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# Innovation: A data-driven approach

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ABSTRACT

A newly introduced product or service becomes an innovation after it has been proven in the market. No one likes the fact that market failures of products and services are much more common than commercial successes. A data-driven approach to innovation is proposed. It is a natural extension of the system of customer requirements in terms of their number and type and the ways of collecting and processing them. The ideas introduced in this paper are applicable to the evaluation of the innovativeness of planned introductions of design changes and design of new 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 toll gates of innovation are the generation of new ideas and their evaluation. People have limited ability to generate and evaluate a large number of potential innovation alternatives. The proposed approach is intended to evaluate many alternatives from a market perspective.

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## 1. Introduction

The study of innovation—the development of new knowledge and artifacts—is of interest to engineering, business, and social and behavioral sciences. Innovations impact the day-to-day lives of individuals (e.g., the introduction of newly discovered drugs affects the life expectancy of many individuals).

Though many innovation studies have been published, the literature on innovation does not yet deserve the label, innovation science. Innovation is often discussed based on experiences specific to a particular application. For example, innovation undertakings at companies such as Procter and Gamble and Apple have been broadly studied. However, it is not known to what degree these findings would produce similar results in other corporations. The need to create innovation science is apparent as outlined in Kusiak (2007a).

### 1.1. What is innovation?

Innovation is an iterative process aimed at the creation of new products, processes, knowledge or services by the use of new or even existing knowledge. Some prefer the terms "technology-based innovation" or "technological innovation" to emphasize the role of technology.

Without being too specific about definitions, many agree that market relevance and market acceptance distinguish innovation from invention and creation (see Fig. 1).

The market determines whether a creation or an invention becomes an innovation. The market acceptance and relevance can be expressed in economic terms (e.g., market share, profit) or other metrics (e.g., social acceptance). A process of transforming a creation or an invention into an innovation has a tremendous failure rate, e.g., 90% or higher. The purpose of innovation science is to dramatically reduce this failure rate.

### 1.2. What drives innovation?

Companies use various means to reach out to customers to incorporate their needs into new products. It has

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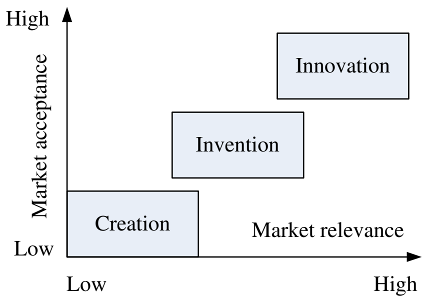


**Fig. 1.** Relationship between creation, invention, and innovation.

been suggested that companies use an incorrect approach and incorrect measurements when consulting with customers. Ulwick (2002) pointed out that companies should not expect solutions to be offered by potential customers; rather, they should elicit from them the desired characteristics of a product. He argued that customers may only know what they have experienced and may have a limited frame of reference when suggesting innovative ideas. In addition, by linking the products too closely to their customers, companies may end up creating incremental innovations. Veryzer (2005) emphasized the need for caution with customer input and pointed out the importance of discontinuous product development, e.g., the customer's input should be introduced later in the project. Christensen (2007) stated that customers may overemphasize the product's functionality. A design and control approach to product and process innovation is presented in Bordoloi and Guerrero (2008).

### *1.3. The process of creative destruction*

The concept of creative destruction was introduced by Schumpeter (1934) 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) who 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 photocopying 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 and Sears.

Successful innovation is typically a source of temporary market dominance, thus eroding the profits and position of less 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 people with obsolete skills, though their creations are valued by the customers. Creative destruction leads to more creative and productive enterprises needing new skills.

## 2. Innovation process

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 follows the generic process model shown in Fig. 2. This model generalizes the steps used in the invention capitalist approach outlined in Nambisan and Sawhney (2007).

Each innovation intermediary performs the following five activities: search, evaluate, develop, refine, and connect, however, in a different risk scenario and cost landscape. This landscape determines the input to the search activity and the 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 process (Fig. 2), 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 different risks and costs. The cost-risk relationship between these landscapes is shown in the grid in Fig. 3 (Nambisan and Sawhney, 2007).

