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ABSTRACT

Among the reasons for difficulty in decision making for the emerging technologies like nanotechnology is the evolving nature of the new technology, new materials, limited or unavailability of the historic and current data, private and protected nature of the data, product knowledge to monitor and control potential toxic exposure, and other untested or unavailable data on the environment and health effects (Phillips, Bahadori, Barry, Bus, Gant, Mostowy, Smith, Willuhn, & Zimmer, 2009). The demand for lighter material in healthcare for prosthetics, the automotive and aerospace industries search for Nanomaterial. The pharmaceutical industries are challenged with the increase of systematic diseases to provide soluble drug delivery targeting affected tissue, organs, or cells. Investors are seeking opportunities to find the hidden niche in the nanotechnology markets. The ultimatum to meet these industry demands, provide opportunities to investors, newly created nanotechnology industries, and industries looking to expand in other markets. In such complex and ambiguous environment, with limited understanding or predictability for the known and unknown effects of the emerging technology on environment and health, development of the framework for a decision-making model would be an imperative. Successful and appropriate decision-making model may come from the leadership insight and governance, stakeholder alliances, sharing of the unknowns, problems, solutions, and advancements. The work presented in the paper is based on a qualitative modified Delphi study by Dr. Audré Dixon for her doctoral degree in Doctor of Health Administration at the University of Phoenix Online.

Keywords: Nanotechnology, Nanomaterial, decision-making-model, framework of a model, leadership & governance, alliances.

Introduction

Nanotechnology is an emerging technology that is replacing existing industries with new markets and products. The term nanotechnology refers to designing and building structures, devices, and systems at molecular levels of less than 100 mm. A relative descriptive scale of nanostructures corresponds to a structure 1,000 times smaller than the width of a human hair (Crichton, 2002). Nanomaterial at the millimeter scale is stable, but the same material at the nanoscale has volatile reactions to heat, light, and strength (Balbus, Maynard, Colvin, Castranova, Daston, & Denison, 2007)

The challenge faced by the 21st century emerging technology leaders is determining if the traditional linear decision-making model is adequate for predicting underdeveloped processes for the environmental safety of Nanomaterials. Olewink and Lewis (2005) described the traditional linear decision-making model's essential tenants for predictability as a stable environment and access to historical, logical, and accurate information. Emerging technology environments are chaotic and unstable with underdeveloped processes. Essentially, the availability of scientific knowledge for risk assessment, dosage, and product safety does not exist for nanotechnology. The main problem is controlling or managing the uncertainty of Nanomaterials.

Incomplete quantitative scientific information creates ambiguity about the environmental risks. Potentially, harmful emission levels may threaten environmental safety (Alvarez & Parker, 2009; Cyert & DeGroot, 1987; Maynard, 2006a; Myers, 2007). The traditional linear decision-making model used for 20th century environmental safety forecasts may be inadequate for 21st century nanomaterial management.

As emerging technology outpaces the knowledge of nanomaterial properties, nanotechnology industry leaders are challenged with using traditional decision-making models. Limited scientific data and unfamiliarity of controlling immature processes, weakens the dynamics of traditional decision-making models and may compromise the accuracy in predicting environmental safety (Burgi & Pradeep, 2006). Flawed decision-making models may threaten corporate profits, competitive advantage, and possibly environmental safety.

Market changes demand global leadership presence and mandate leaders to maneuver the competitive landscape of ambiguity with precision. Competitive advantage rest with leaders willing to consider the idea of releasing old practices, and the willingness to embrace new framework for a decision-making model (Bruce, 2006; Kovner & Neuhauser, 2004). Advantage in decision-making may include a shift in the approach of leadership, communication, and the willingness to identify barriers impeding decision-making predictions.

Following discussion is based on a qualitative modified Delphi study completed by Dr. Audré Dixon for her doctoral degree in Doctor of Health Administration at the University of Phoenix Online.

Research Method

Since only limited knowledge of emerging technology is available, specifically Nanomaterials, the qualitative Delphi method was used as a structured approach to gather and refine information from experts in the field of nanotechnology. The main purpose of the study was to design a framework for an alternative decision-making model for emerging technology manufactures or industries handling Nanomaterials.

Research Questions

The central research questions driving the current study to examine the process for managing the uncertainty of Nanomaterials were as follows:

1. What is the process when forecasting can no longer predict, or explain the uncertainty of environmental safety, or social responsibility?
2. What type of leadership competencies are needed to manage uncertainties of nanomaterial technologies?

The modified Delphi design enabled examination of the three targeted areas in the study (a) best practices, barriers and assessment methods, (b) leadership and governance, and (c) decision model framework. Each target area included a number of Support Questions. These questions were used in the survey for data collection from experts in the industries using Nanotechnology. The list of the support questions in each target area is included below:

Best Practices, Barriers, Assessment Methods

- What is the process when forecasting can no longer predict or explain uncertainty of environmental safety or social responsibility?
- What has been tried in the past with success?
- How has the process changed?

