

VIRTUAL ORGANIZATIONS: TWO CHOICE PROBLEMS

Daniel E. O’Leary
University of Southern California
U.S.A.

Abstract

This paper reviews some virtual organizations and the costs and benefits of being in a virtual organization. Particular emphasis is given to those costs and benefits deriving from the information technology and processes required to facilitate communication and transaction processing in virtual organizations. Using analytic models, this paper analyzes two problems faced by companies joining virtual organizations and by virtual organizations:

- Under what circumstances should a firm join a virtual organization and when should they do extensive information search regarding joining that virtual organization?
- Is it possible to choose a set of standards that are optimal for each company and the virtual organization? Arrow’s impossibility theorem is used to find that there is no standard that meets the optimal needs of the virtual organization and each individual company in the virtual organization.

Keywords: Virtual organizations, information theory, decision theory.

1. INTRODUCTION

Goldman, Nagel and Preiss (1995, p. 7) define a virtual company as one

where complementary resources existing in a number of cooperating companies are left in place, but are integrated to support a particular product effort for as long as it is viable to do so....Resources are selectively allocated to the virtual company if they are underutilized or if they can be profitably utilized there more than in the “home” company.

Typically, a virtual company is bound together using information technology. Recent developments, including the Internet, intelligent agents, and a wide range of other technologies, are used to network independent companies to form a virtual company. Such technologies are necessary in order to exploit slack resources in real time.

The purpose of this paper is to investigate two issues. First, joining a virtual organization is not cost free, since members typically must use standard (the same for all virtual organization members) business processes and information technology in order to facilitate communication and transaction processing in these virtual organizations. As a result, firms must make the decision of whether or not they should join a virtual organization based on the net benefit. Second, since virtual organizations must choose these standard processes and technologies, there is concern over how virtual organizations make these choices (should they vote?), and if it is possible to find a standard that is optimal for each company and the virtual organization. These research issues are analyzed using analytic models.

This paper proceeds as follows. Section 2 provides some background on virtual organizations and elicits the costs and benefits of companies within a virtual organization. Section 3 takes the view of a specific firm and investigates whether or not that firm should join a particular virtual organization. Section 4 investigates the choice of standards by a virtual organization and applies Arrow's (1963) impossibility theorem to virtual organizations. Section 5 provides a brief summary and discusses some extensions.

2. VIRTUAL ORGANIZATIONS

2.1 Some Example Virtual Organizations

A classic example of a virtual organization is the agile infrastructure for manufacturing systems (AIMS) project (Park, Tenenbaum and Dove 1993) funded by the United States Government's Advanced Research Projects Agency (ARPA). AIMS was designed in an attempt to integrate defense and general commerce infrastructures. According to a Lockheed press release (Lockheed 1995), AIMS was headed by Lockheed and included lessor roles from Rocketdyne, Texas Instruments, several universities, a trade association and some small businesses. As noted by Park, Tenenbaum and Dove (p. 2), AIMS's goal was "to create an integrated network of services that encompass key aspects of agile manufacturing from procurement to shipping and one that makes no distinction between whether jobs are done in house or outsourced to subcontractors." The AIMS project manager (Lockheed 1995), noted that Lockheed's role included development of "mechanisms in both business and technology infrastructures, using national information highways, that will allow companies to very rapidly put together partnerships for the development of complex products." That set of mechanisms was ultimately referred to as AIMSNet.

Another early example of an ARPA funded virtual organization was the "Manufacturing Assembly Pilot" (MAP) (AIAG 1994). The goal of MAP was to "improve inter-company communications and practices in order to optimize material flow within the pilot supply chain" (AIAG 1994, p. 3) . In order to keep the project bounds and time feasible, the project was limited to two components of automobile seating: manual seat adjusters and seat covers. As seen in Figure 1, MAP was dominated by some very large firms, including General Motors (GM), Ford, and Chrysler. The infrastructure development of MAP included (AIAG 1994, pp. 38, 42) implementation of electronic data interchange (EDI), inter-company e-mail, cooperative customer-supplier training, integration of EDI into business processes, development and acquisition of new software, and acquisition of new hardware.

