Title of manuscript:

"Using Decision Analysis to Explore Cable Television Delivery"

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ABSTRACT:

In this paper, we demonstrate the efficacy of decision analysis in determining the most efficient strategy for installing cable television in the residence halls of Bucknell University. In particular, our decision analysis compares five distinct approaches for achieving and maintaining a successful delivery of cable television service to students enrolled in this private, residential institution. For each alternative, we incorporate installation costs, likelihood of installation failure, installation failure costs, likelihood of obsolescence, and obsolescence-related costs. In addition to considering the tradeoffs between cost, timing, and riskiness of the various alternatives, we perform thorough sensitivity analyses to gain insight into the parameters that most strongly influence this decision-making process. Our analysis of this problem incorporates the knowledge and judgments of senior administrators and staff members who are eager to make sound decisions that will be critical to the development and initiation of this project.

INTRODUCTION

Decision analysis is a useful approach to assess quantitatively various alternatives in the face of future uncertainties. These uncertainties, often called "states of nature", are characterized by specific probability distributions. By incorporating the associated payoffs of different alternative-state of nature combinations, a decision-maker can determine a preferred alternative. To illustrate how the preferred alternative is affected by changes in underlying parameters, a vast array of sensitivity analyses may be performed.

In this paper, we demonstrate the efficacy of decision analysis in determining the most efficient (i.e. expected cost-minimizing) strategy for installing cable television in the residence halls of Bucknell University. Founded in 1846, this private, residential institution educates about 3,500 (nearly all undergraduate) students. We investigate five distinct alternatives and incorporate a variety of costs and future outcomes. Critical tradeoffs involve the cost and riskiness of separate strategies. To increase the likelihood of model acceptance, we make a concerted effort to evoke the viewpoints and judgments of senior administrators and staff members in the development of our decision analysis model.

Decision analysis has been applied in the analysis of a wide variety of problems facing actual organizations. Cable television delivery, the focus of this paper, may be considered within the class of technology-adoption applications. Although our model, to the best of our knowledge, represents an initial attempt to investigate cable delivery options, a number of previous researchers have explored decision analysis approaches in a technology-adoption environment. Ulvila (1987) developed a decision analysis model to explore the purchase or conversion of specific postal automation equipment for reading addresses on packages. In selecting between currently available technologies versus more efficient ones available in the future, Keeney, Lathrop and Sicherman (1986) developed a decision analysis model for the Baltimore Gas and Electric Company. Among other variables, their model incorporated customer costs and the feasibility of technology implementation. Isik and Khanna (2003) modeled agricultural decision-making and the degree to which uncertainties concerning weather and soil fertility affected specific technologies selected (e.g. fertilizer application). McCardle (1985) explored technology- adoption models using Bayesian theories and techniques. Carter (1992) espoused the use of multiattribute decision models to investigate computer-integrated manufacturing investment. He claimed that part of its benefits included the ability to consider qualitative financial and non-financial factors.

Our paper proceeds as follows. The next section presents a background for this modeling project, highlighting proposed benefits and costs of cable installation, as well as critical events that occurred as a university-wide committee sought to make this plan a reality. This is followed by a discussion of model development. We then provide the results of our modeling effort, including the insights obtained from our sensitivity analyses. Some concluding remarks are offered in the final section.

BACKGROUND

With but few exceptions, cable television service is not provided in the residence halls and dormitories of the Bucknell University campus. Admittedly, the process of securing cable television access has been somewhat grueling and arduous. For several years, various student leaders have espoused the benefits of cable access and advocated its installation to college administrators.

Our involvement in the current project began under a rather unique set of circumstances. In the Spring 2000 semester, one of the authors of this paper taught a decision sciences course. Concurrently, the notion of providing cable television access in individual student dormitory rooms was being informally discussed in various committees that included both students and administrators. A particular student in our course, a member of Bucknell Student Government (BSG), approached the instructor with the suggestion of using decision analysis to explore the cable television adoption decision (as an aside, we were thrilled that this student wisely considered the applicability of decision analysis outside the classroom environment!). Apparently, despite the fact that considerable discussion occurred regarding distinct alternatives in these collaborative meetings, no type of quantitative methodology had been applied to this important real-world problem.

