SYSTE M ATIC RISK MANAGEMENT
FOR THE INNOVATIVE ENTERPRISE

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Abstract

We present systematic decision support for innovation management. At the core of our system is a dynamically evolving risk taxonomy that we map to either qualitative or quantitative decision processes. We describe several experiments that could advance the science behind innovation management. In the context of a portfolio of potential and actual service offerings, we discuss how to spread, hedge, or mitigate risk, and how these activities constitute enterprise innovation management.

1. Introduction

The modern enterprise that bases its business models on innovation requires a management system that provides both encouragement for risk taking and agility at navigating disruptive changes in the ecosystem. Yesterday’s innovative products and services are today’s commodities. In order to maintain a high profit margin and characterization as a growth company, the enterprise must generate new ideas that lead eventually to new lines of business and new business models. It is not enough to simply improve productivity within a fixed line or model.

Disruptive changes in an enterprise ecosystem are accompanied by multiple uncertainties. Leifer et al. have defined four major dimensions of uncertainty that are relevant for all innovation development projects targeting to new lines of business: technological, market, organizational, and resource uncertainties [10]. The management challenge of multiple dimensions of uncertainty is complicated by the fact that the uncertainties interact with each other, in the sense that there are complex correlations. Additional management challenges come when the innovation idea is not perfectly in line with company’s current strategy, which is a frequent case when the innovation would mean a new line of business for the company [8, 9, 10]. Many of these challenges can be met with the aid of a systematic support system for decision making in order to manage the innovative enterprise throughout the innovation life cycle from idea to the termination of line of business.

We present a system that provides decision support for innovation management, focusing on an innovation life cycle from idea to line of business. Our system is based on a set of operating principles including (1) encouraging innovation, (2) efficient decision making, (3) minimizing waste of intellectual capital, (4) an open-ended and dynamic risk taxonomy, and (5) the treatment of risk via either mitigation or insurance, (v. Figure 1). While the focus of (1), (2), and (3) is in the front end activities of the innovation life cycle, (4) and (5) cover the entire life cycle, including the termination of lines of business. In this paper we will focus on principles (4) and (5). Principles (1), (2), and (3) will be presented elsewhere [1]. Here we summarize extensive discussion of the first three principles: (1) we suggest encouraging innovation by soliciting undeveloped, ambiguous ideas (to be combined into project visions) rather than well developed proposals with business cases; (2) we suggest that qualitative techniques for decision support are less expensive and more appropriate than quantitative techniques early in the innovation life cycle; (3) we suggest conserving intellectual capital by recycling ideas that have previously been constituents of the vision of a terminated project.

In this paper we illustrate the development and application of an open-ended hierarchy of risk factors to the design, development, marketing, and delivery of service lines of business. We show how to map this risk taxonomy onto sets of questions appropriate for different stages of development, and how to use sets of responses to these questions both to support decision making and to support the evolution of the risk taxonomy itself. We show how the risk taxonomy can be viewed as a dynamic system, responding to both immediate feedback and eventual experience. We
discuss when to shift from qualitative to quantitative decision support and how to manage a portfolio consisting of a set of current offerings and a set of potential offerings under development. Throughout the paper we discuss how to spread, hedge, or mitigate risk, and how these activities constitute enterprise innovation management.

Encouraged innovation

Efficient decisions

Conserved intellectual capital

Dynamic risk taxonomy

Mitigated or compensated risk

Figure 1: Design Principles (last two are the focus of this paper).

1.1. Methodology

Our work is based on a large interview study done by VTT in 2005 about innovation management practices in companies and public organizations (see [8] for more details). The study identified management of future uncertainty as one of the main challenges to corporate executives. That initiated the research question of the work: How should future uncertainty be managed during the entire innovation life cycle?