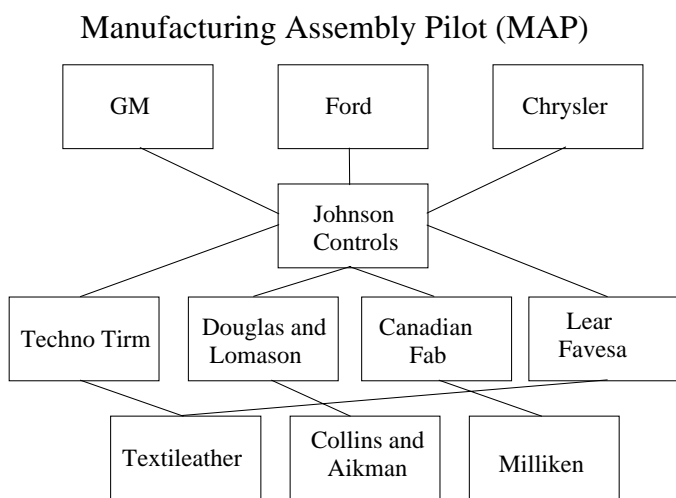


Figure 1. MAP Virtual Organization Structure

A more recent, independently funded, virtual organization was generated by Colgate (Brownlee 1996). Colgate has implemented a network of "supplier managed" inventories, for both its customers and suppliers. As part of building this system, Colgate has provided a number of its suppliers with standard software that allows them to directly access Colgate's systems. As part of the trade-off, Colgate does not have to pay for product ingredients until Colgate actually uses them.

2.2 Fluidity of Virtual Organizations

Although virtual organizations appear very fluid and open, they are not "wide-open." In order to assure that member firms are adequately prepared to be a part of the virtual organization, there are certain constraints that are established. Typically there are particular software and networking requirements that must be satisfied. Further, many business processes, such as purchasing, and corresponding data ex-

changes are standardized. Those processes and systems vary by virtual organization because there are advantages to using specific processes in different industries.

In order to assure that member firms are appropriately informed and prepared, virtual organizations often provide certification functions or require external certification. For example, at the heart of the AIMS effort was a virtual organization of customers and certified suppliers.

A certified supplier is one that employs standard business processes, product data formats and network interfaces. Customers interact with these suppliers using structured messages, requesting information about costs, capabilities and availability, soliciting bids, placing orders and so forth. They can communicate with a provider directly or via third party directory and brokering services. [Park, Tenenbaum and Dove 1993, p. 2]

2.3 Costs and Benefits of Joining Virtual Organizations

Being a part of a virtual organization has both costs and benefits to a particular firm. Many of those costs and benefits derive from the infrastructure of technology and processes that are used to facilitate the virtual company.

There are a broad range of costs associated with joining a virtual organization. First, one of the primary costs of joining a virtual organization can be the costs of changing processes to accommodate the standards adopted by the virtual organization. Typically, virtual organizations adopt a set of “best practices” for business processes such as processing purchase orders. For example, the MAP virtual organization adopted the best practice that “Customers should make a special supplementary contact with their immediate suppliers if they make an unusually large change in material requirements within the early weeks of the schedule” (AIAG 1994). Second, in some settings, firms need to adopt particular software. For example, as noted by Brownlee, Colgate is part of a virtual organization where Colgate, its suppliers and customers used the same software, so that the set of firms could function as a virtual organization. Third, as part of joining a virtual organization, there are costs of adopting the necessary information technology infrastructure required in order to be compatible with the needs of the virtual organization. For example, MAP required implementation of two-way EDI, inter-company e-mail and acquisition of new hardware and software. Fourth, there can be costs of preparing any information required by the virtual organization. For example, virtual organizations such as AIMS planned on having virtual organization members provide information about production facilities availability so that members could include each other in their production plans. Fifth, when a firm joins a virtual organization, in order to adopt to all of these changes, firms will need substantial training. For example, the third largest budgeted expense in MAP was for training. Sixth, firms may be required to attain some level of certification, as seen in the AIMS project and noted above.

The benefit to joining the virtual organization is the change in revenues that derives from a wide range of sources. First, revenues can increase because of incremental utilization of otherwise unused resources. The basic concept behind a virtual organization is leveraging unused assets. Second, standard processes may improve the way the firm does business. Firms may reengineer firm-wide because of the requirement to adopt processes for the virtual organization. Third, infrastructure and software changes can facilitate other activities within a firm. For example, such changes could facilitate sales to other clients outside the scope of the virtual organization. Fourth, joining a virtual organization may have certain political or social advantages. For example, joining a virtual organization could influence the status of that organization.