Leadership and Governance

- What type of leadership competencies are needed to manage uncertainties of nonmaterial emerging technology?
- What are key performance factors?
- How does transnational corporations influence risk assessment and social responsibility?

Decision Making Framework Components

- What three essential components are needed in the framework for an alternative model?
- What is the minimum data needed to launch an exposure assessment?

- What are the knowledge gaps for better understanding of Nanomaterials?
- How can existing systems share data and information about Nanomaterials?

Delphi Method

Three features distinguish the Delphi method from other group interaction methods, (a) anonymous group interaction (b) data is based on the responses from technology experts, and (c) multiple iterations of group responses with interspersed feedback (Skulmoski, Hartman, & Kahn, 2007). The discussions between experts without permitting social exchange prevented opinion forming. Purposeful sampling method was used to support the Delphi design. Population samples from various industries included transnational companies and manufacturers in California, Texas, New York, Massachusetts, and Arizona. Industries included aerospace, automotive, medical, pharmaceutical, cosmetics, and paint and chemical industries. In spite ofthe busy travel and job schedule, 19 industry experts agreed to participate in the Delphi study. Demographics of the sample population are included in table G1.

Participants selected for the study were experts in leadership positions, involved in decision-making, and associated with organizations employing nanotechnology.

Table G1. *Main Study Population Sample Demographics*

Position Title and Description	Participants
President (CEO, Owner)	4
Vice President (Marketing, General Manager, Engineering)	3
Manager (Aerospace, Manufacturing, Production)	4
Research Scientist (Microencapsulation and Nanomaterial)	2
Senior Fellow (Technologist, Lab Director)	1
Director (Business Development, Intellectual Assets, Operations)	3
Pharmacology Professor	1
Principle Licensing Specialist (Commercial partners)	1

Total number of participants (19)

Pilot Study

A pilot study was done to assess the validity, reliability, relevance of research questions to the nanotechnology industry, and feasibility of collecting data using the qualitative, modified Delphi research method. The pilot study generated additional survey questions and modification of the language in the support questions in two of the target areas of research. In the target area, leadership, and governance, original Question 2 was divided into two questions. The two questions addressed risk assessment social responsibility. In the target area, decision-making components, the added support question addressed available resources. The new Support Question 3 was focused on the resources used to

supply information deficiencies. These improvements are included in support questions in the following sections.

Data Collection

A secured website hosted by Survey Monkey contained survey questions for participants to answer. The two central research questions enabled examination of the process for managing uncertainty of Nanomaterials. The supportive questions targeted best practices, barriers and assessment methods, leadership and governance, and decision model framework. NVivo 10 by QSR, a qualitative research software package was used to analyze the survey responses from the Nanotechnology industry experts, identified in table G1.

Results and Analysis

Survey data from the Nanotechnology industry experts was analyzed using the software analysis toll NVivo by QSR. Each of the three target areas is discussed.

Best Practices and Assessment Methods

Support Question 1 was, "What is your current decision making process as it relates to technological forecasting?" Three responses were evident. The first response, about using formal procedures and external and internal consultants (market trends), was 36.4% agreed and 27.3% strongly agreed. The number of participants in disagreement was 27.3% and 9.1% strongly disagreed (see Table 1).

The second group of responses, to use planning models (gap analysis and prediction models), included 36.4% agree responses and 27.3% strongly agree responses. Responses of disagreement were 36.4%. For the third group of responses, to use research journals, the internet, and databases, 60.0% of participants agreed and 40.0% strongly agreed (see Table 1).

Table 1. *Best Practices and Assessment Support Question 1*. What is your current decision-making process as it relates to technological forecasting?

	Agree	Strongly agree	Disagree	Strongly disagree
Formal Procedure (use internal & external consultants)	36.4% (4)	27.3% (3)	27.3% (3)	9.1% (1)
Use planning models (gap analysis pred. Models)	36.4% (4)	27.3% (3)	36.4% (40)	0.0% (0)
Research journals, internet, and databases	60% (6)	40% (4)	0.0% (0)	0.0% (0)

Note: Total participants (*n*=11)

Support Question 2 was, "What happens when this particular decision-making model is no longer effective?" Three responses were included in the ranking. To seek internal/external experts was ranked agree for 54.5% and strongly agree for 45.5% of participants. For the second group of responses, to change the model, 63.6% agreed, 18.2% strongly agreed, and 18.2% disagreed. Responses of use intuition and risk moving forward or trial and error was met with agreement by 36.4% of participants, strong agreement by 27.3%, and disagreement by 36.4% (see Table 2).