Our approach is based on constructivist methodology, focusing on different viewpoints and lived experience of organizational members and is committed to bringing up multiple voices and viewpoints [6, 17]. The authors have wide experience in research, development and consultancy work in the fields of technology foresight and risk management as well as in the development of new technology and services. We draw on this experience in order to specify the research problem in a more detail, and then, to develop tools and methods for the management of the uncertainty. The tools (process building blocks) have been integrated by applying the generic methodology of risk management [7, 19] in order to produce the primary novel contribution of the work: a dynamically evolving risk taxonomy to provide systematic support for decision making in the innovative enterprise. The risk taxonomy itself follows the constructivist methodology: the taxonomy evolves in response to different viewpoints and lived experience of organizational members.

Some of the individual building blocks described in this paper are well known and widely used. However, our concept for their integration into a decision support system is novel and presented as a working hypothesis:

Working Hypothesis 1: The potential and actual lines of business of an innovative enterprise can be efficiently and usefully managed by means of decision support based on a dynamic risk taxonomy.

This conceptual paper enumerates four explicit experiments that should be performed to advance the science supporting this working hypothesis and the second working hypothesis, which is presented in section 3. We invite others to perform and report the results of these experiments.

1.2. Definitions

At the conceptual level, (enterprise) risk is defined in a standard way as the “combination of the probability of an event and its consequences” [7]. This concept of risk covers both positive and negative consequences, both opportunities and threats.

An enterprise is a value delivery system with relatively well-defined boundaries, a portfolio of lines of business (each with a business model), a dominant culture, and motivation to achieve profit. Note that events (changes in the state of reality) may lead to or realize risks; but events are not risks, themselves. Risk management is a systematic process where organizations methodologically “address the risks attaching to their activities with the goal of achieving sustained benefit within each activity and across the portfolio of all activities” [2]. A Risk factor is a factor that may potentially affect the organization. And a risk taxonomy is an organization of (possibly overlapping) risk factors by set inclusion.

We call any specific stage in the innovation life cycle of a potential or actual line of business an assessment point. Much of the methodology of this paper is devoted to assessing risk associated with a risk factor at an assessment point. An important part of our risk management methodology is the prioritizing of risk factors at an assessment point. Related to that we have defined a quantity called risk priority for the estimation of risk level on a five point scale.

We also use terms idea and vision. Following [18] we define an idea as a description of some aspects of a potential future state of reality. A vision is a consistent set of ideas. For purposes of analysis and assessment, we will often equate a risk factor with the set of enterprise related visions that would be classified as belonging to the factor.
2. Decision Support

The innovation life cycle contains several stages which can be sequential or overlapping. Each stage contains at least one strategic decision point, assessment point at which decisions will be made that affect the innovation life cycle (v. Figure2).

![Innovation life cycle](image)

**Figure 2: Life cycle decision points.**

2.1. The basic decision: stop, hold, or go

At each decision point the basic decision is whether to GO on in the potential or actual line of business or to STOP and terminate the process. A third alternative is to put the potential or actual line of business into a temporary HOLD state to wait for a better time to continue the process. While making a hold decision is simple, it is the authors experience that returning an innovation from a hold successfully back into the active process is not as simple.

![Decision point](image)

**Figure 3: Stop, hold, or go.**

We have discussed elsewhere [1] the utility of the signpost method in returning a potential or actual line of business from a temporary HOLD state. The signpost method is a way to systematically explore possible futures, setting up networks of visions punctuated by signposts [18]. A signpost is a potential future event that is both recognizable and actionable. Part of the cost of entering a HOLD state is the cost of defining the signpost that will be used to signal its recommended return. If no such signpost can be found, then it is likely better to end (STOP) the project or offering, since we can’t define explicit conditions under which we believe we should restart it.