The “net benefit” is the difference from the changes in costs and benefits. The net benefit forms the basis of the model discussed in the next section.

3. DECIDING ON WHETHER TO JOIN A VIRTUAL ORGANIZATION¹

Since joining virtual organizations is not cost free, at the individual firm level, companies are faced with the decision of whether or not to join a particular virtual organization based on the net benefit to the firm. Although this model is couched with a single

¹This section employs some arguments similar to those in Elnathan and Kim (1995) and Kirby (1988).

firm joining a virtual organization, a similar analysis could be used to study the virtual organization's analysis of potential new entrants.

3.1 Basic Model

Let U be a random variable representing the particular firm's "net benefit" from joining in a virtual organization. The net benefit can be either positive or negative. As a result, assume that the net benefit U takes a value $U_1 \geq 0$ or $U_2 \leq 0$, where $U_1 > U_2$. Further assume that either U_1 or U_2 can occur with a probability of .5.

Deciding whether or not to join a virtual organization requires that the firm generate information x with accuracy p about U from a wide range of sources including publicly available information, discussion with other members of the virtual organization, or other potential virtual organization members. For example, with the development of AIMS, there were a number of meetings open to those who were interested in joining AIMS in order to provide opportunity information to potential virtual organization members.

Consider the information random variable x and an accuracy variable p . Accuracy is assumed to have a symmetric distribution. Assume that if $U = U_1$ then $x = x_1$ with probability $p \geq .5$ and $x = x_2$ with probability $(1-p)$. Similarly, if $U = U_2$ then $x = x_2$ with probability p and if $U = U_2$ then $x = x_1$ with probability $(1-p) \geq 0$. As a result, $\Pr(U_1 | x_1) = p$ and $\Pr(U_1 | x_2) = (1-p)$. Further, $\Pr(U_2 | x_1) = (1-p)$ and $\Pr(U_2 | x_2) = p$. The variable p measures the accuracy of the information x . If $p = .5$, then the accuracy signal is at its noisiest and is not informative. Generally, as p increases away from .5, the firm, observing x , increases its ability to assess the true value of U . At $p = 1$, x perfectly reveals the value of U . At $p = 0$, the value is perfectly incorrect. The firm must choose p before it observes x . As a result, the ex ante value of x is the increase in the expected profit due to observing x .

Let $F(p)$ be the cost of observing x , with accuracy p . Firms can obtain increases in accuracy if they pay for better information about the information signal x . In a real world setting, we generally assume that you get better information if you pay for it. As a result, assume that $F(\cdot)$ is strictly increasing and strictly convex. Also assume that $F(\cdot)$ is twice differentiable, $F(.5) = 0$ and $F'(p)$ approaches zero as p approaches .5. Further, assume that $F'(p)$ approaches infinity as p approaches 1, since, in a real world setting, it would be impossible to get perfect information about x . With such a functional representation of $F(\cdot)$, it is inexpensive to get some information about U , but it is infinitely expensive to get perfect information. In a Web-based, world this is a reasonable assumption.

3.2 Four Cases for Deciding on Joining a Virtual Organization

If a particular firm is concerned about joining a particular virtual organization consortium, then the decision problem is choosing the level of decision accuracy p , and to decide whether or not to join the virtual organization. Given a value of p and observation of x , the decision of whether or not to join is straightforward. If x_1 is observed, then the firm joins the virtual organization if and only if $pU_1 + (1-p)U_2 \geq 0$. If x_2 is observed then the firm joins the virtual organization if and only if $(1-p)U_1 + pU_2 \geq 0$. There are four possible cases.

Case 1: $U_1 \geq -U_2$, $U_1 + U_2 \geq 0$ and $U_2 \geq 0$

In this case, the company should join the virtual organization without further information gathering. It is a no lose situation.

Case 2: $U_1 < -U_2$, $U_1 + U_2 < 0$ and $U_2 \leq 0$

In this case, the company should not join the virtual organization without further information gathering. It is a no gain situation.

Case 3: $U_1 \geq -U_2$ and $U_1 + U_2 \geq 0$.

In this case, the choice with no information is to join the group because the expected profit of doing so is nonnegative ($U_1 + U_2 \geq 0$). When x , the information signal is observed, with accuracy p , the ex post benefit of observing x depends on the actual realization of x .