Eventually, these committee meetings spurred the creation of the "Task Force for Cable Television on Campus". This university-wide committee was charged with formally and thoroughly investigating the feasibility of providing cable access in campus dormitories. This task force included representatives from the student body, faculty (one of this paper's authors was the faculty representative), staff and administration (representing such areas as Physical Plant, Information Services and Resources, Finance Office, Housing and Residential Life, and Student Services).

Through its deliberations, the Task Force determined some significant reasons for supporting cable television delivery. First, various educational benefits could materialize by providing cable access to individual students. Potentially, the University could use cable television to deliver class films (e.g., the first-year Economics course shows weekly films as part of its course delivery). Thus, students could watch the material at a specific time of their choosing, rather than requiring the instructor or his/her teaching assistant to display a film to a large group of students. Occasionally, professors want students to report on various news, documentary or current events programs on such networks as CNN, MSNBC, and the History Channel. Individual cable television access would provide students with the opportunity to participate in these pedagogical activities. Admittedly, students with cable access may not watch news or current events programs exclusively. Despite the fact that television may provide a distraction, Task Force members felt that college-aged students should be given the responsibility to balance academics with their social life.

Secondly, cable television could prompt the development of a Bucknell television station to broadcast collegiate cultural and athletic events. No such station currently exists. A third benefit is that cable access could help to break the so-called “Bucknell Bubble”. Students often view Bucknell’s location in the central part of Pennsylvania as being far removed from the cultural “hot spots” of such cities as New York City, Washington, D.C., and Boston.

A final benefit for dormitory room cable access is that it would eliminate student inconvenience. Currently in some of our residence halls, there exists a single big-screen television serving the viewing desires of a few hundred students. Obviously, not all viewing needs could be met with just one television.

To bolster the case for providing cable television access, the Task Force approached several stakeholders, requesting their degree of support for this proposal. Different groups enthusiastically approved the idea. For example, the Bucknell Parents’ Board sent a letter to the Board of Trustees fully backing this initiative. Faculty, based on the commentary obtained from a Professor-Student luncheon sponsored by the BSG, appeared to be generally in favor of such a move. As one may expect, students were (and continue to be) wildly positive regarding cable television possibilities. A recent survey of 400 students, commissioned by the BSG, showed that fully 93% of respondents supported cable television delivery. Of those who were positively inclined towards cable access, almost ⅔ suggested that it be a mandatory, as opposed to an optional, service.

To provide an enhanced, external context for these critical sets of decisions, the Task Force surveyed seven local area colleges and universities (Gettysburg, Lycoming, Franklin & Marshall, Colgate, Lehigh, Susquehanna and Bloomsburg) with respect to their delivery of cable television. Each of these seven schools offers cable television on campus. Further, six of them make cable a mandatory service (the only exception being

Lycoming, where access was provided on an optional basis). For what it is worth, none of these schools reported any negative effects (such as lower grade-point average) associated with cable delivery (although these studies made no outright attempt to identify any potential positive consequences, either).

MODEL DEVELOPMENT

We shall begin by describing the five specific delivery alternatives considered in our model. These alternatives were selected based on committee discussions, with staff members from Information Services and Resources, as well as Physical Plant, being especially helpful in this process. The possible delivery choices were each deemed to satisfy certain levels of quality; essentially, none of these options was substantially sub-standard compared to the others. The cable television possibilities ran the gamut from "tried and true" approaches to "cutting edge" technologies.

Not opting to delivery cable signals at all (the so-called "do nothing" alternative) was considered politically unwise. As explained in the previous section, plenty of stakeholders had endorsed the decision to launch cable television delivery. Consequently, the Task Force was charged with recommending one of the five options.