Table 2. *Best Practices and Assessment Support Question 2. What happens when this particular decision-making model is no longer effective?*

	Agree	Strongly agree	Disagree	Strongly disagree
Seek internal or external expert	54.5% (6)	45.5% (5)	0.0% (0)	0.0% (0)
Change model	63.6% (7)	18.2% (2)	18.2% (2)	0.0% (0)
Use intuition, risk moving forward trial and error	36.4% (4)	27.3% (3)	36.4% (4)	0.0% (0)

Note: Total participants (*n*=11)

Support Question 3 was, "What circumstances deem the current decision-making model ineffective?" Three responses were included. The first group of responses, to timeliness of information for patent protection and lack of product knowledge, was ranked agree by 54.5% of participants and disagree by 45.5% of participants. Responses to divergent views, no resolution, and lack of predictability included 45.5% of participants who agreed, 36.4% who strongly agreed, and 18.2% who disagreed. For the third group of responses, to economic conditions and government regulations, 81.8% of participants agreed, 9.1% strongly agreed, and 9.1% strongly disagreed (see Table 3).

Table 3. *Best Practices and Assessment Support Question 3.* What circumstances deem the current decision-making model ineffective?

	Agree	Strongly agree	Disagree	Strongly disagree
Timeliness of information, patent protection, lack of product knowledge	54.5% (6)	0.0% (0)	45.5% (5)	0.0% (0)
Divergent views, no resolution, lack of predictability	45.5% (5)	36.4% (4)	18.2% (2)	0.0% (0)
Economic conditions and government regulations	81.8% (9)	9.1% (1)	0.0% (0)	9.1% (1)

Note: Total participants (*n*=11)

Support Question 4 was, "What other paradigms (decision models) have been used to forecast technological decisions?" Responses to standard operation procedures and consult internally or externally demonstrated that 63.6% of the experts agreed with the statement, 9.1% strongly agreed, and 27.3% disagreed. For the second group of responses, to trial and error, intuition, and fast follower, 45.5% of the experts agreed, 36.4% strongly agreed, and 18.2% disagreed. The third group of responses, to fishbone, trend analysis and other prediction models, demonstrated agreement by 54.5% of the experts, 9.1% strong agreement by 9.1%, and disagreement by 36.4% (see Table 4).

Table 4. *Leadership and Governance Support Question 1*. What other paradigms (decision models) have been used to forecast technological decisions?

	Agree	Strongly agree	Disagree	Strongly disagree
Standard operatic procedure, consult internal or external expert	63.6% (7)	9.1% (1)	27.3% (3)	0.0% (0)
Trial and error, intuition, fast follower	45.5 (5)	36.4% (4)	18.2% (2)	0.0% (0)
Fishbone, trend analysis, other prediction models	54.5% (6)	9.1% (1)	36.4% (4)	0.0% (0)

Note: Total participants (*n*=11)

Leadership and Governance

Support Question 1 was, "What type of executive/managerial leadership competencies are needed to manage uncertainties of emerging nanomaterial technology?" Eleven participants ranked five responses. In response to political awareness, broad network of relationships, and coaching, 63.6% of participants agreed, 27.3% strongly agreed, 9.1% disagreed with the statement. The second ranking, to ethical, innovator, and risk taker as leadership competencies, 54.5% agreed, 36.4% strongly agreed, and 9.1% disagreed. Responses to knowledgeable (broad and technical), openly shares (knowledge), and understands needs of customer (internal and external) were 54.5% agree and 45.5% strongly agree.

Responses to the comfort with extreme uncertainty and the ability to tolerate dissention were 54.5% agree, 36.4% strongly agree, and 9.1% disagree. Responses to ability to react to change, quick decision maker, and ability to create agreement, 27.3% of participants agreed, 63.6% strongly agreed, and 9.1% disagreed (see Table 5).

Table 5. *Leadership and governance Support Question 2. What type or executive/ managerial leadership competencies are needed to manage uncertainties of emerging Nanomaterial and Nanotechnology?*

	Agree	Strongly agree	Disagree	Strongly disagree
Political awareness, broad network of relationships	63.6% (7)	27.3% (3)	9.1% (1)	0.0% (0)
Ethical, innovator, risk taker	54.5% (6)	36.4% (4)	9.1% (1)	0.0% (0)
Knowledge-able, openly shares, understand needs of customers	54.5% (6)	45.5% (5)	0.0% (0)	0.0% (0)
Comfort with extreme uncertainty, tolerate dissention	54.5% (6)	36.4% (4)	9.1% (1)	0.0% (0)
Ability to react to change, quick decision maker, ability to create agreement	27.3% (3)	63.6% (7)	9.1% (1)	0.0% (0)

Note: Total participants (*n*=11)

Support Question 2 was, "In your expert opinion how does a global corporation influence the decision making model in risk assessment analysis?" Responses included four assessment areas. Participant responses to political and social issue influences, technical transfers, and proprietary rights were 72.7% agreed, 9.1% strongly agreed, and 18.2% disagreed. Participant responses to market power, customer expectations, profit, and cost were 63.6% agreed and 36.4% strongly agreed. For governance with formal policy, 72.7% of participants agreed, 9.1% strongly agreed, and 18.2% disagreed. Response to corporations are unable to identify risks due to size and reactive or crisis mode were ranked agree by 63.6% of participants and disagree by 27.3% of participants (see Table 6).