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. 3 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 outside sources needs to carefully balance the three different

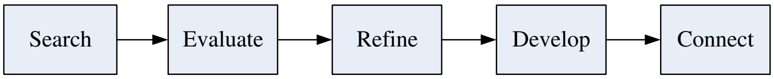


**Fig. 2.** Innovation landscape process model.

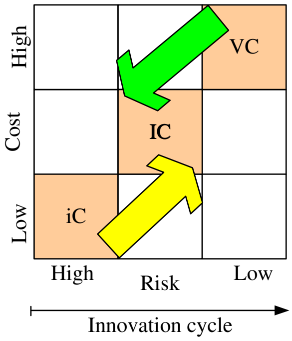


**Fig. 3.** Cost-risk innovation grid.

innovation landscapes. According to Nambisan and Sawhney (2007), basing innovation on the lower left square in Fig. 3 appears to be attractive to consumer products and markets populated with many different and relatively simple products. The top left right area may apply to 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. 3.

### 2.1. 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 improving their ability to generate, develop, and disseminate new ideas (Hansen and Birkinshaw, 2007).

Improving innovation calls for viewing the 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. 4 illustrates the innovation value chain model drawn according to the IDEF (Integrated Definition) notation.

Creative ideas can be generated locally (within a unit), across different units, or obtained from external sources. The input to the conversion phase includes ideas that are generated from one or more sources (this is indicated with the logical asynchronous OR junction in Fig. 4, denoted as O). At the conversion phase the main ideas are either:

- selected when they are mature enough and do not require further development, or
- developed into a market acceptable solution, if the number of candidate ideas is satisfactory, or
- selected and further developed into a market acceptable solution.

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

Management of the innovation value chain is key to a 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 rich case is not likely to advance a 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 developed at the idea generation phase.
- Percentage of ideas selected and pursued, or the percentage of financially supported 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 across the innovation value chain is apparent. Cost and time are two obvious variables that need to be reflected in such metrics.

The community of practice has made numerous contributions to innovation. According to the information included at http://www.getfuturethink.com, the basic components of innovation are (see Fig. 5):

- Ideas: Consider many alternatives.
- Strategy: Set goals and ways of achieving them.
- Process: Establish basic innovation steps.
- Environment: Make innovation a natural activity.

Despite the absence of innovation science, industry has pursued an innovation agenda. Many approaches published in the literature can be captured in the form of business rules. Examples of high impact business rules categorized into the four components of innovation shown in Fig. 5 are listed next.

*Ideas*.

*Rule* 1: Problem: Select important, not merely interesting problem (Carlson and Wilmot, 2006).

