INNOVATION OF PRODUCTS AND SERVICES: BRIDGING WORLD'S ECONOMIES

A. Kusiak
Industrial Engineering, 3131 Seamans Center, The University of Iowa, Iowa City, Iowa 52242-1527, USA
andrew-kusiak@uiowa.edu

Abstract
A newly introduced product or a service is labeled 'successful innovation' only after it has been proven in market. Certainly, market failures of products/services or their improvements are much more common than commercial successes, which is a significant drawback. The ideas introduced in this paper are applicable to evaluation of innovativeness of planned introductions of design changes, products, and services. In fact, blends of products and services could be the most promising way of bringing innovations to the market. The most important aspects of innovation are generation of new ideas and their evaluation. People have limited ability to generate and evaluate a large number of potential innovation alternatives. The proposed computational approach generates a large number of such alternatives and evaluates them from the market perspective.

Keywords:
Innovation, Innovation science, Computational innovation, Data mining, Genetic programming.

1 INTRODUCTION

The volume of innovation literature is rapidly growing, yet there is not universally agreed framework that could be taught and applied in practice. At present a newly introduced product or a service is labeled as innovative only after it has been proven in market. Certainly, market failures of products/services are much more common than commercial successes, which is a significant drawback.

The ideas introduced in this paper are applicable to evaluate innovativeness of planned introductions of products and services. In fact, blends of products and services could be a promising way of bringing innovations to the market. Such a joint product/service offering would be a practical instantiation of the concept of customer involvement in the product/service development process advocated by Benkler (2007) and von Hippel (2005), as well as the principle of customer experience management discussed by Meyer and Schwager (2007). Do not type page numbers in the electronic version.

1.1 Emerging markets statistics (USA Today 2007)

At present, emerging markets constitute 21% of the global economy. It is estimated that 25 years from now emerging markets will make up at least 50% of the global economy. In the past 20 years US exports to emerging markets have increased 338%, which is much faster than the domestic demand. Companies are recognizing growing importance of emerging markets, e.g., General Electric plans to double sales in emerging markets between 2007 and 2010 from 15% to 30%; Dell and GM increasingly produce in India and China for local markets.

2 INNOVATION BASICS

2.1 Product and service innovation

Product innovation is concerned with the introduction of new goods that differ from the ones existing in the market. Service innovation is the creation and modification of the existing services. The direct sales model introduced by the Dell Corporation is a clear example of service innovation that has become the company's core strength. It began with an attempt to eliminate the lengthy and costly selling process, which impacted the total product cost. While many computer manufacturers concentrated on enterprise integration, Dell decided to outsource many non-competitive tasks. Buying experience, affordable pricing, and excellent customer support have resulted in business success.

A way to analyze and understand innovation is through product/service requirements (Kusiak 2007). From a requirements-driven standpoint, the idea of product/service innovation can often be traced back to the deficiency of certain product/service functions. If the product/service design is modular, it is much easier for a company to improve or redesign such functions. The innovation produced from mapping product/service functions into customer requirements is generally incremental. It appears that more successful innovations often address customer requirements beyond the function and form.

2.2 Corporate renewal though creative destruction

The concept of creative destruction was introduced by Joseph Schumpeter (Schumpeter 1942) and later elaborated by Aghion and Howitt (1992, 1997) and Nolan and Croson (1995). Schumpeter's thesis was that innovation led to a long-term economic growth usually at the cost of destruction of established companies that might have monopolized the market.

A more recent case supporting Schumpeter's view was presented in Page (1999). Page traced Manhattan's constant reinvention, often at the expense of preserving the past. He described the historical circumstances, economics, social conditions and personalities that have produced visible changes in Manhattan.