Table 6. *Leadership and Governance Support Question 3.* In your opinion how does a global corporation influence the decision-making model in risk assessment?

	Agree	Strongly agree	Disagree	Strongly disagree
Political and social issues influence technical transfer, proprietary rights	72.7% (8)	9.1% (1)	18.2% (2)	0.0% (0)
Market power, customer expectations, profit and cost	63.6 (7)	36.4% (4)	0.0% (0)	0.0% (0)
Governance with formal policy	72.7% (8)	9.1% (1)	18.2% (2)	0.0% (0)
Corporation unable to ID risk, risk size, reactive or crisis mode	63.3 (7)	0.0% (0)	27.3% (3)	9.1% (1)

Note: Total participants (*n*=11)

Support Question 3 was, "How does a transnational corporation influence the decision-making model in social responsibility?" Participants ranked four responses. Responses to use internal perception of public perception of good (corporate) citizens were 54.5% agree, 9.1% strongly agree, and 36.4% disagree. Meet legal standard requirements, increase value, with consideration of cost was ranked agree by 72.7% of participants and strongly agree by 27.3% of participants. Negatively impacts the decision-making model, less responsibility was ranked agree by 27.3% of participants; 72.7% of participants disagreed with the statement. Formal corporate policies, including values of safety and culture, demonstrated 100% agreement (see Table 7).

Table 7. *Leadership and Governance Support Question 4*. How does a global corporation influence the Decision-making model in social responsibility?

	Agree	Strongly agree	Disagree	Strongly disagree
Use internal perception, public perception, good citizen	54.5% (6)	9.1% (1)	36.4% (4)	0.0% (0)
Meet legal standard requirements, increase value, consider cost	72.7% (8)	27.3% (3)	0.0% (0)	0.0% (0)
Negative impact, less responsibility	27.3% (3)	0.0% (0)	72.7% (8)	0.0% (0)
Formal corporate policies, include value of safety and culture	100.0% (11)	0.0% (0)	0.0% (0)	0.0% (0)

Note: Total participants (*n*=11)

Decision-Making Framework Components

Support Question 1 was, "What essential decision-making components are needed for your current decision-making model?" Participants ranked four responses. Industry knowledge, market potential, (multidisciplinary technology) to increase value was ranked agree by 54.5% of participants and strongly agree by 45.5% of participants. Quantitative data historical forecast, risk assessment, dosage, and product safety was ranked agree by 81.8% of participants and strongly agree by 18.2% of participants. Communication structures, team strength, team skills, and resources were ranked agree by 54.5% of participants, strongly agree by 36.4%, and disagree by 9.1%. Governance, formal policies alignment and agreement, and employee engagement were ranked agree by 72.7% of participants, strongly agree by 9.1%, and disagree by 18.2% (see Table 8).

Table 8. *Decision-making Components Support Question 1*. What essential decision-making components are needed for your current decision-making model?

	Agree	Strongly agree	Disagree	Strongly disagree
Industry knowledge, market potential, (multidisciplinary technology) to increase value	54.5% (6)	45.5% (5)	0.0% (0)	0.0% (0)
Quantitative data, historical forecast, risk assessment, dosage, product safety	81.8% (9)	18.2% (2)	0.0% (0)	0.0% (0)
Communication structure, team strength and skills, resources	54.4% (6)	36.4% (4)	9.1% (1)	0.0% (0)
Governance, formal policies, alignment and agreements, employee engagement	72.7% (8)	9.1% (1)	18.2% (2)	0.0% (0)

Note: Total participants (*n*=11)

Support Question 2 was, "What is the minimum amount of information needed to derive an acceptable risk or safety assessment for your current decision-making model?" Participants ranked three responses. Risk assessment and management of risk was ranked agree by 61.6% of participants and agree by 36.4%. Research about technical merit or potential societal benefits of alternatives was ranked agree by 90.9% of participants and disagree by 9.1%. Regulatory standards were ranked agree by 63.6% of the participant, strongly agree by 18.2%, and disagree by 18.2% (see Table 9).

Support Question 3 was, "What are the resources used to supply information deficiencies?" Participants ranked three statements. For consultants' internal/ external technical researchers, 72.7% of participants agreed and 27.3% strongly agreed. For web database, survey-public opinion, and policies of other companies, 54.5% of participants agreed, 18.2% strongly agreed, and 27.3% disagreed.