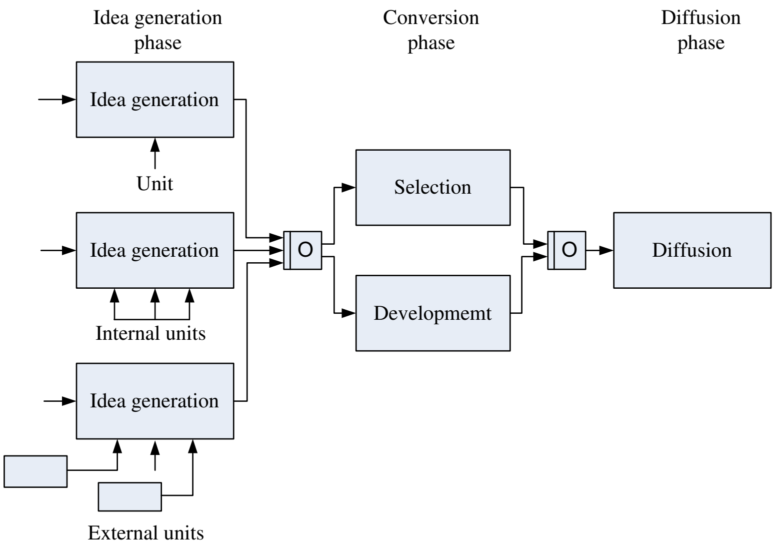


**Fig. 4.** Model of the innovation value chain.

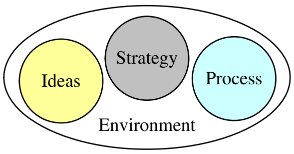


**Fig. 5.** Basic components of innovation.

The inventor of the computer mouse and hypertext, Douglas Engelbart, asked his development team "to make the world a better place by augmenting and extending the human intellect."

*Rule* 2: Expand customer requirements: Assess each innovation for its value to the customers (Carlson and Wilmot, 2006).

Look beyond cost, quality, functions, and so on into, e.g., convenience, conscience, and customer experience.

*Strategy*.

*Rule* 3: Expand project scope: Consider the intersection of diverse ideas and combine them into the next offerings of products (Pentilla, 2007).

This rule has been practiced by Xerox Corporation.

*Process*.

*Rule* 4: Process: Rapid and consistent innovation comes from highly disciplined processes (Carlson and Wilmot, 2006).

This rule contradicts some of the findings published in the literature pointing to unstructured activities supporting creativity.

*Rule* 5: Back-casting: Start with an end-product and work backward towards the basic idea that is cost and technologically feasible (Pentilla, 2007).

This is one of the rules practiced at McDonald's Corporation.

*Rule* 6: Rapid prototyping: Quickly transform ideas from a blackboard to 3-D models (Pentilla, 2007).

This is another rule used at McDonald's Corporation.

*Environment*.

*Rule* 7: Leadership: Appoint a champion insanely committed to the project (Carlson and Wilmot, 2006).

Highly successful projects point to strongly committed leaders.

*Rule* 8: Teaming: Build teams across the organization (Carlson and Wilmot, 2006).

Forming teams and increasing connectivity among the team members is key to the fostering and success of innovation. The topic of collaborative innovation has been widely discussed in the literature, e.g., Hacklin et al. (2006).

## 3. Requirements-guided innovation

The customer perspective has been driving design processes in the last two decades. This market focus has generally been reflected in the product's functionality and form. Other commonly used attributes to attract customers and at the same time improve business performance have been quality, reliability, and cost.

The level of innovation $I$ can be expressed as a function of requirements $X$, $I = F(X)$, involving various classes of requirements ($X$): function, form, surprise, culture, emotion, and experience (see Fig. 6).

The list of requirements impacting innovation expands beyond function and form. In fact, the AND/OR tree representation allowing the inclusion of alternatives may be used to elicit and represent requirements (Kusiak and Szczerbicki, 1992). The approach advocated in this paper calls for broadening the range of requirements over the traditionally considered ones (mostly function and form).

Understanding the breadth, content, and structure of customer requirements is crucial in innovation. A customer of today purchases a product that meets her/his functional requirements (product personalization), but also seriously considers additional attributes such as

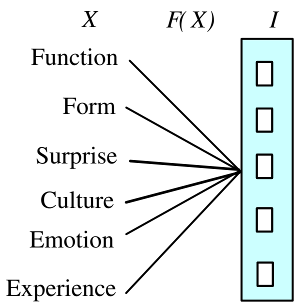


**Fig. 6.** A tree of expanded requirements.

surprise (e.g., unexpected product function), pleasure (e.g., driving a car), buying experience, and so on.

Ultimately the increased level of innovation $I$ has to translate into business benefits, e.g., increased market share.

## 4. Sources of requirements

In the past two decades, the design of products and services has been largely driven by customers. After all, the customer buys a product or uses a service. The "customer-as-the-king" model was preceded by the "engineer-as-the-king" (often designer) model, in which technical experts made the decisions for the customer. The customer was expected to accept the offered product or service.