- (a) If x_1 occurs, then $pU_1 + (1-p)U_2$ is positive independent of p . As a result, the firm should join the virtual organization.
- (b) However, if x_2 occurs, then $(1-p)U_1 + pU_2$ can be negative for p sufficiently close to one. If $(1-p)U_1 + pU_2$ is negative, then the decision is to not join the virtual organization. When this situation occurs, the ex post benefit of observing x is $-[(1-p)U_1 + pU_2]$ or the loss saved from obtaining the information. Since the probability of observing either x_1 or x_2 is .5 for any given accuracy p , the expected ex ante benefit of observing x is

$$V(x) = \text{Max} (0, -.5 [(1-p)U_1 + pU_2]) - F(p)$$

If there is a level of accuracy p for which $V(x) \geq 0$, then information should be obtained.

Case 4: $U_1 < -U_2$ and $U_1 + U_2 < 0$.

In this situation, the choice without information is to not to join the virtual organization because the expected net benefit of joining is negative. When the information signal x with a parameter p is observed, the ex post benefit of observing x depends on x 's realization.

- (a) If x_1 occurs, then $pU_1 + (1-p)U_2$ can be positive for p sufficiently large. If $pU_1 + (1-p)U_2 > 0$ after observing the signal, then the firm should join the virtual organization. When that occurs, the ex post benefit is the result of the information search. Since the probability of observing either x_1 or x_2 is .5, then the ex ante net benefit of observing x for any given p is

$$V(x) = \text{Max} (0, .5 [pU_1 + (1-p)U_2]) - F(p)$$

As before, if there is a p for which $V(x) \geq 0$, the information is obtained.

- (b) If x_2 occurs, then $(1-p)U_1 + pU_2$ is negative for all values of p , and, as a result, the firm should not join the virtual organization. Accordingly, there is no benefit of observing x .

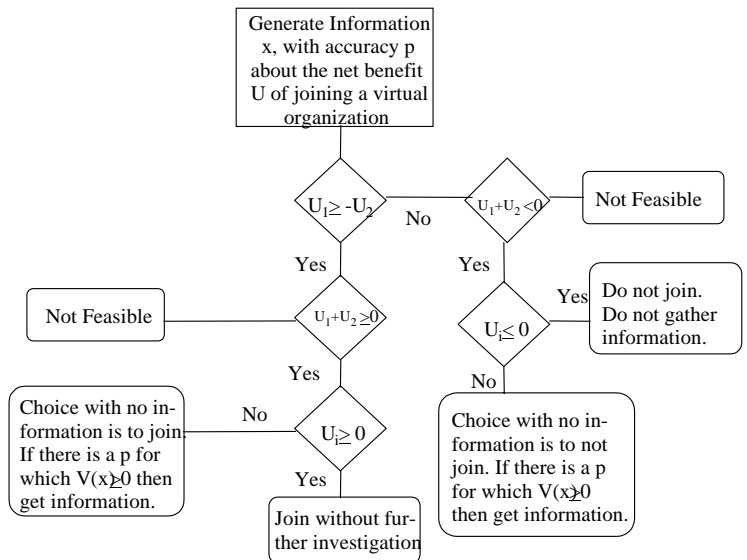


Figure 2. Summary of the Four Cases

Flowchart of the Four Cases. These four cases are summarized in Figure 2.

3.3 Ex Ante Benefit of the Two Cases

When the accuracy p can be freely chosen, the ex ante benefit can now be written as a single expression.

$$V(x) = \text{Max}_p \{ \text{Max} (0, .5 [p(U_1 - U_2) - \text{Max}(|U_1|, |U_2|)]) - F(p) \}$$

Because a net benefit of 0 is assured by choosing $p = .5$, since $F(.5) = 0$, $V(x)$ equals the following

$$V(x) = \text{Max}_p \{ 0, .5 [p(U_1 - U_2) - \text{Max}(|U_1|, |U_2|)] - F(p) \}$$

Based on the assumptions of the cost function made above, there exists a unique p that maximizes $.5 [p(U_1 - U_2) - \text{Max}(|U_1|, |U_2|)] - F(p)$. This unique p is characterized by

$$.5(U_1 - U_2) - F'(p) = 0, \text{ and } p > .5,$$

given the assumptions of the cost function. As a result, the firm should choose to spend $F(p)$ and observe x with accuracy p such that $.5(U_1 - U_2) - F'(p) = 0$ and p such that $V(x) \geq 0$. If the expected net benefit is negative for such a p , the firm chooses $p = .5$ and does not gather any preliminary information.