Companies that once dominated the economy, e.g., Xerox in photo coping and Polaroid in instant photography have seen their profits diminished due improvements in design and manufacturing and reduced costs to the customers of products/ services offered by emerging companies. Wal-Mart is a recent example of a company that has achieved a strong market position due to improvements in inventory management, marketing, and management of human resources. All these have resulted in lower prices thus reducing profits of competing companies. However, Wal-Mart today faces the same threat as the companies it has once outperformed, e.g., Montgomery Ward, Sears.

Successful innovation is typically a source of temporary market dominance, eroding the profits and position of less

A. Kusiak, Innovation A Data-Driven of Products and Services: Bridging World's Economies, *19th International Conference on Production Research*, *ICPR 19,* Valparaiso, Chile, August 2007, pp. 1-6.

innovative companies. Creative destruction is an economic concept for understanding the dynamics of industrial change. It has been the inspiration of endogenous growth theory and evolutionary economics.

Creative destruction may lead to layoffs of personnel with obsolete skills, though its creations are valued by the customers. Creative destruction leads to more creative and productive enterprises in need to new skills.

Emerging economies will join the global equation of creative destruction that creates opportunities and pitfalls.

3 INNOVATION PROCESS

3.1 Innovation sourcing

Nambisan and Sawhney (2007) discussed three types of innovation intermediaries, each operating in its own landscape:

- Invention capitalist (iC),
- Innovation capitalist (IC), and
- Venture capitalist (VC).

Each of the three innovation landscapes follow the generic process model shown in Fig. 1. This model generalizes the steps followed by the invention capitalist outlined in Nambisan and Sawhney (2007).

Figure 1: Innovation landscape process model.

Each innovation intermediary performs the following five activities: search, evaluate, develop, refine, and connect, however, in a different risk and cost landscape. This landscape determines input to the search activity and output of the connect activity. The input to the search activity for an invention capitalist includes predominantly inventions and ideas and the goal is to connect companies with the inventions and ideas that are promising but not market ready yet. For an innovation capitalist the inputs are market-ready ideas and the goal is to connect companies with the market-ready ideas. A venture capitalist follows the same process (Fig. 1), where the input constitutes market-ready products and the goal is to connect companies with the market-ready ventures.

Each of the three innovation landscapes involves deferent risk and costs. The cost-risk relationship between these landscapes is shown in the grid in Fig. 2. The innovation capitalist (IC) optimizes the tradeoff between the cost of bringing market-ready ideas to market and the associated risk.

The transition from the invention square (iC) to the venture square (VC) in its simplest form is along the diagonal of the grid.

The arrow below the diagonal in Fig. 2 indicates the natural progression from the iC to the VC landscape. While the focus of business activities in recent decades has been on the VC quadrant, the arrow above the diagonal symbolizes the direction of focus needed to energize innovation for companies focused on venture capital driven innovation.

A company interested in innovation from outsides sources, needs to carefully balance between the three different innovation landscapes. According to Nambisan and Sawhney (2007), basing innovation on the lower left square in Fig. 2 appears to be attractive to consumer products and markets populated with many different simple products. The top left right area is more suitable for companies that are science and technology driven, e.g., 3M and DuPont. Development cost of products manufactured by these companies is high, and therefore the innovation is likely to come from collaborating companies with significant human and capital resources. The innovation diffusion can be accelerated by management strategies moving companies from the upper right and lower left squares towards the center of the grid in Fig. 2.

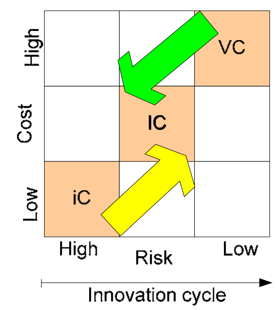

Figure 2: Cost-risk innovation grid.

3.2 Innovation value chain

It appears that there is no generic process model of innovating across different corporations. Every company has its own set of challenges when it comes to improve their ability to generate, develop, and disseminate new ideas (Hansen and Birkinshaw (2007).

