CHAPTER 5: ACCOUNTING FOR FREQUENTLY OVERLOOKED INDIRECT BENEFITS OF POLLUTION PREVENTION ASSISTANCE

5.1. INTRODUCTION

Organizations that provide pollution prevention (P2) technical assistance and businesses that make P2 improvements are often interested in analyzing the impact of implemented P2 suggestions. Depending on the accounting method used, service providers could overlook the monetary value of some benefits. For example, the National Pollution Prevention Roundtable (NPPR) and the Pacific Northwest Pollution Prevention Resource Center's (PPRC) P2 accounting systems do not provide methods to quantify the monetary value of indirect benefits (e.g., time savings from intern's research, future liability reductions) that are difficult to precisely quantify (Goldberg et al., 2004). In some cases, indirect benefits may be important factors influencing the adoption of P2 measures. It would, therefore, be useful for P2 service providers to increase the number of indirect savings that are quantified.

There is a variety of terms used in technical literature to define the types of benefits resulting from the implementation of P2 measures (Burgees, 1981; Brauer, 1993; Freeman, 1995). This study uses the following definitions. Direct benefits are those that relate directly to the waste reduction, such as reduced waste disposal costs, and have been typically quantified by University of Nebraska-Lincoln (UNL) technical assistance providers. Intangible benefits are savings that can not be reasonably and consistently quantified. For example, the revenue from an improved corporate image would be an intangible benefit. Indirect savings are secondary savings from a P2 suggestion that are often not quantified, but can be. For example, the monetary value of time saved from a P2 suggestion would be an indirect benefit.

The goal of this study was to quantify cost savings from four benefits often considered intangible, thus converting the intangible benefits to indirect benefits. Indirect benefits that will be quantified include savings from research, reduced operating costs, reduced regulatory burdens and reduced future liabilities. There are many other intangible or indirect benefits resulting from implemented P2 suggestions that could not be consistently quantified among multiple clients. Savings that are likely to occur but were not quantified include private (e.g., improved corporate image, less workers compensation costs) as well as public (e.g., reduced environmental damage, decreased landfill use) benefits. This study also does not quantify the value of long term educational benefits from the UNL assistance program training interns and interns training clients in P2 methods.

Only a few studies have been conducted to quantify the indirect benefits of waste reductions, safety and publich health projects (Lave, 1980; Rouse and Boff, 1999; Hughes, 2004). Hughes (2004) presented a method to assess subjective benefits, such as safety and efficiency, from construction projects. Lave (1980) discussed the economics of a public health program. Rouse and Boff (1999) presented the theoretical framework often used to calculate indirect benefits from human efficiency improvements.

Many methods are available to help organizations quantify benefits from waste management or safety improvements. These methods apply concepts such as life-cycle impact analysis to better understand the environmental and economic significance of a P2 project (Freeman, 1995; Woldt et al, 2003). Common methods to quantify savings involve applying formulas developed within an organization for a specific situation (Lave, 1980; Hawkey, 2004) or using computer methods (Rose and Boff, 1999; Junker, 2000; Hawkey, 2004). Both methods tend to require a company to track variables needed for calculations. Consequently, these methods best serve organizations with a strong commitment towards documenting project successes.

P2 technical assistance providers are challenged when applying these commonly used methods. Assistance providers often need to account for savings from multiple clients with different amounts of corporate interest towards benefits tracking. As a result, they need to use an easy, yet reliable approach to calculate clients' savings.

One such approach is to use empirical equations developed by the United States Environmental Protection Agency (USEPA) to estimate monetary values of indirect benefits (USEPA, 1989; USEPA, 1995; USEPA, 1996). A previous P2 study was successful in using USEPA equations to estimate potential savings from suggestions given to an asphalt testing laboratory (Behrens et al., 2000). This study follows Behrens' work by conducting in-depth studies of twenty clients assisted by a University of Nebraska-Lincoln (UNL) P2 program to quantify direct and indirect cost savings. After savings data were determined, an analysis was conducted to identify circumstances when each type of indirect savings is larger than other indirect savings. The analysis also examined the relationship between clients' indirect and direct savings.