Table 9. *Decision-making Components Support Question 2.* What is the minimum amount of information needed to drive an acceptable risk or safety assessment for your current decision-making model?

	Agree	Strongly agree	Disagree	Strongly disagree
Risk assessment and management	63.6% (7)	36.4% (4)	0.0% (0)	0.0% (0)
Research about technical merit or potential social benefits of alternatives	90.9% (10)	0.0% (0)	9.1% (1)	0.0% (0)
Regulatory standards	63.7% (7)	18.2% (2)	18.2% (2)	0.0% (0)

Note: Total participants (*n*=11)

For literature, market reports, journals, government publications, and issue analysis, 63.6% of participants agreed, 18.2% strongly agreed, and 18.2% disagreed (see Table 10).

Table 10. *Decision-making Components Support Question 3*. What are the resources used to fill information deficiencies?

	Agree	Strongly agree	Disagree	Strongly disagree
Internal and external consultants and researchers	72.7% (8)	27.3% (3)	0.0% (0)	0.0% (0)
Web database, surveys, public opinion, policies of other companies	54.5% (6)	18.2% (2)	27.3% (3)	0.0% (0)
Literature, market reports, journals, government publications, issue analysis	63.7% (7)	18.2% (2)	18.2% (2)	0.0% (0)

Note: Total participants (*n*=11)

Support Question 4 was, "What is the knowledge deficiency for improved understanding of Nanomaterials?" Participants ranked four responses. For lack of environmental exposure data, 36.4% of participants agreed, 36.4% strongly agreed, and 27.3% disagreed. For no quantitative data, metrics, dose, and risk assessment, 45.5% of participants agreed, 36.4% strongly agreed, and 27.3% disagreed. For deficiency of product knowledge and multidisciplinary technology uses, 63.6% of participants agreed, 18.2% strongly agreed, and 18.2% disagreed. For companies do not share information to maintain competitive advantage, 9.1% of participants agreed, 36.4% strongly agreed, and 54.5% disagreed (see Table 11).

Table 11. *Decision-making Components Support Question 4*. What is the knowledge deficiency for improved understanding of Nanomaterials?

	Agree	Strongly agree	Disagree	Strongly disagree
Lack of environmental data	36.4% (4)	36.4% (4)	27.3% (3)	0.0% (0)
Quantitative data, metrics, dose, risk assessment	45.5% (5)	36.4% (4)	18.2% (2)	0.0% (0)
Product knowledge, multidisciplinary technology use	63.6% (7)	18.2% (2)	18.2% (2)	0.0% (0)
Companies do not share information to maintain competitive advantage	9.1% (1)	36.4% (4)	54.5% (6)	0.0% (0)

Note: Total participants (*n*=11)

Support Question 5 was, "What is the evaluation methodology used to determine if the decision-making model has achieved the intended goals and objectives?" Participants ranked three statements. For adoption rates, level of customer demands, and commercialization, 63.6% of participants agreed, 27.3%

strongly agreed, and 9.1% disagreed. For patents, technology licenses, and outcome trends with decisions, 45.5% of participants agreed, 9.1% strongly agreed, and 45.5% disagreed. For established metrics or benchmarks and cost/ benefits analysis, 81.8% of participants agreed, 9.1% strongly agreed, and 9.1% disagreed (see Table 12).

Table 12. *Decision-making Component Support Question 5.* What is the evaluation methodology used to determine if the decision-making model achieved the intended goals and objectives?