3.4 Preliminary Information Gathering

$V(x)$ suggests that the choice of p , the extent of information gathering about the virtual organization, depends on the uncertainty of the choice problem, the ease of the choice problem and the magnitude of the marginal information gathering cost. These factors result in Theorem 1.

Uncertainty of the Choice Problem. The uncertainty of the choice problem captures the degree of uncertainty of the net benefit of joining the virtual organization. The uncertainty is measured by the difference in the expected profits between the two realizations of joining the virtual organization ($U_1 - U_2$).

Ease of the Problem. "Ease of the decision problem" is measured by $\text{Max}(|U_1|, |U_2|)$, which indicates how far the benefit from being in a virtual organization is from zero (the net benefit if the firm does not join the virtual organization). If the net benefit is large, then the decision is easy—join the virtual organization (if $U_1 - U_2$ is positive) or don't join (if $U_1 - U_2$ is negative). For a fixed level of uncertainty ($U_1 - U_2$), the ease of the decision making problem becomes more difficult as U_1 approaches $-U_2$. In particular, the measure of ease $\text{Max}(|U_1|, |U_2|)$, reaches its minimum when $U_1 = -U_2$, and it reaches the maximum as either U_1 or U_2 becomes zero.

Magnitude of the Information Gathering Costs. $F(p)$ is the information gathering cost. As that cost increases, the net benefit of joining the virtual organization decreases.

Theorem 1

The optimal p is greater than $.5$ only for sufficiently small $\text{Max}(|U_1|, |U_2|)$, and is increasing in $U_1 - U_2$, and in any shifts of the function F that reduce $F'(p)$.

That is, for a firm facing the choice problem of whether or not to join a virtual organization, the amount of preliminary information gathering is

1. positive only for a sufficiently difficult choice problem of choosing whether or not to join a virtual organization.
2. higher for a more uncertain choice problem of deciding whether or not to join a virtual organization, and for lower marginal information gathering costs.

Proof

By the two versions of $V(x)$ presented above and the above discussion.

3.5 Discussion of Theorem 1

Theorem 1 suggests that a firm gathers additional information about whether to join a virtual organization only when the choice without the information is sufficiently “difficult”; that is, when the expected profits generated by joining a virtual organization or not joining a virtual organization are sufficiently close. Further, information is gathered when its benefit is greater or its marginal cost is lower. In addition, the benefit of gathering information is greater when there is more, rather than less uncertainty.

There have been some institutional developments in virtual organizations that are consistent with Theorem 1. Virtual organizations try to provide information to firms that may potentially join the virtual organization. For example, the AIMS project (Park, Tenenbaum and Dove 1993) aimed at developing a standard infrastructure that would facilitate adoption by suppliers and customers. In addition, the AIMS project included an “outreach” program, designed to encourage designers to try AIMS. The outreach program included educational efforts (Park, Tenenbaum and Dove 1993) to allow particular “job shops to disseminate ...information.”

The model summarized in Theorem 1 could be used as the basis of an empirical investigation of virtual organization behavior.² That extension of this model could address a number of empirical questions including:

- To what extent do virtual organizations employ outreach programs?
- To what extent do outreach programs influence firms’ decisions to join virtual organizations?
- Is there some minimum level of information gathering that firms use when considering joining virtual organizations?
- What are the magnitudes of expenditures used by firms in making these decisions?

4. CHOOSING STANDARDS FOR A VIRTUAL ORGANIZATIONS³

In order to effectively communicate and to facilitate business transaction processing, virtual organizations must make many standardization choices, including technologies (software, hardware, and networks) and business practices. However, for each standard that must be chosen, there are multiple standards that could be chosen. Unfortunately, some of those multiple alternatives are likely to better meet the needs of different companies. Thus, we need to address the issue of which of those standards should be chosen to best meet the virtual organization’s needs. Arrow addressed this issue, in general, with his “impossibility theorem.” This section applies that theorem and its discussion to the problem of choosing standards in virtual organizations.

Suppose that a virtual organization must make a choice of one standard from among at least three different standards. It is assumed that the standards are substantially different in terms of their impact on resource allocation (or else companies would not care which standard was used) and that individual company preferences with respect to the standards may differ.