5.2. P3 TECHNICAL ASSISTANCE

Since 1997, UNL has offered P2 technical assistance to Nebraska businesses through the Partners in Pollution Prevention (P3) program. The P3 program provides two weeks of training for engineering student interns after which, the interns conduct summer technical assistance projects for clients throughout the state. P3 projects involve an intern assessing a client's waste streams and then presenting suggestions to reduce waste generation. Over 300 businesses have been assisted during the program's eight years. Typically, the businesses participating in the program have limited experience with P2; consequently, involvement with the P3 program increases P2 activity at a company.

To meet clients' needs, the P3 program offers various assistance modes. The modes provide different depths and complexities of assistance projects. The modes are categorized in this study as small business and industrial modes. In general, clients participating in the small business mode request small scale, simple assistance projects that take the intern an average of two weeks to complete. For example, many small business clients require assistance starting a recycling program or finding alternatives to hazardous cleaning products. Clients participating in this mode are typically small service or manufacturing industries with little existing knowledge of P2.

The clients participating in the industry mode generally request larger scale, more complex projects. Assistance projects tend to take the intern five to nine weeks to complete. Clients participating in the industry mode usually require assistance modifying entire manufacturing processes to reduce waste generation. Clients in this mode tend to be regional manufacturing organizations with some existing knowledge of P2. A detailed description of the P3 program's intern training and assistance modes is provided in Dvorak et al. (2003).

5.3. INDIRECT BENEFITS NOT QUANTIFIED IN PREVIOUS P3 STUDIES

After five years of providing technical assistance, two studies were conducted to determine the P3 program's actual impact on participating companies. The two studies of previous clients were: (1) surveys and (2) reassessment interviews. Both studies were not able to quantify indirect monetary savings from P2 measures. This section will present conclusions from the previous studies concerning the occurrence of indirect savings.

The P3 program's first study was a survey of clients; 65% of the 222 past P3 clients assisted previous to 2001 responded to the survey. Surveys were used to determine clients' opinion concerning the most valuable aspects of participating in the P3 program. As was concluded in Chapter 3, over three-quarters of respondents stated that the program saved their company time (77%); one-half of the respondents felt the program was beneficial in increasing knowledge of P2 (56%) and improving working conditions (47%). These three benefits are likely to result in some indirect savings. Survey methods and results are discussed in more detail in Chapter 3.

The second study was reassessment interviews with clients. Nearly one-third (29%) of all clients assisted by the P3 program were revisited from 2001 to 2004. During the visits, P3 researchers interviewed the client to quantify the monetary savings and waste reductions resulting from previous P3 technical assistance. Clients provided direct savings quantities during reassessments. Many clients stated there were additional savings from suggestions that address health, safety and prevention but they were hesitant to quantify the savings. Consequently, P3 interviewers simply tracked whether implemented suggestions did or did not have health, safety or preventative components. It was concluded that over one-third (37%) of the 216 implemented P2 suggestions had health, safety and/or preventative components. It is likely the health, safety and preventative components result in indirect savings. Reassessment methods and results are discussed further in Chapter 4.

Indirect benefits were found to occur from implemented suggestions made by P3 interns. In many cases, the indirect benefits were an important element in the decision to adopt P2 measures. It is possible that these indirect benefits have significant monetary value; however, the exact quantity of savings was uncertain when accounting for program impact using surveys and reassessments.

5.4. DIRECT AND INDIRECT SAVINGS ESTIMATION METHODS

This study determines direct and indirect savings from twenty previous clients that received P3 technical assistance. The twenty clients participating in this study were randomly selected from 280 P3 clients assisted between 1997 and 2003. One-half (10) of the clients were assisted by small business mode interns. The other half of the studied clients was assisted by industry mode interns. This section will describe the method used to calculate a client's direct and indirect savings. An application of the calculation method is provided in Section 5.5.