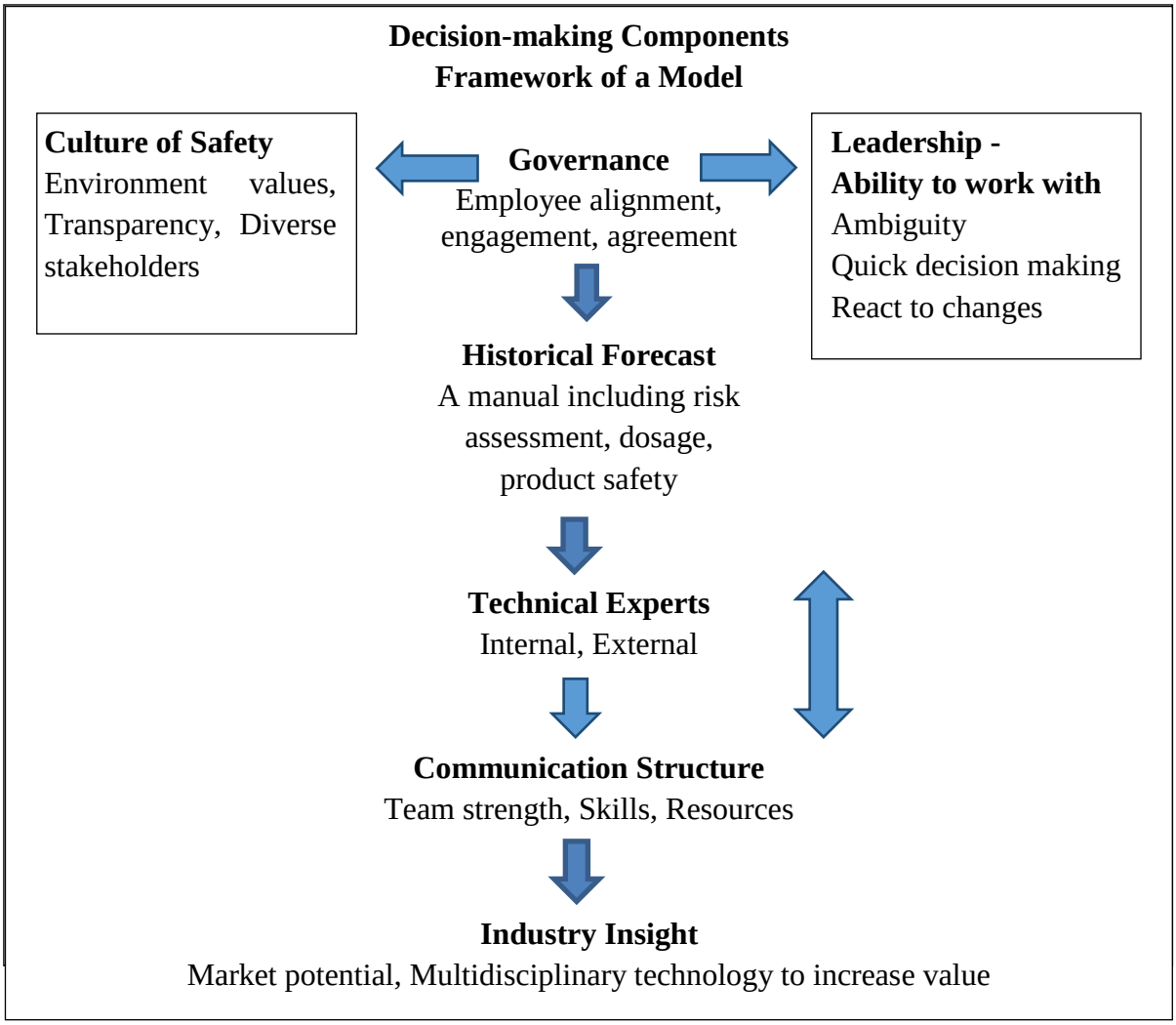
	Agree	Strongly agree	Disagree	Strongly disagree
Adoption rates, level of customer demand, commercialization	63.7% (7)	27.3% (3)	9.1% (1)	0.0% (0)
Patents, technology licenses, outcome trends with decisions	45.5% (5)	9.1% (1)	45.5% (5)	0.0% (0)
Established metrics or benchmarks, cost/benefit analysis	81.8% (9)	9.1% (1)	9.1% (1)	0.0% (0)

Note: Total participants (*n*=11)

Framework for the Decision-Making Model

The main purpose of the study was to design a framework for an alternative decision-making model for emerging technology manufactures or industries handling Nanomaterials. Based on data gathered using qualitative modified Delphi study design and results and analysis included in the previous section, an emerging technology dilemma was noted, existing models fail to predict or explain environmental safety. The model represents a framework for an alternative decision-making model (see Figure 1).

Figure 1. *Decision-making Model Framework*



Conclusions

According to the nanotechnology experts participating in the qualitative modified Delphi study, the chief finding is that emerging nanomaterial technology challenges environmental safety predictions based on current and traditional decision models. Table 11 details the deficiencies of decision-making models.

The finding is not exclusive to Nanomaterials and could be relevant to any emerging technology. The logical conclusions based on nanotechnology experts' knowledge and experience includes the following:

1. Current and traditional decision-making models are inadequate (see Table 11).

2. Ineffective models that fail to address one of the central questions; namely, what happens when decision models can no longer predict or explain environmental safety (Table 2), have replaced existing models.
3. A research framework for alternative decision-making models requires support to achieve the purpose of the research. The current Qualitative Modified Delphi study offers a framework for an alternate decision-making model (Figure 1).

Implications and Recommendations

The proposed framework model in Figure 1 identifies reluctance to change among the leaders comfortable with traditional paradigms. Alliances between non-homogenous stakeholders appear impractical and unclear. Communicating and establishing relationships leading to new multidisciplinary technology require trust and understanding of stakeholders needs.

Establishing common meanings and information to share among different stakeholders requires the arduous task of creating a common vocabulary or common language specific to products or processes. Creating a product history chronicle for materials in development or in use might be worth considering.