The first alternative entails building a brand-new "cable plant". This would involve installing a main coax cable "highway" from a central location to each campus dormitory. From the equipment in each dormitory, separate coax runs would be installed, eventually connecting to individual televisions in all dormitory rooms. Although this represented the traditional way to provide cable television service, Task Force members determined that this was the costliest of all the alternatives.

Previously, we indicated that Bucknell University does provide cable television service in a limited number of student rooms. The second option takes this into account by using some of the existing fiberoptics already in place for cable delivery on campus, rather than building a brand-new "cable plant" as required in the first alternative.   For those buildings not currently wired for cable service, coax highways would be installed, with coax runs established for individual rooms. This alternative is less costly than the first one since an entirely new, complete infrastructure is not required.

The third alternative resembles option two, except that instead of requiring separate coax runs to individual rooms, one would use Lucent Giga Speed Unshielded Twisted Pair (UTP) cable for student room access. Despite the fact that it is less costly than establishing separate coax runs, Task Force members learned that it could only support a maximum of 77 channels of cable television. It was not known if this would fully accommodate the current (and future) world of cable channel possibilities.

A fourth alternative provides cable television service directly through the existing Bucknell data network. This would eliminate the need for a coax highway between buildings, as well as coax runs to separate student televisions. Students would be required to purchase a set-top box (a device that would connect into the existing data port in each room in order to receive cable signals). Although this alternative could deliver up to 270 channels and picture quality would supposedly be excellent, Task Force members realized that this represented more of a "cutting-edge" technology. Frequently, newer technologies have some initial unforeseen technical issues.

The final option entails delivering cable television content directly to a student's computer (e.g. Web TV), thus eliminating the need for a set-top box (in addition to the coax highways required in the first three options). Although this alternative had the least installation costs, decision-makers felt that it was so “cutting edge” that its eventual utilization would most likely become more practical several years into the future. Further, the user’s interface was thought to be less than desirable. For example, the size of the television viewing area was limited to the PC monitor size, and one could not use a remote control to change channels.

Table 1 provides the installation costs for the five delivery alternatives. Due to reasons of confidentiality, all costs have been scaled. One can interpret this table by noting that the installation costs of Web TV (alternative #5) were 10% of the costs of UTP cable (option #3) and that replacing the entire cable plant (alternative #1) was 1.84 times the costs of the UTP cable. Stakeholders from the Finance Office, Information Services and Resources, and Physical Plant were confident that these costs accurately characterized the given alternatives.

===== insert Table 1 about here =====

We determined two relevant uncertainties with respect to selecting the cable television delivery option. The first uncertainty concerned the probability of success of the specific choice. Although the concept of “success” may appear vague, the Task Force settled on it relating to the notion that the particular technology worked as anticipated and that it provided an appropriate level of reliability for Bucknell students.

Given that the particular option was successful, a second uncertainty involved the likelihood that it would become obsolete. We termed obsolescence to mean that the technology would be effectively replaced by another delivery option.

Decision-makers did not attempt to tackle the (seemingly impossible) problem of determining when a specific delivery mode would become obsolete; rather, they were simply concerned with establishing the likelihood of the technology eventually becoming outdated.

We determined the probabilities of these various uncertainties in direct consultation with various college stakeholders. Initially, they had qualitatively assessed different risks using terms like “very low”, “medium” and “high”. Obviously, we needed to quantify these different uncertainties by providing a probability estimate. We discussed ranges of probability values before zeroing in on a specific estimate. A more objective approach to quantify risk could have involved the use of event trees. (For a thorough discussion of event trees, the interested reader can see Andrews and Dunnett (2000), Beim and Hobbs (1997), Ellickson and Penalva-Zuasti (1997) or Heslinga and Stassen (1992)). Although event trees may have provided a scientific method to elicit risk values, we are confident that our iterative approach of generating specific probability estimates by talking to Task Force members yielded accurate probability values. We were careful not to make the development of our model a “black box”, thus potentially limiting its eventual use as an aid in actual decision making.