5.4.1. Interview Process

Implemented P2 suggestions can result in a wide range of benefits (Burgees, 1981; Brauer, 1993; Freeman, 1995; Behrens, 2000). P2 service providers and companies interested in P2 benefit accounting find some of these benefits difficult to quantify, consider them intangible and thus neglect their contributions in cost analyses. In this study, several common benefits that are difficult to quantify (research performed, operational costs reduced, regulatory burdens reduced, and future liabilities reduced) were estimated in order to determine the associated (indirect) cost savings. The benefits included in this study were selected because they could be estimated in a relatively consistent manner between multiple clients.

Lists of interview questions were developed with respect to the types of direct and indirect savings to be quantified. The questions were designed to help a P3 staff member conduct interviews with clients to determine variables needed to solve indirect savings equations (USEPA, 1989). A list of all questions and detailed interview notes can be found in Appendices E and F respectively.

5.4.2 Direct Savings

Direct savings were the easiest type of savings to quantify. These savings included savings from reduced purchasing of raw materials and disposal of waste. Direct savings do not include the payback period based on capital expenditures to implement suggestions due to inconsistent data provided by clients. Direct savings were quantified by consulting a client's purchasing records and disposal manifests. Clients were typically able to document their direct savings so there is little uncertainty to this type of benefit.

5.4.3 Indirect Savings

Indirect savings tended to be more difficult to estimate than direct savings. This type of savings includes clients' savings associated with research performed by interns, operational costs reduced, regulatory burdens reduced and future liabilities reduced. Research, operational cost and regulatory burden cost savings were similar in nature because they resulted from less of a client's time spent on waste issues. The equations to estimate research, operational cost and regulatory burden savings (USEPA, 1989) are in the form:

$$C = f \times \left[n + \left(t \times w\right)\right] \tag{5.1}$$

Where C is the cost savings in dollars per year, f is the frequency of an event occurring per year, n is the non-labor cost per event, t is the time required per event and w is the wage rate per hour of the employee involved.

Future liability reductions were the most difficult type of indirect savings to precisely quantify because the cost of a future liability is very uncertain. Future liabilities estimated in this study include costs of hazardous waste releases and personnel injuries. One can consider future liability reductions as being analogous to insurance payments in the event of a release or accident.

USEPA (1989) presents equations for estimating monetary savings from reduced future liabilities. Different equations and constants are given for savings resulting from reduced personnel injury, economic loss, real property damage, soil and waste removal and treatment, natural resource damage and ground water removal and treatment (USEPA, 1989). Equations to calculate annual future liability reductions require a user to multiply variables that are provided by clients or empirically developed, to calculate an annual savings.

The calculated future liability reductions must be adjusted by multiplying it by the probability of a release. Behrens (1998) calculated the probability of release by dividing the number of regulated facilities in Nebraska by the number of reported releases each year (1.5% to 4.0%). Next, the total cost must be divided by the years after a release in which liability payments are likely to occur. USEPA (1989), recommends a range of 6 to 41 years for storage tank releases and immediately (1 year) for transportation releases.

The constants provided for future liability reduction equations were published in 1989. The RS Means cost estimation guide recommends one uses the Engineering New Record's (ENR) Construction Cost Index (CCI) to adjust projects for inflation (R.S. Means Co, 2003). The model's cost results were updated from 1989 to December 2004 values by the use of the ENR construction cost index (Engineering News Record, 2004).

5.4.5 Fuzzy Set Theory

A degree of uncertainty exists for indirect savings resulting from implemented suggestions. Fuzzy set theory can be used to model the uncertainty in the amount of cost savings. Fuzzy set theory was selected as the method to model uncertainty because savings data in this study were most similar to the linguistic format of fuzzy set theory.