Maynard (2006b) explicitly noted missing from the literature the standardized tests for dose type and application. Building historical data could possibly transform beliefs and understanding of perceived threats and risks to humans and the environment. An understanding of safety prediction deficiencies with traditional decision-making model could help nanotechnology industry leaders to develop new and effective models.

Emerging technology leaders striving to maintain competitive advantage require new competencies and leadership practices to manage partnerships and alliances (Atchison & Bujak, 2001; Heifetz, Grashow, & Linsky, 2009; Shoemaker, 2008; Zadek, 2004). Unrelenting environments with high levels of uncertainty demand new levels of leadership competencies (see Table 5). Stressful cultural experiences of ambiguity with constant changes in procedures and priorities limit production, increase dissention, and serve to disengage stakeholders.

New leadership requires spending time communicating and drawing on experiences with the widest possible range of stakeholders (Heifetz et al., 2009). Through relationships, information leading to decisions and the implementation of new ideas builds a space for transition (Arenas, Lozano, & Albareda, 2009). Communication with stakeholders includes dialogue regarding fundamental problems (Daboub & Calton, 2002; Isaac, 1999), including assessment processes (Bendell, 2000; Crane & Livesey, 2003). The strategy for competitive advantage supports deliberation with stakeholders outside of the homogenous stakeholder alliance.

Transparency to stakeholders outside the corporation advances the stakeholder model, and new knowledge including multidisciplinary technological information for stakeholders and leaders provides a framework for alternative

decision-making models. Stakeholders' ethical decisions will reflect the corporate governance conscience, social responsibility, and protection of the environment. From this perspective, assessment of safety values points to the use of power in a responsible way when managing or producing Nanomaterials.

Nanotechnology is a global industry extending into diverse areas of engineering, chemistry, biology, physics, and medicine. Globalization influences decisions to race for market advantage with patented technology applications (Bawa, 2007). According to Rocco, "The nanotechnology industry estimated $1 trillion in profits by 2015" (2003, p. 9). Approximately, 1300 new nanomaterial applications exist across several industries (Gwinn & Vallyatha, 2006).

Although Nanomaterials offer significant technological advances in a multitude of disciplines, the potential harmful emission levels may threaten environmental safety (Alvarez & Parker, 2009; Balbus, Denison, Florini & Walsh, 2006). New information might improve leaders' global contributions to non-homogenous stakeholder conversations and enhance the global community framework for alternative decision-making models. New understandings of the emerging technology will increase the focus required in healthcare leadership competences and healthcare practitioners' comprehension of nanotechnology as an emerging technology. The legitimacy theory relates to the proper roles of business in society and has importance to those who operate globally (Palazzo & Scherer, 2006). Legitimacy conforms to the norms, values, and expectations of society (Oliver, 1996; Parsons, 1960; Pfeffer & Salancik, 1978).

Technology decisions extend beyond inventiveness to the leader's commitment to safety and the well-being of the global community, which are as important to the decision making process. Concerns about environmental, ethical, or moral decisions address transnational corporations not bounded by law (Kooskera, 2006). Leaders willing to operate with government officials hold significant insights to expand policy knowledge of transnational laws. The relationship between knowledge of the political environment, government regulations, and policies is an important factor in global decision-making strategies. Environmental implications may support regulatory compliance when producing or managing the safety of the emerging technology.

Ideas for Further Research

Further research of an evaluation process may produce guidelines to determine if decision-making processes meet their objectives. As an extension of this study, additional development of evaluation methods would provide another framework for the decision-making component. Without scientific nanomaterial information, predictions or measurable objectives remain ambiguous and uncertain. Study participants in pilot study round two, under the heading decision-making, emphasized an evaluation focus on available data and the opinions of experts.

Research exploration about building internal and external communication structures may benefit industries in expediting nanomaterial information. New and

different communication techniques may be explored to expedite sharing of information and learning.

Nanomaterials are part of an emerging technology expanding into global markets and research may require multiyear field studies. Research about technical merit or potential societal benefits of alternatives may provide an acceptable risk management or safety assessment strategy.

Future research on relevant governmental policies and regulatory standards with respect to risk management or safety assessment may assist nanotechnology industry leaders to remain in regulatory compliance. There is no reason why such research cannot be global in scope.

References

Alvarez, S., & Parker, S. (2009). Emerging firms and the allocation of control rights: A Bayesian approach. *Academy of Management Review, 34* (2), 209-227.

Arenas, D., Lozano, J., &Albareda, L. (2009). The role of NGOs in CSR: Mutual perceptions among stakeholders. *Journal of Business Ethics, 88* (1), 175-197.

Atchison, T. A., &Bujak, J. S. (2001). *Leading transformational change: The physician-executive partnership*. Chicago: Health Administration Press.