2.2. Approximate Delphi: the basic qualitative building block of decision support

When we produce any measure or estimate that will be used in support of a decision, we use one of two processes: (1) direct measurement, observation, or report of an authoritative data source, or (2) a weighted average of quantitative or qualitative estimates made by various subject matter experts. When the weights used in the weighted average of the latter process are self assessed measures of expertise relevant to the specific estimate, then we call this latter process approximate Delphi (because it approximates the consensus we might have obtained by performing a Delphi process with all experts participating simultaneously in a meeting (v. [14], [16], [18])). In [1] we discussed the use of approximate Delphi as a means to make inexpensive qualitative estimates in support of efficient decisions in the early part of the innovation life cycle.

Below, we will discuss mapping risk factors into questions. These questions are directed to multiple subject matter experts who respond according to the approximate Delphi process. Later, some of these questions are answered by means of quantitative studies.

Here we mention the first of several experiments to be performed in order to improve our system.

**Experiment 1.** *With the same set of subject matter experts, perform concurrently approximate Delphi and a standard Delphi process to measure the accuracy of approximate Delphi and to determine any systematic bias it may introduce.*

We welcome any independent reports of results of experiments of this type.
2.3. Reference class forecasting: one quantitative building block of decision support

A quantitative approach to risk assessment and general forecasting is that characterized by [5] as reference class forecasting. The idea is to select a class of empirical data already available for similar initiatives and to use that data as if it represented a distribution from which the initiative being analyzed were a random choice. Of course, the difficulty with this approach resides in the selection of the reference class. The more innovative the initiative under consideration, the more difficult will be the selection of a reference class. However, once a new line of business is launched, its past experience is obviously a useful reference class for forecasting future experience.

Another area where reference class forecasting has been used to advantage in innovation management is the area of assessing the risk from competitive technology including competitive intellectual property. Strong, et al., discuss the use of patent activity as a proxy for investment in research and development [18].

2.4. Decision support versus inflexible decision rules.

The choice to stop or hold an initiative under development cannot be made lightly. If we stop, then we may recycle the basic ideas; but we have definitely expended some research and development effort without any return to show for it. If we put an initiative on hold, we have the ability to resume the initiative when conditions are more auspicious. But there is always a cost in stopping a productive team in the middle and redirecting or even breaking up that team. For this reason, we advocate systematic decision support but flexible human judgment in decision making.

3. Risk

In this paper we treat risks associated with potential or actual enterprise lines of business that are products of innovation. We follow the generic methodology of risk management, including the steps of identification of risks, analysis of risks, evaluation and selection of risk reducing measures, and implementation and follow up [19] with some refinement based on the controllability of risk factors. In general, risk management aims to protect the property, income and different activities of a company while minimizing costs. Note that, according to the definition in section 1.2, risks may be associated with events having either positive (opportunity) or negative (threat) impact to the enterprise.

The framework of risk management developed in this work is shown in Figure 4. The process starts from a taxonomy based risk identification where check lists are used for potential risk factors. Identified risks are qualitatively analyzed and evaluated by experts with the help of questionnaires. After ranking and prioritizing the risks (risk profile and consequence analysis), negative risk reducing measures are selected. If necessary, qualitative risk analysis is supplemented by a quantitative study. The result is a complete package of support for a specific decision point. Once the decision is made, any negative risk reduction measures can be implemented and tracked for consideration at the next decision point.

It is important to point out that in our framework the risk assessment (in the first level) is based on qualitative estimation of likelihood and consequences. Qualitative estimates of likelihood should not treated as probabilities, and they should not be used to estimate expected costs.

![Figure 4. Framework of risk management steps for systematic innovation management (adapted from [19])](image-url)
the approach that treats risk as volatility in a time series (cf. [21]). We use brainstorming among a team of subject matter experts to enumerate visions relevant to a given risk factor. We reorganize the separate visions to be as independent as possible. Then we sum the products of estimated probabilities and impacts in order to estimate the risk.

