman et al., 2014; Wu and Wu, 2014), need refinement and replication. The two simulation applications (Miorando et al., 2014; Van Zee and Spinler, 2014) do have some