Fuzzy set theory has been applied to many areas of environmental engineering. (Tannehill et al., 1997, Behrens et al., 2000; Dvorak and Schauble, 2001, Woldt et al., 2003). A useful application of fuzzy set theory involves a special case of fuzzy sets, the so-called fuzzy numbers (Bárdossy and Duckstein, 1995). Fuzzy numbers are used to represent imprecise parameters in analytical, empirical and other modeling approaches. Fuzzy numbers are defined as a fuzzy subset of the set of real numbers with the fuzzy subset having both normality (a membership equal to 1) and convexity (monotonically increasing and decreasing parts, with possible flat parts). The higher the membership value of a fuzzy number, the greater the possibility (or likelihood) that a parameter value will be compatible with the concept (or value) expressed by the fuzzy number.

In this study, clients were asked a series of questions to provide values that construct the vertices of triangular fuzzy numbers similar to Figure 5.1. The most credible value was assigned a membership value of 1. The smallest and largest possible values were assigned membership values of 0. The parameters considered in this study were the variables to solve the USEPA (1989) equations.

Results containing fuzzy numbers can be difficult to interpret. Fuzzy data can be defuzzified (i.e., returned to a single scalar quantity) for a quantitative comparison. This study used the centroid method to defuzzify clients' data. The centroid method considers the center of gravity, or average value below a fuzzy number as the savings (Ross, 1995). The centroids of fuzzy numbers were calculated using Microsoft Excel in this study.

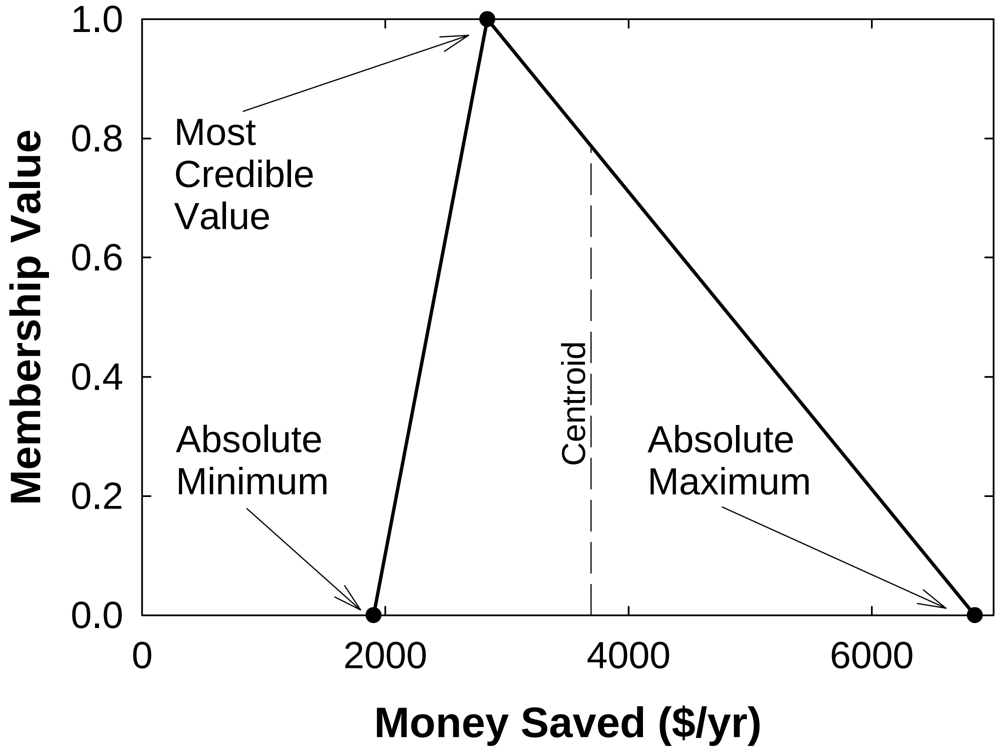

Figure 5.1. Typical Triangular Fuzzy Shape.

Variables used, fuzzy numbers calculated and defuzzified savings for the twenty studied clients are tabulated in Appendix H.