Let Ω be the set of feasible standards for which the choice decision is being made. Let company i ’s utility function be

$$E(U_i | n_i^*(j), j) = \sum_{x_c} X \varphi_i(x|j) E(U_i | n_i^*(x,j), x,j),$$

where $\varphi_i(x|j)$ is the posterior probability of company i that is a function of the information that they receive (signal x from standard j), $U_i(x)$ is company i ’s preference with respect to the possible outcomes, and $n_i^*(x,j)$ is the most preferred action for company i given receipt of signal x from standard j .

²The author would like to thank one of the anonymous referees for suggesting this set of empirical extensions.

³This section applies Arrow’s (1963) well-known impossibility theorem to standard adoption by virtual organizations. Accordingly, this section employs some arguments similar to those in Arrow, in Demski and Feltham (1976), and in Luce and Raiffa (1957).

If company i regards standard j at least as desirable as standard k , then the expected utility associated with the use of j is greater than or equal to k , i.e., $E(U_i | n_i^*(j), j) \geq E(U_i | n_i^*(k), k)$, where $n_i^*(j)$ is the most preferred action for company i , given use of standard j . That preference is expressed as $j >_{(i)} k$, for j and k in Ω for company i . Further, by making the appropriate rationality assumptions, we can assure that the binary relation $>_{(i)}$ for each company i is complete and transitive over the set of standards, Ω . In a similar manner, if j is at least as desirable as k , at the global, virtual organization level (VO), $j >_{(VO)} k$. The optimality question then takes the form of specifying the relationship between the company preference relations $i, i=1, 2, \dots, n$ and the virtual organization preference relation. Accordingly, we are interested in finding a collective choice rule $f(\cdot)_{>_{(VO)}} = f(>_{(1)}, \dots, >_{(i)}, \dots, >_{(n)})$. Thus, the problem is to find a standard that meets the preferences of each company. There are a number of collective choice rules. However, in his well-known theorem, Arrow found that the imposition of a set of apparently desirable conditions reduces the acceptable set to the null set. Informally, there is no solution that satisfies the needs of all companies and the virtual organization.

Arrow's Impossibility Theorem for Virtual organizations

- (a) *Universal Domain.* All logically possible orders of Ω are admissible. The domain of $f(\cdot)$ must include all combinations of complete and transitive orders of Ω . "Weird" companies are not disallowed, as long as they are completely and transitively "weird."
- (b) *Pareto Optimality.* If for any pair j and k in Ω , all individuals strictly prefer j to k , $f(\cdot)$ must guarantee social preference for j over k . This is a necessary property, since not requiring it would amount to constructing a theory of choice among standards based on systematically denying companies their preferred option.
- (c) *Independence of Irrelevant Alternatives.* For any subset of Ω , any pair of sets of company orderings that rank identically the standards in the specified subset must have identical virtual organization choices of the standards in the subset. This condition eliminates intercompany utility comparisons. For example, it requires that the choice between some pair j and k in Ω be determined solely by the company's preferences for j and k ; other alternatives are not allowed to influence the virtual organization's choice between j and k .
- (d) *Dictatorship.* There is no individual i such that $(>_{(VO)}) = (>_{(i)})$ regardless of the other individuals' preferences.

The set of collective choice rules $f(\cdot)$ that provides complete and transitive ranking of Ω and also satisfied the universal domain, Pareto optimality, independence of irrelevant alternatives, and non-dictatorship conditions are null. That is, the four conditions are mutually inconsistent. For proof and extensive discussion of this theorem and related issues see Arrow (1963), Luce and Raiffa (1957), and Demski and Feltham (1976).

There are at least two implications of this result for virtual organizations. First, given Arrow's, structure this result precludes viewing the standard problem as optimization of some aggregate level utility, cost-benefit, or social welfare function. Second, since virtual organization's decisions about standards must be made and the conditions imposed by Arrow are inconsistent, we must violate at least one of them regardless of the manner in which standards are chosen.

4.1 So How Do Virtual Organizations Choose Standards?

As noted by Arrow, if all of the preferences are single peaked, then majority voting will work. However, for this situation, such an approach would assume that each company was equally important. In some virtual organizations, that may not be appropriate. For each of the three virtual organizations summarized in section 2, there is a set of companies that are "more equal" than other companies. For example, in AIMS there is Lockheed, in MAP there are GM, Ford, Chrysler, and Johnson Controls, and in the Colgate virtual organization, there is Colgate. In these settings some might argue that there is the equivalent of a "dictatorship," where decisions on choosing virtual organization standards are made by a few companies.