Table 2 offers the respective probabilities used in our decision analysis model. We note that a more attractive alternative would yield a higher estimate for successful installation and a lower value for obsolescence risk.

===== insert Table 2 about here =====

Tradeoffs are readily apparent with these alternatives. “Older” approaches such as replacing the entire cable plant are almost guaranteed to be successful; the problem arises due to their preponderance to become obsolete. For example, personnel from Information Services and Resources pointed out that “tried and true” technologies may be unable to handle emerging video services such as two-way interactive television. Newer technologies may be able to manage the “cable television world of tomorrow”, but it is not certain that they will operate successfully within the confines of the actual collegiate application explored in this paper. We point out that the data network possesses rather attractive values for either form of uncertainty. The fact that this technology is currently being sold to various Internet Service Providers certainly is beneficial. Web TV has a relatively healthy obsolescence risk since, according to various members of our Task Force, it stands a reasonably good chance of being replaced by some other “futuristic” delivery mode.

Once the uncertainties were outlined, we needed to assess costs for future “unfortunate outcomes.” In other words, we were required to quantify the costs of unsuccessful installations and obsolete technologies. After thorough discussion between Task Force members, we determined reasonable estimates of pertinent values; namely, an installation failure of $2.5 million while obsolescence cost was quantified at $2.0 million (we did not scale these costs since they are essentially not confidential). The exception to these costs involved Web TV with an installation failure set at $3.5 million. Admittedly, these costs were not derived from an analytical model; nonetheless, Task Force members were confident that they were a good approximation for these outcomes. Besides, we performed sensitivity analysis on these values to judge the effects of changes on our decision-making process.

We include a cut-away of our decision tree in Figure 1. Since each alternative was subject to the same set of uncertainties, we illustrate the tree for a single option. We recognize that the preferred outcome is for the delivery mode to be successfully installed and not to become obsolete within a reasonable time frame. In the case of unfortunate outcomes (risks associated with unsuccessful installations or technological obsolescence), specific penalty costs are incurred. The alternative with the lowest expected monetary value (EMV) is our best option. Although one may have selected other objectives (e.g. disruption to campus operations, dependability of underlying service), Task Force members were confident in using EMV minimization to determine the best choice.

===== insert Figure 1 about here =====

MODEL RESULTS

Having identified the specific alternatives in addition to their relevant costs and the likelihood of various uncertainties, we can now turn our attention to solving the decision analysis model. We use a spreadsheet add-in *PrecisionTree* (available from Palisade Decision Tools) to solve our model and perform all sensitivity analysis. Albright, Winston and Zappe (2003) provide a detailed guide to using *PrecisionTree*.

Table 3 provides the EMV's of each alternative. As with other confidential data, we have scaled the results, using the lowest EMV as a base value. The preferred alternative is to adopt the data network as the cable television delivery mode. Although its installation is somewhat riskier than "tried and true" technologies (such as replacing the entire cable plant), the data network benefits from its relatively lower installation costs. Further, it possesses the least amount of obsolescence risk.

===== insert Table 3 about here =====

We observe a rather large difference between the results of our best option and the EMV's of competing technologies. Adopting UTP cable, the second best alternative, has an EMV 1.83 times the EMV of using the data network. From an EMV perspective, the least preferred delivery mode would be to replace the entire cable plant.

Determining the preferred alternative is an important part of real-world decision analysis. However, we felt that it was crucial to show other Task Force members the sensitivity of our model to changes in key parameter values. By performing a wide range of sensitivity analyses, decision makers can observe the degree to which model results are affected by different parameter values. We provide the results of some of our more interesting findings in this section. Since the preferred option involved using the data network, Task Force members were particularly interested in any sensitivity analysis involving this specific alternative.