Experiment 2. With the same set of subject matter experts and with respect to the same assessment point and risk factor, enumerate the visions associated with the risk factor. Use approximate Delphi to estimate (a) the risk priority, (b) the likelihood of each of the visions, (c) the negative impact of each of the visions. Repeat this operation for several different assessment points and risk factors. Test for the degree of correlation between (a) and the inner product of (b) and (c).

A similar experiment could be performed to compare the efficacy of simple approximate Delphi estimates of risk priority with a combination of reference class forecasting (section 2.3) and approximate Delphi.

If there is good correlation between risk priority and the product of likelihood and impact, then we can skip estimations (b) and (c) in favor of (a). In any case, we believe we can use (a) to decide when estimations (b) and (c) are necessary. This we phrase as a working hypothesis:

Working Hypothesis 2: Approximate Delphi estimations of risk priority are sufficiently correlated with estimations of associated risk as a product of likelihood and impact that they can be used to determine when it is necessary to further assess risk before deciding to continue an initiative.

3.1. Risk Taxonomy

A risk taxonomy is a hierarchical organization of (possibly overlapping) risk factors, the hierarchy representing set inclusion of the associated ideas. It is helpful to bifurcate the hierarchy (at the top) with a classification of risk factors that are controllable and those that are not. By controllable, we mean that the enterprise has either the ability to mitigate the risk or to compensate for the risk. Note that it is easy to construct risk factors that are partially controllable and partially not. Moreover, there are risk factors and enterprises for which the classification is unknown. However, where possible, we attempt to deal only with risk factors that are known to be exclusively controllable or exclusively not controllable by the enterprise.

Another desirable quality for a risk taxonomy is comprehensiveness. It would be nice if the set of risk factors covered every imaginable risk related to the enterprise and its portfolio of potential and actual lines of business. However, the nature of human knowledge makes this type of comprehensiveness impossible. Instead, we choose to define our taxonomy as comprehensive if it is a dynamic structure that is open-ended and the union of risk factors covered by its nodes is intended to represent all known risk factors relevant to the enterprise.

A risk taxonomy can be used as a checklist at decision points in the innovation life cycle [11]. Note that a risk taxonomy may be comprehensive for one enterprise but not for another. Nevertheless, we believe that good risk taxonomies are reusable resources and that the exercise of adapting a risk taxonomy from one enterprise to another is likely much faster and less expensive than developing a new risk taxonomy for each enterprise.

Service Enterprise Risk Factors

- **Controllable**
  - Concept
    - Idea
      - Value Proposition
    - Plan
      - Technical
      - Marketing
      - Delivery
  - Enterprise ecosystem
    - Collaboration network
    - Resources
      - Supplies
      - Technology
      - People
    - Intellectual Property

- **Uncontrollable**
  - Market environment
    - Client preferences
    - Competition
    - Economy
  - Other environment
  - External ecosystem
    - Collaborators
    - Vendors
    - Intellectual Property

Figure 5. High level portion of a services risk taxonomy

3.2. Map from risk factors to questions

In order to provide a single standard type of expert estimate, we define a question as a request for an estimate that can be answered with any rational number on a five point scale (from 1 to 5). For qualitative estimates, the end points of the scale are
given meanings and the middle point of the scale (value 3) is considered neutral between values 1 and 5. Thus the generic map from risk factors to questions produces a scale with 1 defined as “low risk,” 3 defined as “medium risk,” and 5 defined as “high risk.” This is the question used to measure the priority of a risk factor.

Often a more specific and more appropriate question can be generated for a given risk factor. Our preferred systematic approach is to map controllable risk factors to questions where the scale has 1 defined as “low risk priority” and 5 defined as “needs attention;” and to map uncontrollable risk factors to questions where the scale has 1 defined as “low risk” but 5 is defined as “not the right time for this line of business due to this risk factor” or “wrong time” (short label). The implication of the “wrong time” rating is that the project to develop the potential line of business should be placed on hold but not terminated. If the line of business is already offered, then the implication is that the enterprise should temporarily (not permanently) cease offering it.