Improving innovation calls for viewing process of transforming ideas into innovations as an integrated process model, similar to manufacturing where raw material is transformed into usable products (Hansen and Birkinshaw (2007). According to Hansen and Birkinshaw (2007) such an integrated flow model should involve three passes: Idea generation, Conversion, and Diffusion.

Fig. 3 illustrates the innovation value chain model drawn according to the IDEF (Integrated Definition) notation.

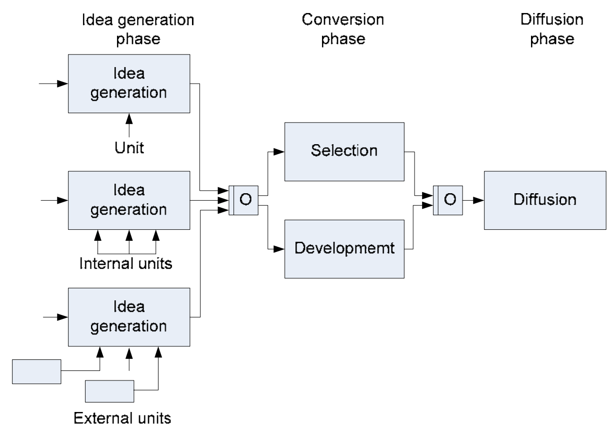

Figure 3: Model of the innovation value chain.

Creative ideas can be generated locally (within a unit), across different units, or can be obtained from external sources. The input to the conversion phase includes ideas that are generated from the one or more sources (this indicated with the logical asynchronous OR junction in Fig. 3, denoted as O). At the conversion phase the main ideas are either:

- selected if they are mature enough and do not require further development, or
- developed into a market acceptable solution, if the number of candidate idea is obvious or the number of concepts is limited, or
- selected and further developed into a market acceptable solution.

At the final diffusion phase, the output (deliverables) from the conversion phase undergoes diffusion.

Management of the innovation value chain is key to company's success. For example, placing significant emphasis on the conversion phase when the number of new ideas is small is likely to lead to wasted resources. Conversely, limited resources at the conversion phase in an idea reach case, is not likely to advance company's innovation standing.

Metrics are needed to manage the innovation value chain. Examples of simple metrics are (Hansen and Birkinshaw 2007):

- Number of ideas generated for the idea generation phase
- Percentage of ides selected and pursued, or the percentage of founded ideas that has brought in revenue for the conversion phase
- Market penetration or its increase for the diffusion phase.

The need for forming other metrics to be used actress the innovation value chain is apparent. Cost and time are two obvious variables that need to be reflected in such metrics.

4 INNOVATION EVALUATION METHODS AND TOOLS

The interest in innovation is not new, however, it has become of particular interest in recent years due to numerous factors, including the increasing dynamics of world/s economy. Next, examples of methods and tools for evaluation of innovations are discussed.

4.1 Trial and error approach

A widely used approach to innovation is by trial and error approach. Designers see the consequences of the design choices made and learn from them. The advantage of the trial and error approach it is easy and everyone can use it. The major limitation of this approach is in the lack of predictability of the outcome.

4.2 Lead user study

The lead user market research method is built based on the concept that the need for new products, processes, or services needs is best understood by a few well informed uses, called lead users. This concept was introduced by von Hippel (1986). The lead users can be engaged into a development process of joint of new a product, process, or a service with the company's developers. Herstatt and von Hippel (1992) demonstrated in a case study that the lead user approach was almost twice as fast as traditional ways of identifying promising new product concepts and less costly as well.

The lead user method involves four major steps (von Hippel 1986, 1988):

Step 1: Specification of product/service characteristics of interests to future customers.

Lead users of a product, process, or a service are persons who display two characteristics:

(A) They anticipate important marketplace trend(s),

(B) They have good sense of benefits offered by the purported solution.

Step 2: Identification of lead users.

Step 3: Engagement of lead users in the development of product/service concepts.

Step 4: Test the concepts developed by lead users in a sample market of typical users.