We constructed a tornado diagram as illustrated in Figure 2. This graphical representation depicts the sensitivity of the optimal option's EMV to each our selected parameters over user-defined ranges. We incorporated specific parameters that we felt characterized the essence of our decision analysis model. The length of each bar in the tornado diagram indicates the percentage change in the EMV in either direction; as a result, longer bars imply that changes in the particular input have a more substantial effect on EMV. In our model, the data network's likelihood of installation success has a significant effect on EMV. Decision-makers need to be confident that its current value of 60% is indeed an accurate representation of this uncertainty.

===== insert Figure 2 about here =====

Figures 3 through 5 illustrate two-way strategy regions. This form of sensitivity analysis is used to depict the best alternative under various combinations of two important model parameters. As it turned out, these graphical representations were quite valuable in communicating our modeling efforts to other Task Force members. Administrators and staff members could observe the ranges over which particular alternatives were preferred.

Figure 3 compares the installation costs of the data network and UTP cable, the top two choices for cable delivery. Cost values were removed on each axis to preserve confidentiality. Clearly, the data network is an attractive choice as it remains the preferred option under nearly all combinations of these two costs. Delivering signals via UTP cable makes sense only if its installation costs decrease significantly (actually, the costs would need to drop to about 1/3 of their current value), combined with a concomitant increase in data network costs (about a 5-fold escalation).

In Figure 4, we evaluate the likelihood of successful installation for the two "cutting edge" technologies, data network and Web TV. As we observed with Figure 3, the data network is an appealing alternative. Figure 5 compares the failure cost of Web TV with data network's probability of installation success. Only when Web TV's failure cost drops appreciably is the data network rejected as the best option.

===== insert Figures 3, 4 and 5 about here =====

CONCLUSIONS

Our paper has described the development of a decision analysis model to explore cable television delivery options within the residence halls of Bucknell University. Working closely with senior administrators and staff members, we created a model that considered separate alternatives, relevant costs, and probabilities associated with various uncertainties. Our results show that this institution should adopt the data network as the mode for cable delivery. Sensitivity analysis further supports this notion. Decision-makers need to be sure that the probability of successful installation for the data network option is accurate, for this parameter had the most substantial effect on the EMV of the optimal alternative.

By virtue of this modeling project, we have cultivated an enhanced understanding regarding the practice of decision analysis. Incorporating the viewpoints of several stakeholders in a decision analysis model may be a time-consuming process, but it is incredibly valuable. Such activities enhance model understanding and eventually model implementation. The process becomes less of a "black box" for those who will actually use the results derived from the modeling effort. Sensitivity analysis is particularly important in the process of communicating the results of any quantitative model.

The genesis for this project occurred after a comment from an exceptionally motivated student in one of our decision sciences courses. Indeed, we were quite gratified that this study resulted from a student suggestion and explicitly incorporated student input. Ultimately, we have seen that activities in which are students are involved may be turned into fruitful scholarly endeavors.

Spreadsheets serve as powerful tools in facilitating our efforts to model real-world problems. Graphical decision tree programs such as *PrecisionTree* enable decision makers to visualize alternatives, uncertainties, and the results from sensitivity analyses. Besides their modeling benefit, spreadsheets have become an important part of the pedagogical delivery of material in our classroom. In fact, we have used parts of this project as a discussion case study in our courses. Students display keen interest in the model, perhaps since it is an application that directly affects them! Ultimately, they obtain a greater appreciation of the utility of spreadsheet analysis, in addition to an enhanced understanding of the role of decision analysis.

Task Force members were especially pleased with the model. Its findings became an additional piece of evidence in favor of adopting the data network as the cable television delivery mode. In fact, our campus recently conducted a 5-week pilot study to gauge the suitability of delivering cable television signals over the data network. From March 31st to May 4th, 2004, about 70 rooms were set up for this delivery option. Generally, results were quite encouraging and a full-scale “roll-out” of this technology occurred in August, 2004. As demonstrated through this project, decision analysis can be an especially powerful approach in helping to solve real-world decision problems.