5.5. EXAMPLE OF ESTIMATING DIRECT AND INDIRECT SAVINGS

To illustrate the method used to estimate direct and indirect savings, calculations from one P2 suggestion implemented by an example client are presented. In 2002 a P3 intern provided P2 suggestions to a client to minimize chemical drag out between galvanization dip tanks. A reduction in drag out resulted in one less disposal and refill of the client's hazardous zinc ammonium chloride bath each year. Sample calculations for all of the example client's implemented suggestions, including the reduced chemical bath change out, can be found in Appendix I.

5.5.1 Direct Savings

An interview with the example client's plant manager verified that a P3 intern's suggestions helped to reduce purchasing and disposal of zinc ammonium chloride by 22,700 liters per year. Purchasing and disposal records indicate the company saved $11,570 per year as direct savings.

5.5.2 Indirect Savings

Reducing chemical bath disposal resulted in multiple types of indirect savings in the form of reducing time required by the client's staff to perform specific tasks. First, there was an operating cost reduction from less time spent changing out the chemical bath. Second, one less disposal each year resulted in reduced regulatory burdens from less time spent documenting and labeling the waste.

A third type of time savings, savings due to the intern's research, occurred but the example client (and all other clients in this study) struggled to separate the intern's research savings among multiple P2 suggestions given to them. When asked to estimate research savings, all clients provided the amount of time it would take for their staff to conduct research comparable to their intern's entire summer research effort. For brevity, this example will not present the calculation of research savings. Research savings are detailed, along with all of the sample client's savings, in Appendix I.

During the interview with the example client, questions were asked of the client to determine variables needed to solve Equation 5.1. One change out was reduced each year. There was no non-labor cost for the change out because the company owns all of the necessary equipment. The wage rate of staff and the EHS coordinator (including overhead) was $45 per hour. Labor records indicated that the total staff time saved per chemical bath change out was 96 hours (used for operating cost reductions). The client's EHS coordinator estimated that each disposal required four hours to coordinate (used for reduced regulatory burdens). The example client, therefore, saved $4,320 per year in operating cost reductions and $180 per year in reduced regulatory burdens.

Reducing the frequency of the chemical bath change out and disposal at the client's facility led to an additional indirect savings, future liabilities reductions. Liabilities are reduced because there is less chance that soil and ground water could become contaminated during the change, storage and transportation of the hazardous flux. The reduction in liabilities from soil contamination was negligible ($6) and will not be detailed in this example (Appendix I). The savings from reduced potential for ground water contamination is substantial and will be discussed further in this section.

The ground water removal and treatment equation requires one to input variables estimating the distance to the nearest drinking water well, width of the potential ground water plume, velocity of the ground water, equipment cost of ground water treatment, and the operating and maintenance cost of ground water treatment. The example client's plant manager was unable to estimate any of the requisite variables. USEPA-recommended variables (USEPA, 1989) and variables specific to Nebraska (Behrens, 1998) were used. To model the range of possible variables, the smallest and largest values for a variable were assigned membership values of 0 (As in Figure 5.1). The most credible value for a variable was assigned a membership value of 1.

Minimum, maximum and most credible savings from reduced ground water liabilities were calculated using the range of variables (membership values of 0 and 1). The example client was found to save between $500,000 and $4,700,000 per year (most credible value of $1,700,000) due to reduced ground water contamination liabilities. This range of values was adjusted for the probability of a release, time for liability payments to occur and inflation to range between $1,900 and $6,800 per year (most credible value of $2,800).

5.5.3 Defuzzification

The direct and indirect cost savings discussed in the example are plotted as fuzzy numbers in Figure 5.2. The direct cost savings, and operating cost and regulatory burden reductions were, in this case, reported as crisp numbers. Crisp numbers have a membership value of only 1 and are plotted as a single, vertical line. Future liability reduction was plotted as a triangular fuzzy number. The three cost savings were then added to give a total savings represented by a fuzzy number in Figure 5.2. Finally, the total savings number was defuzzified by the centroid method to a total savings of $20,500 per year.