Both models of eliciting requirements have focused on the product and service functions. Product innovation calls for additional requirements, making it worthy of the label "innovative product." The sources of innovation-fostering requirements are much wider and they include:

- Customers. The information from the customers should be collected over the product's life cycle rather than during a limited time frame. Processing that information and blending it with other sources of data and information could be the ultimate key to the success of the designed product.
- Domain experts. Though the importance of the voice of the engineer in forming requirements has been marginalized in the last few decades, it needs to be brought back and expanded when innovating. It is true that the customer is the one who ultimately pays for the product; however, he may not be aware of the possibilities that a new technology or a product/process combination may offer. A technologist may generate innovative features of a product.
- Legacy materials. All kinds of standard and digital libraries could be searched in the quest for innovation. The search would involve hypotheses, theories, innovation rules, and information about inventors and innovators. Data-mining algorithms could create previously unseen value in fusing data and information from various sources.
- Product life-cycle data. A product leaves a data trail over its life cycle. This is in addition to the information provided by the customers or experts before and after the product has entered the market. The volume of data collected can be large, e.g., imagine a database of cockpit and maintenance data collected over the useful life of an airplane. The product's lifetime data can deliver valuable knowledge leading to requirements spurring innovation. Some of the product life-cycle data could appear in the form of tacit knowledge (Koskinen and Vanharanta, 2002).

Having outlined the role of requirements in innovation as a "data generator," the role of data mining in this exciting undertaking is obvious. It will be used to discover patterns leading to market acceptance of candidate solutions.

## 5. Innovation evaluation

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 a global economy. Next, examples of methods used to evaluate innovations are discussed.

### 5.1. Trial-and-error approach

A widely used approach to innovation is trial and error. Designers observe the consequences of the design choices made and learn from them. The advantage of the trial-and-error approach is that it is easy and everyone can use it. The major limitation of this approach is the lack of predictability of the outcome and a high cost.

### 5.2. Lead user study

The lead-user market research method is based on the concept that the need for new products, processes, or services 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 incorporated into development of a new product 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 at lower cost.

The lead-user method involves four major steps (von Hippel, 1986; Herstatt and von Hippel, 1992):

*Step* 1: Specifying product/service characteristics of interest to future customers.

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

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

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

*Step* 2: Identifying lead users.

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

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

Next the steps of the lead-user method are discussed in more detail.

*Step 1(A)*: Identification of trends.

Identification of important trends in the evolution of user needs is the focus of this step usually involving surveying experts. Herstatt and von Hippel (1992) in their case study sought out the advice of experts at universities, professional engineering organizations, and municipal departments. Ultimately, the panel of experts who provided information for this study consisted of eight leading engineers, two researchers, an engineer from a professional organization, and a municipal engineer.

The panel of experts identified the following three trends in pipe hanger systems (Herstatt and von Hippel, 1992):

*Trend 1*: There is an increasing need for pipe hanger systems that are extremely easy to assemble, without any manual. Such systems should have significantly fewer components and be versatile.

*Trend 2*: There is a need for rapidly actuated, positive, interlocking fasteners to connect pipe hanger elements together securely, and to attach the completed hangers securely to building walls and ceilings.

*Trend 3*: Pipe hangers that are lighter and made of non-corrodible materials are needed. Pipe hangers should therefore increasingly be made of plastics rather than steel elements, which are used almost exclusively today.

Of course, each of the three trends was justified.

Solutions that offered improvements with respect to these trends were expected to result in significant benefits for the users of pipe hangers. The skills required of installers would be reduced, fewer components would be stocked, the products would be easier and safer to install, and the risk of field failures would be reduced.

*Step 1(B)*: Identification of benefits expected from future products/services.

Customer benefits expected from future products/services could be determined by surveying knowledgeable customers themselves (von Hippel 1986, 1988). For example, Herstatt and von Hippel (1992) interviewed 74 customers. The same sample was also used to identify customers who became lead users is Step 2 below.

*Step 2*: Identification of lead users.

Once the trends and the user benefit characteristics are specified, lead users are selected. In their industrial study, Herstatt and von Hippel (1992) selected 22 lead users of pipe hanging hardware of the sample of 74 customers previously interviewed to determine the anticipated customer benefits.