Balbus, J.M., Maynard, A.D., Colvin, V. L., Castranova, V., Daston, G. P., & Denison, R. A. (2007). Meeting report: Hazard assessment for nanoparticles: Report from an interdisciplinary workshop. *Environmental Health Perspectives, 115*(11), 1654-1659.

Balbus, J. M., Florini, K., Dennison, R. A., & Walsh, S.A. (2006). Getting it right the first time. *Annals of the New York Academy of Sciences, 1076*(1), 331-342. doi: 10.1196/annals.1371.027

Bawa, R. (2007). Patents and nanomedicine. *Nanomedicine, 2* (3), 351-374.

Bendell, J. (2000). Talking for change: Reflection on effective stakeholder dialogue. In S. Waddock, B. Husted, & S. Rahman (Eds.), *Unfolding stakeholder thinking 2: Relationships, communication, reporting and performance* (pp. 53-69). Sheffield, ILL: Greenleaf.

Bruce, D. (2006). Ethical and social issues in nanobiotechnologies: Nano2life provides a European ethical think tank for research in biology at the nanoscale. *EMBO, 7* (8), 754-758.

Burgi, B. R., & Pradeep, T. (2006). Societal implications of nanoscience and nanotechnology in developing countries. *Current Science, 90* (5), 645-658.

Crane, A., & Livesey, D. (2003). Are you talking to me? Stakeholder communication and the risks and rewards of dialogue. In S. Waddock, B. Husted, S. S. Rahman, & J. Andriof (Eds.), *Unfolding stakeholder thinking 2: Relationships, communication, reporting, and performance* (pp. 39-52). Sheffield, IL: Greenleaf.

Crichton, M. (2002). *Prey*. New York: Avon Books Harper Collins Publisher.

Cyert, R. M., &DeGroot, M. H. (1987). *Bayesian analysis and uncertainty in economic theory*. Totowa, NJ: Roman and Littlefield.

Daboub, A. J., & Calton, J. M. (2002). Stakeholder learning dialogues: How to preserve ethical responsibility in networks. *Journal of Business Ethics, 41* (1/2), 85-89.

Gwinn, M. R., & Vallyathan, V. (2006). Nanoparticles: Pros and cons. *Environmental Health Perspectives, 114* (12), 1818-1825.

Heifetz, R., Grashow, A., &Linsky, M. (2009). Leadership in a permanent crisis. *Harvard Business Review, 87* (7/8), 62-71.

Isaac, W. (1999). *Dialogue and the art of thinking together*. New York: Currency-Doubleday.

Kooskera, M. (2006). Corporate governance from the perspective stakeholder theory and in light of perceptions among Estonian owners and managers of relations with stakeholders. *EBS Review, 21* (1/2), 27-47.

Kovner, A. R., & Neuhauser, D. (2004). *Health services management*. Chicago, IL: Health Administration Press.

Maynard, A. (2006a). Is nanotechnology hazardous to your health? *Machine Design, 78* (23), 71.

Maynard, A. (2006b). *Nanotechnology: A research strategy for addressing risk.* Retrieved August 11, 2009, from http://www.nanwerk.com/nanotechnology/reports/report pdf/report63.pdf

Myers, M. (2007). Anticipation of risks and benefits of emerging technologies: A prospective analysis method. *Human and Ecological Risk Assessment, 13* (5), 1042-1052.

Olewnik, A., & Lewis, K. (2005). On validating engineering design decision support tools. *Concurrent Engineering Research and Applications, 13* (2), 111-122.

Oliver, C. (1996). The institutional embeddedness of economic activity. *Advances in Strategic Management, 13*, 163-186.

Palazzo, G., & Scherer, A. G. (2006). Corporate legitimacy as deliberation: A communicative framework. *Journal of Business Ethics, 66* (1), 71-88.

Parsons, T. (1960). *Structure and process in modern society*. Glencoe, IL: Free Press.

Pfeffer, J., &Salancik, G. (1978). *The external control of organizations: A resource dependence perspective*. New York: Harper & Row.

Phillips, R. D., Bahadori, T., Barry, B. E., Bus, J. S., Gant, T. W., Mostowy, J. M., Smith, C.M., William, M., &Zimmer, U. (2009). Twenty first century approaches to toxicity testing, biomonitoring and risk assessment: perspectives from the global chemical industry. *Journal of Exposure Science & Environmental Epidemiology*, *19*(6), 536 - 543.

Shoemaker, P. H. (2008). The future challenges of business: Rethinking management education. *California Management Review, 50* (3), 119-139.

Skulmoski, G. J., Hartman, F. T., &Krahn, J. (2007). The Delphi method for graduate research. *Journal of Information Technology Education*. Retrieved July 11, 2009, from http://jite.org/documents/Vol6/JITEv6o001-0215jyknisju212.pdf

Zadek, S. (2004). The path to corporate responsibility. *Harvard Business Review, 82* (12), 104-113.