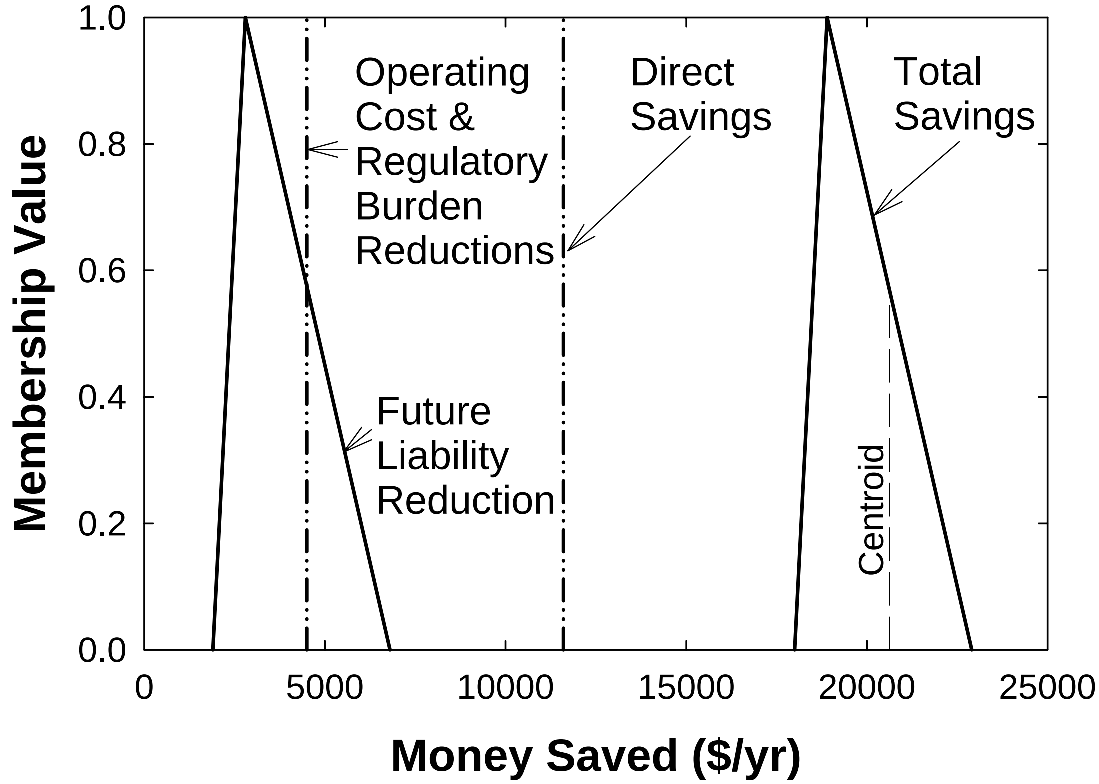

Figure 5.2. Annual Savings from Reducing Chemical Bath Change Out (Total Savings = Direct Savings + Operating Cost and Regulatory Burden Reductions + Future Liability Reduction)

5.6. RESULTS

By using USEPA equations to estimate four categories of indirect savings and fuzzy set theory to model uncertainty, direct and indirect savings were determined for the twenty studied clients. The twenty clients and their cost savings are summarized in Table 5.1. The general business type of each client is provided in Column 1 of Table 5.1. The second column lists the mode of P3 assistance provided to each client.

Table 5.1. Annual Direct and Indirect P2 Savings for 20 Clients.