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

A sample of 22 lead users of pipe hangers was identified (Herstatt and von Hippel, 1992). This task was to bring some of these lead users (22 of Step 2) and the company's experts together to generate promising concepts.

Herstatt and von Hippel (1992) applied two additional tests to the sample of 22 lead users. These additional tests were intended to assess the user on two issues:

- clarity of presenting lead user's ideas,
- strength of lead user's personal interest in the development of improved pipe hanger systems.

Fourteen of the 22 lead users met the two additional tests and were invited to join a workshop. All users who joined the workshop formally agreed that any inventions or ideas developed during the sessions would be the property of the project imitating company. As compensation, every participant was offered a small honorarium. Interestingly, most of the participants did not accept the honorarium. They felt sufficiently rewarded by simply attending and contributing to the three-day workshop.

*Step 4*: Test the concepts developed by lead users in a sample market of typical users. The final step in the lead user market research method involves testing whether typical users in a marketplace find the product or service offered attractive.

The customers selected for this test user sample were drawn from the original group of 74 interviewed customers. The selection criteria were that the telephone interview data showed them not to be lead users, and that they had had a long, close relationship with the company. The latter requirement was to meet the confidentiality obligation. The interviewees selected were buyers as well as users. They had a dominant role in the purchasing decisions of their own companies with respect to pipe hangers.

These 12 user-evaluators were asked to review the proposed pipe hanger system in detail, noting particular strengths and weaknesses. Their response was very positive. Ten of the 12 preferred the lead-user product concept over existing, commercially available solutions. All except one of the 10 expressed a willingness to buy such a pipe hanger system when it became available, and estimated that they would be willing to pay a 20% higher price for it relative to existing systems.

The case study was judged as successful in terms of identifying trends for generating novel product concepts and increased speed and lower cost.

### 5.3. Innovation networks

Innovation enables companies to effectively compete (Christensen, 2007), by supporting the innovation process, e.g., the idea generation phase, conversion, or diffusion phase (see Fig. 4). 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 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 the 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.

In recent years there has been an increased interest in innovation in networked environments, especially in the European literature. This could be due to the networked research environment promoted by the projects sponsored by the European Commission. In fact, the focus of some of these projects has been on studying collaboration, e.g., the ECOLEAD initiative (www.ecolead.org) involving over 20 partners from 12 countries. 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 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 environmental-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 in order to consider the innovation trends in networked organizations and their distributed services. The modification studied 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 unfamiliar with collaborative networks, is that of handling intellectual property. Many will agree that research is needed to develop different models of handling a company's confidential information. A natural way of limiting the release of proprietary information is by using an open communication channel customer feature rather than technical product/service features. The diffusion of intellectual property needs further studies. Decision support tools, including simulation (Albino et al., 2006), may uncover the proper balance between revealing information and innovation benefits.

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 thoroughly. In fact handling issues related to intellectual property in a networked environment could be considered as a measure of success. Some results of handling intellectual property issues have begun to emerge. For example, Henkel (2006) discussed the results of a quantitative study ($N = 268$) of patterns of freely revealing firm-developed innovations embedded in 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 this open exchange of information would be 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 selectively revealing information. A corporation would reveal, on average, about half of the code it had 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. Perhaps the best proof that innovation in the open works is provided by the P&G's Connect+Develop (C+D) model (http://www.pgconnect-develop.com). This model has become the envy of many industries.

## 6. Proposed innovation framework

The key issue in innovation is an early evaluation of many possible solution alternatives. A traditional approach limits the number of alternatives due to the time and cost necessary to create and evaluate them.