Note that controllability is a dynamic attribute of risk factors. Controllability may be affected by changes in offerings of other enterprises in the relevant ecosystem. For example, some enterprise may initiate an offering of a type of financial option, swap, or other derivative that would allow a purchaser to hedge against a particular risk factor. Consider a planned line of business within a jurisdiction where the relevant transactions are not currently taxed. The risk of a new tax or tax increase might not be controllable by the enterprise until some other enterprise offered tax increase insurance.

Generally, lack of knowledge about a market is a controllable risk factor; but market preferences and competition are not. However, the introduction of prediction markets [4, 20] with appropriate derivative options could make all three risk factors at least somewhat controllable.

![Map: risk factors → questions](image)

**Figure 6. Map from risk factors to questions**

Whether the question asks about “needs attention” or about “wrong time” the decision supported by the question has all three possible outcomes (from section 2.1). The “wrong time” rating suggests a decision of HOLD rather than STOP and the “needs attention” rating suggests STOP rather than HOLD; but these are simply systematic decision support recommendations, not rigid rules.

### 3.3. Tolerable risk

In general innovation management decisions are made by analyzing both risk and reward potential. While many of the techniques we discuss can also be used to analyze rewards, a general system for reward management is beyond the scope of this paper. Instead we emphasize how much can be done while operating strictly on the risk assessment side and treating the reward analysis (business case analysis) as a risk factor.

A partial reason for standardizing our risk assessment with questions on a uniform five point scale is the possibility of adopting a uniform threshold for tolerable risk priority. When risks are assessed below a tolerability threshold, no further analysis work would be necessary. Only when risk factors were evaluated above such a threshold would they require further analysis, e.g. analysis about right timing and analysis about ability to mitigate or control risk in the future. Such a threshold would be computed separately for controllable and uncontrollable risk, with the controllable risk threshold shrinking to some minimum at the assessment point corresponding to a launch decision. Note that such thresholds could be used as throttles to control the rate of development of potential new lines of business.

Initially, such thresholds could be set via approximate Delphi, but we would expect to use machine learning techniques to adjust them over time. This envisioned process suggests experiments that could be performed on a small set of real assessment points for potential lines of business.

**Experiment 3. Break a large group of subject matter experts into two groups, controlling for as many group differentiating factors as possible. The two groups perform the following two approximate Delphi assessments in opposite order: (1) estimate a uniform tolerability threshold for controllable risk factors, and (2) estimate risk priority for a set of controllable risk factors. Compare the results of the two groups for systematic bias.**

**Experiment 4. Compare controllable risk priority assessments over the course of several subsequent**
assessment points. Can we predict later assessments from early assessments? Is there a threshold such that assessments above the threshold remain above the threshold and tend to increase while assessments below the threshold remain below the threshold and tend to decrease?

3.4. Dynamic risk taxonomy

Our risk taxonomy is dynamic with respect to total content, and organization. The content is dynamic in order to meet our comprehensiveness requirement. Whenever we discover a new risk factor that is not covered by the current taxonomy, we must add it to the taxonomy in order to maintain comprehensiveness (coverage of all known risk factors). When we use approximate Delphi to evaluate risk factors, we also ask our subject matter experts for any suggestions of risk factors we may have missed.

The organization determines order of application in life cycle (high level for early, more detailed for later). At each assessment point, we select a comprehensive frontier of the risk taxonomy for analysis. Figure 7 illustrates the difference between the frontier selected for an early assessment point and that selected for a later assessment point. The process of moving the frontier to a more detailed level is motivated by our principle of efficient decisions: we wish to save more detailed and thus more expensive analysis for later in the life cycle. This is the same reason we prefer qualitative to quantitative analysis early in the life cycle. For simplicity, we attempt to keep the frontier selected at a uniform level in the hierarchy. Note that in figure 7, the early frontier is at level 2 and the late frontier is at level 5 except where the hierarchy does not extend to level 5.