(1) Company	(2) Technical Assistance Mode	(3) Technology Change	(4) Source of Hazardous Waste Reduced	Indirect Savings ($/yr)				(9) Total Indirect Savings ($/yr)	(10) Total Direct Savings ($/yr)	(11) Total Savings ($/yr)
				(5) Research Savings	(6) Operating Costs Reduced	(7) Regulatory Burdens Reduced	(8) Future Liabilities Reduced			
Wood Products	Industry	No	None	1,100	35,000	0	0	36,100	19,000	55,100
Metal Finishing A	Industry	Yes	Chem. Baths	2,500	4,300	400	7,300	14,500	17,000	31,500
Laboratory A	Industry	Yes	Solvents	700	5,500	1,400	4,900	12,500	13,000	25,500
Metal Products A	Industry	No	Solvents	3,400	0	0	1,600	5,000	17,000	22,000
Metal Products B	Industry	No	Solvents	400	0	60	14,000	14,460	4,700	19,160
Metal Products C	Industry	Yes	Fugitive Oil	200	0	0	14,000	14,200	3,500	17,700
Wood Products	Industry	No	None	200	0	0	0	200	12,000	12,200
Metal Products D	Industry	Yes	Parts Washer	700	0	200	7,800	8,700	2,600	11,300
Metal Finishing B	Industry	Yes	None	900	5,500[a]	0	400	6,800	0	6,800
Medical Products	Industry	No	None	1,900	0	0	0	1,900	2,100	4,000
Printing A	Small Business	Yes	Print Chem.	100	53,000[a]	300	0	53,400	38,000	91,400
Well Drilling	Small Business	No	None	0	3,100	0	6,600	9,700	3,500	13,200
Auto Maintenance A	Small Business	Yes	Parts Washer	0	200	100	400	700	6,000	6,700
Metal Finishing C	Small Business	No	None	500	0	0	0	500	0	500
Auto Maintenance B	Small Business	No	Parts Washer	100	0	0	0	100	300	400
Auto Maintenance C	Small Business	No	Paint	200	0	40	0	240	0	240
Laboratory B	Small Business	No	None	70	0	0	0	70	0	70
Printing B	Small Business	No	None	30	0	0	0	30	0	30
Glass Work	Small Business	No	None	30	0	0	0	30	0	30
Auto Maintenance D	Small Business	No	None	10	0	0	0	10	0	10

[a] Clients were unable to separate the operational cost of labor and direct cost of materials to repair frequently damaged equipment. The clients indicated labor costs were the larger of the two.

Modes indicate the scale and complexity of assistance projects with industry projects being of larger scale and more complexity. Within each mode, the rows in Table 5.1 are arranged from the client with the most to least total savings.

Multiple P2 suggestions were made to each client. Column 3 of Table 5.1 provides information on whether any of the P2 suggestions that were implemented required technology changes. Column 4 indicates which clients had hazardous waste reductions. Note that clients with hazardous waste reductions may have realized some non-hazardous reductions. Also, clients with “none” in the hazardous waste reduction column may have some non-hazardous reductions. Direct and indirect savings are listed in Columns 5 through 11 and are discussed subsequently. All fuzzy indirect savings presented in Table 5.1 were defuzzified using the centroid method.

5.6.1. Indirect Savings

Certain clients had much larger research, operating cost, reduced regulatory burden and future liability reduction savings than other clients. This first objective of the analysis was to identify types of assistance projects with notable indirect savings. Many of the reasons for higher indirect savings were mentioned by clients during the interviews (Appendix G) and confirmed by the savings totals in Table 5.1.

First, indirect savings from interns’ research, tabulated in Column 5 of Table 5.1, were evaluated. Most (18 of 20) clients perceived a benefit in terms of saved time from interns’ research. Research savings for the industry mode clients are larger than small business; clients tended to report larger research savings from longer-term assistance projects. Clients perceiving some savings were expected considering all clients worked with interns whose main responsibility was to conduct P2 research. Two of twenty clients reported that they did not perceive a financial benefit from the intern research. Both clients were less positive about the P3 program's assistance. These clients stated during interviews that the cost of time to explain their company's operations to interns exceeded any benefits gained from the assistance (Appendix G).

Next, operating cost reductions in Column 6 of Table 5.1 were evaluated. Five out of the seven clients that implemented a P2 suggestion requiring a new technology (Column 3) were found to have indirect savings related to reduced operating costs. These reduced operating costs are mostly a result of time saved to a client's staff. Examples of technology changes that directly resulted in reduced operating costs were equipment to clean chemical baths and a printing process that does not use hazardous chemicals. These technology changes reduced staff time needed to maintain equipment. Clients in this study were likely to have operating cost reductions when implementing P2 suggestions that require new technology.