4.3 Innovation networks

Innovation enables organizations to effectively compete (Christensen 1997) by supporting the innovation process, e.g., the idea generation phase, conversion, or even the diffusion phase (see Fig. 3). The need to innovate has resulted in renewed interest among research and corporate communities. Though numerous innovation studies have been published, myths and inconclusive research findings are quite common. Innovation is often discussed based on experiences specific to a particular case study. For example, innovation undertakings at companies such as 3M and Apple Computer have been broadly studied. However, is not known to what degree these findings would produce similar results in other corporations.

The most difficult issue is that of predicting success of a product/service at an early stage of its development. The published literature does not provide any evidence that such a tool exists.

Recent years there have marked increased interest in innovation in networked environments, especially in the European literature. This could be due to networked research environment promoted by the projects sponsored by the European Commission. In fact, the focus of some of these projects has focused on studying collaboration, e.g., the ECOLEAD initiative (www.ecolead.org) involving over 20 partners from 12 countries and funded at the level of Euro 18M. Another measure of the growing interest in networked organizations is the recently established Society of Collaborative Networks, SOCOLNET (http://www.socolnet.org).

The emergence of domestic networks seeking customer-based information needs to be noted, e.g., http://www.ninesigma.net and erewards@e-rewards.net. Though the scope, functionality, and the research value added by the commercial networks may be limited the trajectory of using market information in the development of products/services is clear.

Chiffoleau (2005) presented the results of a longitudinal ethnographic case study. A small cooperative implemented environment-friendly viticulture in Southern France. The study stressed the involvement of domain experts beyond 'traditional' leadership and management of 'practice networks' by integrating these networks and linking diverse strategic positions to handle innovation challenges.

The synthesis approach to innovation in service and manufacturing was studied by de Vries (2006). The theory of Gallouj and Weinstein (1997) was modified to enable reasoning about innovation trends in networked organizations and in the distribution of services. The studied modification was based on several case studies.

Corporations attempt to improve their performance by engaging in radical or incremental innovation through partnerships and networking with other corporations. The simulation experiments reported by Gilberta et al. (2007) showed the impact of various learning activities on innovation.

An issue of concern, especially for novices of collaborative networks, is that of handling intellectual property. Many will agree that research is needed to develop different models of handling company privy information. A natural way of limiting the release of proprietary information is by using in open communication channels customer features the rather than technical product/service features.

Benkler (2006) and von Hippel (2005) used different terms to describe the involvement of the market in the innovation process, and both have stressed that handling intellectual property needs to be investigated in years to come. In fact ways of handing intellectual property related issues in a networked environment could become a measure of success. Some results of handling intellectual property issues have begun to emerge. For example, Henkel (2006) discussed results of a quantitative study (N = 268) of patterns of free revealing of firm-developed innovations within embedded Linux, an open source software. The author observed that corporations contributed (without obligation) their own developments to the Linux code. In return they elicited and received informal development support from other corporations. Though unthinkable for traditionally minded managers, a part of corporate product development was performed in an open environment. The issue of intellectual property was addressed by selective revealing of information. A corporation would reveal, on average, about half of the code it has developed, while protecting the other half by various means. Revealing was strongly heterogeneous among firms. Analysis of reasons for revealing and of the type of revealed codes showed that the rationale for openness varied across corporations. The conflict between benefits and drawbacks of openness appeared to be manageable.

5 COMPUTERIZED INNOVATION SOLUTION

5.1 Motivation

Over the course of almost a decade-long research in data mining (mostly public and some proprietary), numerous analogies and similarities have been discovered between diverse processes, e.g., managing the recovery of an infant after a heart surgery and the combustion process control. The core of this paper is based on a hypothesis exploring analogy between virtual testing developed for a combustion process (Song and Kusiak 2007, and Kusiak and Song 2006) and testing products in a virtual market. This hypothesis considers the analogy between a physics-based model and a market-based model and it will be validated in this paper. Most of combustion variables (controllable, uncontrollable, and impact variables) defined in Kusiak and Song (2006) can be measured by sensors and their values are registered at certain time intervals (e.g., 60 sec). The outcome variable, e.g., process efficiency, is computed from physics-based equation based on the selected process variables.