4.2 Agenda Setting as an Implementation Strategy

The impossibility theorem has some implications for the types of negotiations that can take place between companies in virtual organizations in the choice of standards. As noted by Kleindorfer, Kunreuther, and Schoemaker (1993, p. 265), so called “agenda setting” can influence the choice of alternatives that are ultimately adopted if pairwise comparison and adoption is done. Suppose that $j \succ_{(F)} k$, $k \succ_{(F)} x$ and $x \succ_{(F)} j$, that is on a pairwise basis, j is preferred to k and k is preferred to x , and x is preferred to j . If the agenda is set (j versus k) versus x , then pairwise choice leads to x . However, if the agenda is set as (k versus x) versus j , then the choice leads to j .

4.3 Extension to Empirical Studies

Arrow’s impossibility theorem, as discussed here for virtual organizations, can be used as to provide a theoretical structure for an empirical analysis of virtual organizations. In particular, an empirical analysis extending this discussion could be made of standard setting in virtual organizations to address questions including the following:

- How are standards set in some virtual organizations?
- Do virtual organizations use “majority votes” or are they dominated by major participants?
- To what extent do we see issues such as agenda setting in virtual organization choices?

5. SUMMARY AND EXTENSIONS

5.1 Summary

This paper has investigated two decisions that relate to virtual organizations. First is a model of a firm’s choice decision to join a virtual organization. The model found that the firm’s information search plays a critical role in its decision to join the virtual organization. Second, a virtual organization’s choice of standards for its component companies was investigated using Arrow’s impossibility theorem. It was found that it is impossible to choose a set of standards for a virtual organization that are optimal for all companies and the virtual organization. These models are general and can be used in other settings where facilities or information need to be shared.

5.2 Extensions

This research can be extended in a number of directions. First, this paper assumed that a firm’s decision was whether or not to join a virtual organization. Although this is a legitimate issue, there are other similar decision problems, for example, modeling a firm’s choice between joining multiple virtual organizations. Second, the range of issues could be expanded beyond the choice problem of a single virtual organization to multiple interacting virtual organizations. Third, the results for choice of whether or not to join a virtual organization assume symmetric probabilities. The results can be extended to asymmetric probability models. Fourth, the model of choice of whether or not to join a virtual organization can be extended to the mirror choice of virtual organizations for new entrants. Fifth, as noted in both sections 3 and 4, each of these models can provide a theoretical structure that could be used for empirical analysis.

Acknowledgments

The author would like to acknowledge the comments of Rick Watson and three anonymous ICIS referees.

References

- AIAG. "Manufacturing Assembly Pilot," unpublished project report, Automotive Industry Action Group, December 1994.
- Arrow, K. *Social Choice and Individual Values*, Cowles Foundation Monograph 12, Wiley, New York, 1963.
- Brownlee, L. "Overall," *Wall Street Journal*, November 18, 1996, pp. R12 and R17.
- Demski, J., and Feltham, G. *Cost Determination: A Conceptual Approach*, Iowa State Press, Ames, IA, 1976.
- Elnathan, D., and Kim, O. "Partner Selection and Group Formation in Cooperative Benchmarking," *Journal of Accounting and Economics* (19), 1995, pp. 345-364.
- Goldman, S.; Nagel, R.; Preiss, K. *Agile Competitors and Virtual Organizations*, Van Nostrand Reinhold, New York, 1995.
- Kirby, A. "Trade Associations as Information Exchange Mechanisms," *Rand Journal of Economics* (19:1), 1988, pp. 138-146.
- Kleindorfer, P.; Kunreuther, H.; and Schoemaker, P. *Decision Sciences: An Integration Perspective*, Cambridge University Press, Cambridge, England, 1993.
- Lockheed. "Lockheed Heads Team to Design Technology and Business Infrastructure for Agile Manufacturing," *Lockheed Web News Release*, January 10, 1995.
- Luce, R., and Raiffa, H. *Games and Decisions*, Wiley, New York, 1957.
- Park, H.; Tenenbaum, J.; Dove, R. "Agile Infrastructure for Manufacturing Systems (AIMS)," *Proceedings of Defense Manufacturing Conference*, 1993.