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Alternative	Installation costs
#1: Replace entire cable plant	1.84
#2: Existing fiberoptics, coax	1.50
#3: UTP cable	1.00
#4: Data network	0.38
#5: Web TV	0.10

Table 1: The installation costs varied across the different alternatives. For reasons of confidentially, the installation costs have been scaled. We use the UTP cable installation cost as a base value. For example, replacing the entire cable plant costs 1.84 times the UTP installation cost, while adopting Web TV would cost about 10% of our base value cost.

Alternative	Probability of successful installation	Obsolescence risk
#1: Replace entire cable plant	0.97	0.98
#2: Existing fiberoptics, coax	0.98	0.98
#3: UTP cable	0.90	0.80
#4: Data network	0.60	0.20
#5: Web TV	0.10	0.40

Table 2: Each of our alternatives was subject to two types of uncertainty; namely, probability of successful installation and obsolescence risk. Generally, "older" technologies had high probabilities of being successfully installed, but tended to become obsolete. "Cutting edge" approaches had lower installation success rates, but in the event that they were successful, they had less of a risk of becoming obsolete.

Alternative	Expected Monetary Value
#4: Data network	1.00
#3: UTP cable	1.83
#5: Web TV	2.14
#2: Existing fiberoptics, coax	2.47
#1: Replace entire cable plant	2.71

Table 3: The Expected Monetary Values (EMV) for each alternative show that adopting the data network is the preferred cable television delivery mode. To preserve confidentiality, we scale our results, using the lowest EMV as a base value. We note a rather large gap between our optimal alternative and the other technologies. For example, the second best alternative, UTP cable, has an EMV 1.83 times the EMV of using the data network.

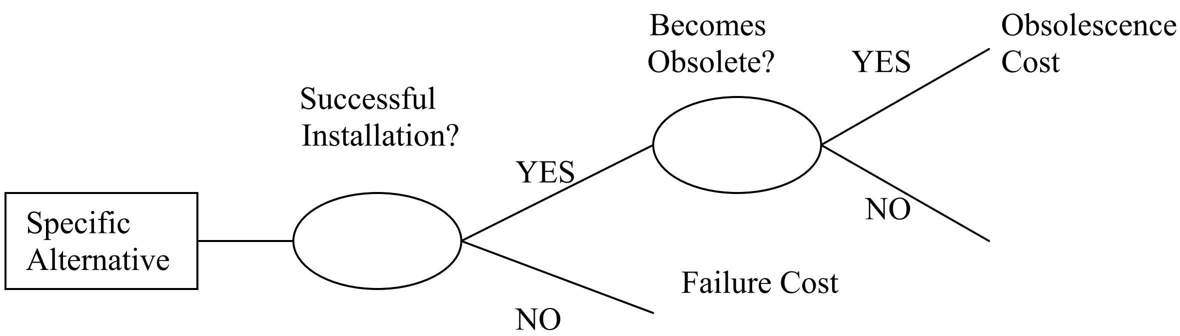

Figure 1: To enhance conciseness, we illustrate a portion of our decision tree since each alternative was subject to the same set of uncertainties. Failure costs occur if in the installation proves unsuccessful, while an obsolescence cost is incurred if an alternative becomes outdated. The optimal choice is the option with the lowest expected monetary value (EMV).