A product/service could be represented with different variables (parameters). In this paper product/service requirements will be used. Similar to the combustion process, a vector of product/service variables has the following form = [c_1, …., c_a; u_1, …., u_b; p_1, …., p_c], where c denotes controllable variable, u is uncontrollable variable, and p is the impact variable. The value of the controllable variables can be modified, e.g., product price. The uncontrollable variable remains constant, e.g., the product function meeting a safety standard. The impact variable can not be directly controlled, however, its value changes as a controllable variable is modified. For the product weight decreases a lower density material is selected. Though the product weight was not intentionally addressed it changed as a new material was selected. Each product/service X_i has a corresponding label (metric) that reflects configuration (innovation) success. The innovation literature does not point to a single and generally accepted innovation metric.

5.2 Solution architecture

The key issue in innovation is that of early evaluation of solution alternatives. Traditional (manual) approaches limit the number of alternatives due to time and cost necessary to create and evaluate them.

The basic steps of the proposed computational three-phase approach are illustrated in Fig. 5 through Fig. 7.

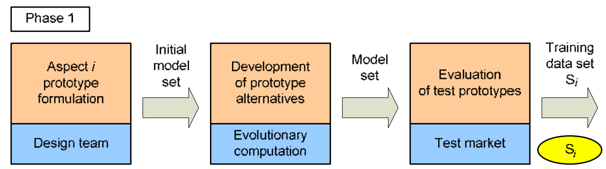

Figure 5: Aspect *i* learning mode.

Fig. 5 illustrates the Phase 1 where a training data set is generated. A design team develops a prototype model (or a few prototype variants) involving innovation features (called here an aspect). The initial prototype set (Fig. 5) is expanded by an evolutionary computation algorithm into a large prototype set evaluated in the test market producing a training data set S_i, *i* = 1,.., *n*.

In Phase 2, the training data sets S*i* for *n* aspects are integrated into a single data set $\mathcal{S}$ used to build a classifier shown in Fig. 6.

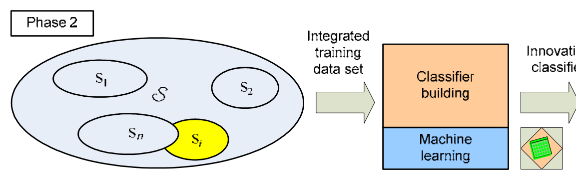

Figure 6: Learning from an integrated data set of n aspects.

In Phase 3, the classifier or an ensemble of classifiers built in Phase 2 is evaluated for accuracy and used to predict the success (e.g., innovation score) of the test configurations to be considered for further development (see Fig. 7).

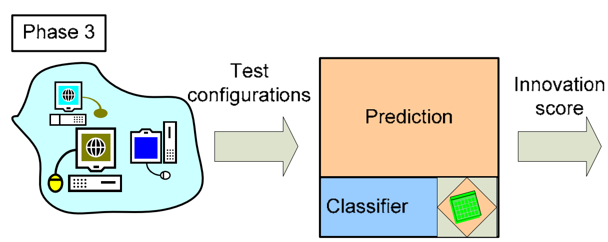

Figure 7: Prediction of innovation scores.

Evolutionary computation, in particular a genetic programming algorithm (Koza 1992), appears to naturally match the methodology gap of Phase 1. Generation of solution (configuration) alternatives though realized by the genetic programming algorithm requires an innovation evaluation (fitness) function. A data-mining scheme is proposed to develop a classifier for evaluation of a large number of the expert and genetic programming-generated configurations (solutions). The classifier will be extracted from a training data set produced of the intermediate solution set. The intermediate solution set will be usually larger that the initial solution set, however, much smaller than the expanded solution set.