The basic steps of the proposed three-phase approach are illustrated in Figs. 7–9 (Kusiak, 2007b). Fig. 7 illustrates Phase 1, where a training data set is generated. A design team develops a prototype model (or a few

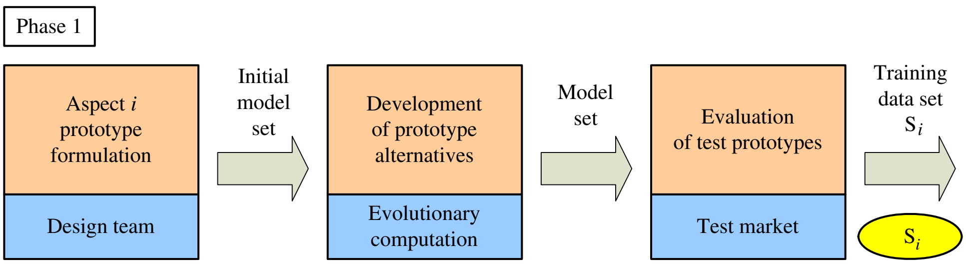


**Fig. 7.** Aspect $i$ learning mode.

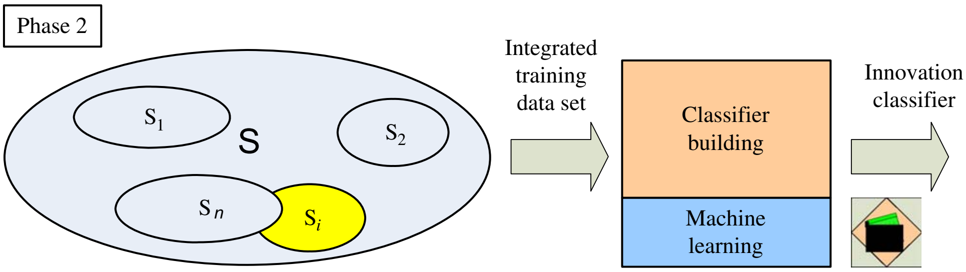


**Fig. 8.** Learning from an integrated data set of $n$ aspects.

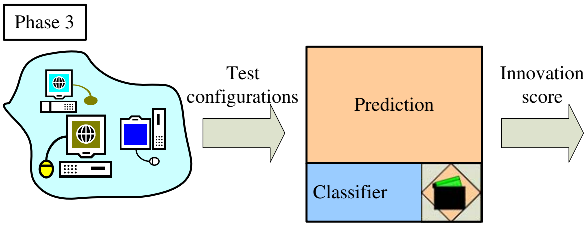


**Fig. 9.** Prediction of innovation scores.

prototype variants) involving innovation features (called here an aspect $i$). The initial prototype set (Fig. 7) is expanded by an evolutionary computation algorithm into a larger prototype set that is evaluated in the test market, and it produces a training data set S$i$, $i = 1,\ldots,n$.

In Phase 2, the training data sets S$i$ for $n$ aspects are integrated into a single data set S that is used to build a classifier shown in Fig. 8.

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. 9).

The three-phase approach presented involves feedback loops not shown in Figs. 7–9. For example, the configurations evaluated at the end of Phase 3 could be introduced to the training set used as input in Phase 2.

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

The novelty of the research presented in this paper is realized at two different levels. The first level is the most challenging part of the proposed research, the design of a system enabling innovation. The sources of data, as well as interoperability among all constructs and algorithms, will be established. The proposed solution to test innovations will be known as the Living Laboratory of Innovation Discovery (LIVLID) outlined in Kusiak (2007c). The framework is a step towards the realization of innovation science (Kusiak 2007a, 2007c).

## 7. Conclusion

A framework was outlined for innovation based on the requirements elicited from multiple sources. Like innovations generated through market success, any development process has to target the market-expected requirements. With the abundance of data in the cyber world, new ways to analyze and use the data are needed. The collected data and requirements are refined and analyzed by tools and human resources all assembled as the Living Innovation Laboratory in service of innovation.

The novelty of this research is the system enabling innovation. The proposed approach established a new paradigm in innovation beginning with a large number of design alternatives and selecting the most promising ones. The selection of the most promising alternative(s) enhances innovation and dramatically reduces the failure rate of the invention–innovation path.

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