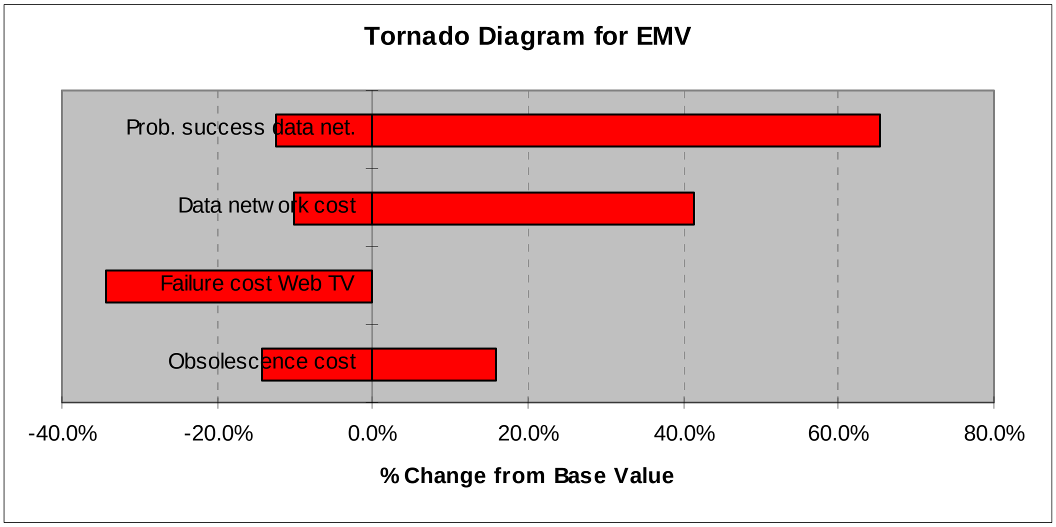

Figure 2: A tornado diagram illustrates the sensitivity of the optimal alternative's EMV to each of the particular parameters. The length of each bar depicts the percentage change in the EMV in either direction; hence, longer bars suggest that the EMV is more sensitive to that specific parameter. Of the inputs we selected for this tornado diagram, the probability of successful installation for the data network has the most significant effect on optimal EMV.

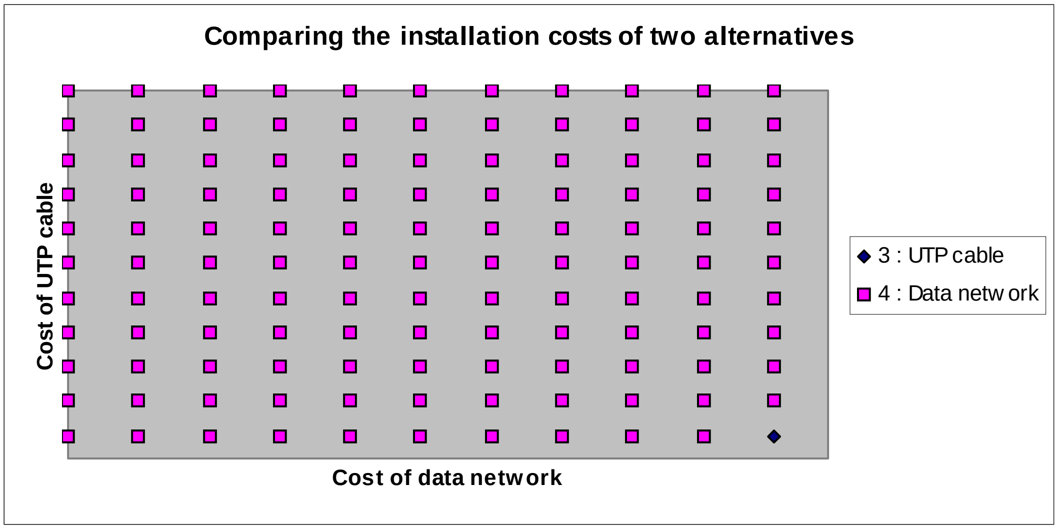

Figure 3: We provide a two-way strategy region for comparing the installation costs of two alternatives; namely, the data network and UTP cable. Recall that from an EMV perspective, these options were the top two choices for cable delivery. The strategy region shows the best alternative (given by the symbol found in the associated key) under various combinations of either cost. Under nearly all combinations of data network and UTP installation costs, the data network remains the optimal choice. Only in the event that UTP installation costs fall dramatically (to about 1/3 of their current value) and data network costs rise substantially (about a 5-fold increase) will the decision change. For reasons of confidentially, we removed the costs values on each axis.