5.3 Population of prototypes

An initial population of prototype products/services will be generated in the first step of the genetic programming algorithm.

Genetic programming (GP) is a search algorithm based on the concepts of natural genetics. A GP is initiated with a set of solutions (represented by chromosomes) called the population (Koza 1992). Each solution in the population is evaluated in terms of its fitness. Solutions chosen to form new chromosomes (offspring) are selected according to their fitness, i.e., the more suitable they are the higher likelihood they will reproduce (Koza et al. 1993). This is repeated until some condition (for example, the number of populations or improvement of the best solution) is satisfied. GP operators and solution encoding scheme need to be carefully chosen to appropriately explore and exploit the solution space (Goldberg 1989).

5.4 Evaluation of innovations

For any innovation to be tested, a test market needs to represent the actual market. While using actual customers to evaluate a small number of innovations can be done, doing it for a large number of innovations is not possible. The proposed approach will use actual customers to evaluate innovations, however, the population of customers per innovation to be evaluated will be small and therefore the proposed approach will scale up to a large number of solution alternatives.

Virtual evaluation of prototypes

Traditional approach to evaluate innovation ideas has been through the market. In essence all products are tested in the market after they have been released for sale. The time horizon of such evaluation is close to the product/service useful life which significantly diminished the value of any data collected. A dream of any corporation is to evaluate a product/service model before its introduction to the market. For example, a pharmaceutical company would like to know effectiveness of a drug before its release as much as automotive company would to design a car that would open new markets. The proposed approach aims at increasing prediction accuracy of innovations by the introduction of a novel approach of evaluating innovations in a virtual market.

The proposed approach for virtual evaluation of potential innovations is highlighted using Fig. 8. Consider three data sets A, B, and C, $A = B \cup C$, where B = sample market data set, C = test data set.

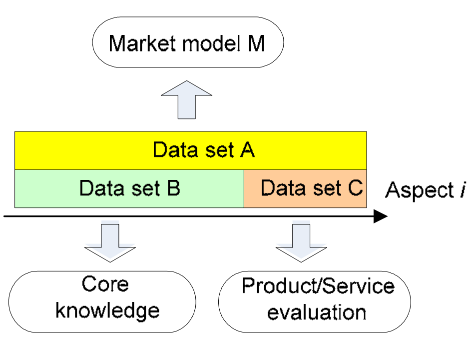

Figure 8: Virtual evaluation of innovations.

The market model S consists of knowledge extracted from the data set $A = B \cup C$ using all variables (adjustable and fixed). Model M can be built using data-mining algorithms, e.g., decision-tree algorithm, neural network. The accuracy of this model can be tested using standard approaches, e.g., cross-validation and bootstrapping.

Once the system model S is built, it becomes a virtual market over the space determined by the data set A. Representative configurations made of adjustable variables are extracted from data set B, i.e., the core knowledge representing different outcome metrics (e.g., innovation level). The data set C represents the test product/service configurations (known fixed and adjustable variables as well as the outcomes). These configurations represent a future set of products/services to be tested in the virtual market. Based on the representative product/service configurations obtained from B, the adjustable variables corresponding to each configuration in C are modified so that the outcome is improved.

The proposed computational approach is intended to improve the speed, quality, and predictability of planned innovations. It constitutes a valuable contribution to innovation science outlined in Kusiak (2007a).

6 CONCLUSION

Global competition calls for enhanced innovation of products and services. Innovation is a vehicle for success in the global economy. Emerging economies need to embrace the creative destruction paradigm offering many challenges and opportunities for future success.

The basic innovation phases were characterized. Examples of traditional methods for generation of novel ideas and their evaluation were presented. As humans have limited cognitive ability to create and evaluate large number of potential innovations, a novel computational approach supporting the innovation process was presented. Some of the concepts presented in the paper were illustrated with examples.

7 REFERENCES

[1] Aghion, Ph. and Howitt, P., 1992, A model of growth through creative destruction, Econometrica, Vol. 60, No. 2, pp. 323-351.