Both assessment points in Figure 7 are assumed to occur before delivery. After delivery, some of the lower level risk factors such as “Research and Development” may no longer be relevant. Subject matter experts are shown the entire risk taxonomy; but asked to respond to questions that have been mapped from the chosen level of the hierarchy. In free form comments they can also suggest whether a given factor is relevant. If necessary, relevance of a factor can also be assessed by approximate Delphi.

Launching a line of business eliminates branches of the hierarchy that apply only to development stages (v. Figure 8).

![Figure 7. Portion of risk factors analyzed for early versus late assessment points](image)

![Figure 8. Risk factors analyzed for service delivery assessment point](image)

![Figure 9. Risk taxonomy organization before and after feedback induced demotion of one factor](image)
answered. If the answer is that the assessment point is too early, then we effectively demote the risk factor by one or more levels in the hierarchy, replacing it with placeholders not intended for evaluation when necessary (v. Figure 9).

Likewise, the submitted estimates may be widely distributed. When the expertise weight is widely distributed we may suspect that the risk factor has separate aspects with different estimates. Having ascertained this information from the subject matter experts, either by asking directly, or from their free form comments, we may promote the risk factor higher in the hierarchy, so that it is evaluated earlier and its constituents are evaluated for the current assessment point (v. Figure 10).

We envision each potential or actual line of business having an associated official risk taxonomy, mapped at an active frontier of the hierarchy into a list of questions with the latest qualitative or quantitative estimates, visualized for easy presentation, as part of a governance (decision making) package.

### 3.5. Portfolio management and control of negative risk

Decisions about whether to continue developing or offering a particular line of business should be made in the context of the whole enterprise portfolio of potential and actual lines of business. This management principle is justified by the need to optimize investment but also by the potential for compensating risks. For example, if costs are somehow estimated without bias and the costs for several initiatives (in the portfolio) are known to be independent, then the risks associated with random cost overruns among the initiatives would be compensating. Cost estimation is typically quantitative and we can only expect to approximate unbiased cost estimation and initiative independence. In this context, approximate Delphi qualitative techniques for assessing independence may be as good as any others. (This suggests a set of experiments analogous to Experiment 1.)

Controllable negative risks should be tolerably controlled before we proceed to launch or resume offering a line of business. This is a special case of a broader principle that suggests making larger investments in order to mitigate larger risks corresponding to larger investments associated with later stages in the innovation life cycle: “Like any activity in project management, the efforts spent in risk management must commensurate with the risks involved, the scale of the projects, the costs of managing such risks and how it will affect the objectives of the project” [3]

We have already mentioned a number of techniques for hedging or spreading negative risk, including the use of financial market futures, options, and prediction markets. We should also include the idea of either purchasing insurance directly from a custom insurer or explicitly self-insuring against negative risk.

### 4. Conclusion

In this paper we have introduced the concept of a dynamic risk taxonomy. We describe risk assessment by the qualitative technique of approximate Delphi and by quantitative techniques such as reference class forecasting. We have shown how to use increasingly deeper levels in a risk taxonomy over the course of the complete innovation life cycle. We have suggested increasingly shifting from qualitative to quantitative techniques over this same course. In each case the idea is to use less expensive techniques early in the life cycle and increasingly detailed and thus expensive techniques as we near the point of launching a new line of business. We have suggested applying modern portfolio management theory to the enterprise portfolio of potential and actual lines of business. Finally, we have illustrated how the dynamic risk taxonomy can evolve as a byproduct of our qualitative and quantitative assessments.

In addition to this conceptual level study of innovation management decision support, we have outlined a number of experiments that could improve the efficiency and accuracy of our techniques. We expect to perform these experiments during the employment of these techniques and to report on the results. The experiments are specified in a way that we hope encourages independent research and consulting organizations to perform them and report on the
results. They are intended to advance the science behind innovation management.

5. References