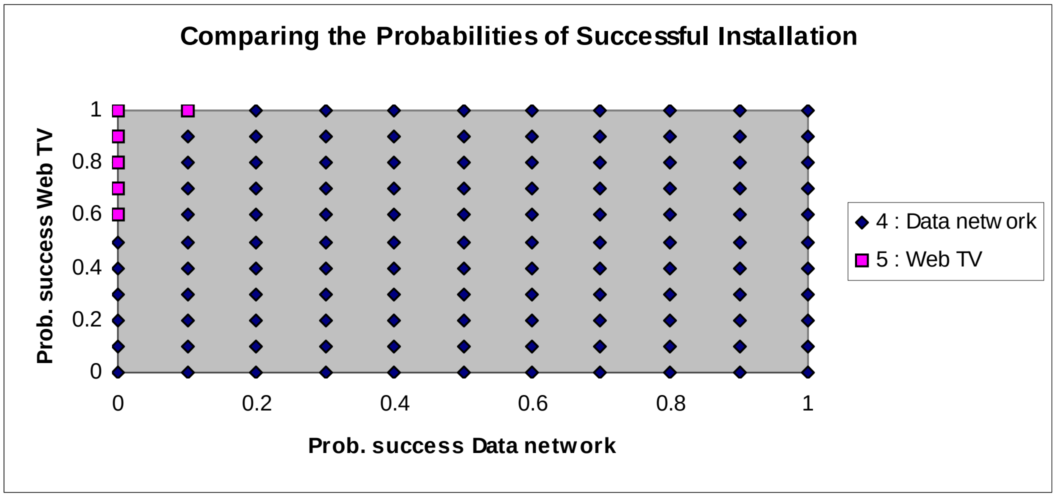

Figure 4: This two-strategy region compares the probabilities of successful installation for our two "cutting edge" technologies, data network and Web TV. The data network remains the better choice under nearly all combinations of either probability. Only when the data network has a limited chance of installation success, combined with a rather high likelihood that Web TV will work, does the decision vary.

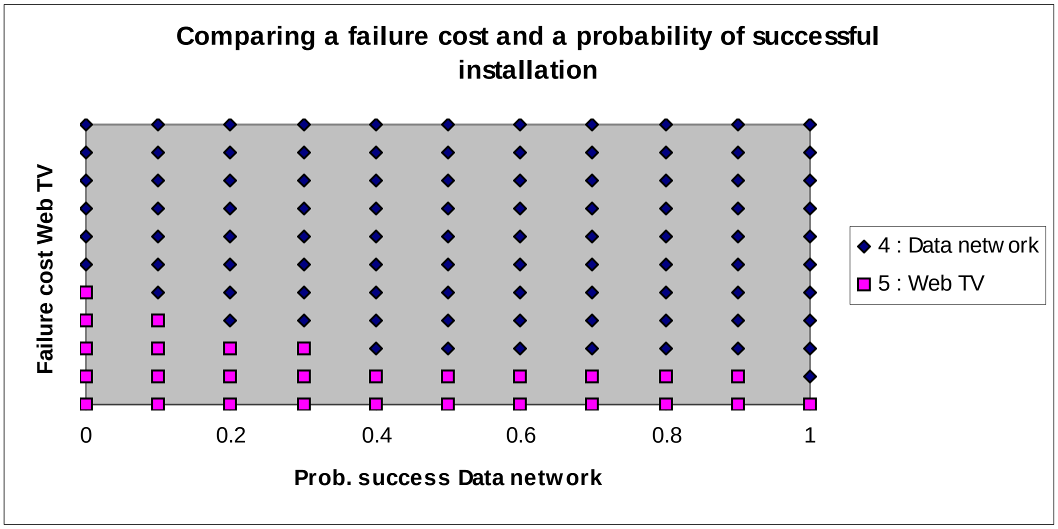

Figure 5: We compare the failure cost of Web TV with the probability of the data network being successfully installed. We removed the cost values on the vertical axis to preserve confidentiality. The data network remains an attractive choice over a wide range of parameter values. Web TV becomes the best option when its failure cost falls (to less than ½ its current value).