[2] Aghion, Ph. and Howitt, P., 1997, Endogenous Growth Theory, MIT Press, Cambridge, MA.

[3] Benkler, Y., 2006, The Wealth of Networks, Yale University Press, New Heaven, CT.

[4] Christensen, C., 1997, The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail, Harvard Business School Press, Boston, MA.

[5] Chiffoleau, Y., 2005, Learning about innovation through networks: The development of environment-friendly viticulture, Technovation, Vol. 25, No. 10, pp. 1193-1204.

[6] De Vries, E.J., 2006, Innovation in services in networks of organizations and in the distribution of services, Research Policy, Vol. 35, No.7, pp. 1037-1051.

[7] Gallouj, F. and Weinstein, O., 1997, Innovation in services, Research Policy, Vol. 26, pp. 537–556.

[8] Gilberta, N., Ahrweilerb, P., and Pykac, A., 2007, Learning in innovation networks: Some simulation experiments, Physica A: Statistical Mechanics and its Applications, Vol. 378, No. 1, pp. 100-109.

[9] Goldberg, E.D., 1989, Genetic Algorithms, Addison Wesley Longman, New York.

A. Kusiak, Innovation A Data-Driven of Products and Services: Bridging World's Economies, *19th International Conference on Production Research*, *ICPR 19,* Valparaiso, Chile, August 2007, pp. 1-6.

[10] Henkel, J., 2006, Selective revealing in open innovation processes: The case of embedded Linux, Research Policy, Vol. 35, No. 7, pp. 953-969.

[11] Herstatt, C. and von Hippel, E., 1992, From experience: Developing new product concepts via the lead user method: A case study in a "low tech field", Journal of Product Innovation Management, Vol. 9, pp. 213-221.

[12] Hansen, M.T. and Birkinshaw, J., 2007, The innovation value chain, Harvard Business Review, Vol. 85, No. 6, pp. 121-130.

[13] Koza, J.R., 1992, Genetic Programming, MIT Press, Cambridge, MA.

[14] Koza, J.R. et al., 2003, Genetic Programming IV: Routine Human-Competitive Intelligence, Kluwer, Norwell, MA.

[15] Kusiak, A., 2007, Innovation: From data to knowledge, BONEZone, Vol. 6, No. 1, pp. 24-26.

[16] Kusiak, A., 2007a, Innovation science: A primer, International Journal of Computer Applications in Technology, Vol. 28, No. 2-3, pp. 140-149.

[17] Kusiak, A. and Song, Z. 2006, Combustion efficiency optimization and virtual testing: A data-mining approach, IEEE Transactions on Industrial Informatics, Vol. 2, No. 3, pp. 176-184.

[18] Nambisan, S. and Sawhney, M., 2007, A buyer's guide to the innovation bazaar, Harvard Business Review, Vol. 85, No. 6, pp. 109-118.

[19] Nolan, R.L. and Croson, D.C., 2005, Creative Destruction: A Six-Stage Process for Transforming the Organization, Harvard Business School Press, Boston, MA.

[20] Page, M., 1999, The Creative Destruction of Manhattan, 1900-1940, University of Chicago Press, Chicago, IL.

[21] Schumpeter, J.A., 1942, The Process of Creative Destruction.

[22] Song, Z. and Kusiak, A., 2007, Constraint-based control of boiler efficiency: A data-mining approach, IEEE Transactions on Industrial Informatics, Vol. 3, No. 1, pp. 73-83.

[23] Von Hippel, E., 2005, Democratizing Innovation, MIT Press, Cambridge, MA.

[24] Von Hippel, E., 1986, Lead users: A source of novel product concepts, Management Science, Vol. 32, No. 7, pp. 791-805.

[25] Von Hippel, E., 1988, The Sources of Innovation, Oxford University Press, New York.

[26] USA Today, March 7, 2007, p. 11A.