Indirect savings from regulatory burden reductions (Column 7 of Table 5.1) were evaluated next. Regulatory burden reductions in this study resulted from saved staff time from less regulatory reporting. Seven of ten clients that reduced generation of hazardous waste (Column 4) experienced savings from reduced regulatory burdens. No clients reported a reduced regulatory reporting burden that did not result from reducing or eliminating a hazardous waste stream. Also, no trend was observed indicating larger reduced regulatory burdens if a client eliminated a waste stream as opposed to reducing generation quantities.

Three clients had a hazardous waste reduction or elimination, but did not experience any regulatory burden reductions. These clients implemented P2 suggestions that addressed small quantities of waste. As a result, the reductions did not affect the regulatory reporting workload.

The factor influencing the amount of regulatory burden reductions may not be the quantity of waste reduced, but instead the number of waste disposal events that are reduced. For example, one client, Metal Finishing A, reduced hazardous waste disposal by 22,700 L per year and estimated an indirect savings of $400 per year saved in regulatory burden reductions (staff labor for reporting). Metal Finishing A generates the 22,700 L of waste at one time and, consequently, avoids one less disposal event a year. On the other hand, Laboratory A reduces hazardous waste disposal by 5,500 L per year and saves $1,400 in regulatory burden reductions. Laboratory A generates the waste at a relatively constant rate throughout the year and avoids 4 disposal events a year. So, clients in this study were likely to have regulatory burden reductions when they reduce the amount of hazardous waste disposal events each year.

Finally, indirect savings from future liability reductions were evaluated (Column 8 of Table 5.1). Seven of ten clients that either reduced their generation of hazardous waste or eliminated a hazardous waste stream (Column 4) experienced indirect savings from future liability reductions. The three clients that generated some hazardous waste and had no future liability reductions generated small amounts of hazardous wastes each year (e.g., refurbished one used computer per four years, reduce lead-based paint use by less than 2 liters per year) and typically did not quantify such small reductions during reassessments. In these cases, the future liability reductions were considered negligible.

Two clients did not reduce the generation of any hazardous waste but experienced future liability reductions. The first client, Metal Finishing B implemented a suggestion that improved the safety for over fifty employees. The second, the Well Driller implemented a suggestion that addressed an illicit drain. So, clients participating in this study are likely to have future liability reductions when they reduce large quantities of hazardous waste, improve safety or address illicit waste discharges.

Evaluation of indirect savings indicated circumstances where clients' savings are larger for some categories of indirect savings. The amount of time spent on assistance influenced the research savings reported by clients. Whether a client had a technology change or not influenced the amount of operating cost reductions. Finally, whether a client reduced hazardous waste or only implemented suggestions that reduced non-hazardous waste influenced the amount of regulatory burdens and future liability reductions.

5.6.2 Indirect to Direct Savings Comparison

The second objective of the analysis was to compare the magnitude of projects' indirect savings to direct savings. It was concluded in Section 5.6.1 that clients in this study have larger indirect savings when they make technology changes and/or have hazardous waste reductions. Almost all (6 of 7) clients with a technology change also reduced hazardous waste. As a result, a comparison of savings from clients with technology changes is almost identical to the hazardous waste case and is not included for brevity.

The total indirect and direct cost savings are compared by computing ratios of the two costs. The fuzzy indirect savings that were calculated in this study were added. Indirect savings sums (Appendix H) were divided by the direct savings (Column 10 in Table 5.1) to determine the minimum, most credible and maximum ratios of indirect to direct savings. Larger ratios of indirect to direct savings indicate that clients generally observe more indirect savings than direct savings.

Ratios of indirect to direct savings for clients in the small business and industry modes are shown by the two fuzzy numbers presented in Figure 5.3(a). Clients participating in both assistance modes had similar ratios of indirect to direct savings. The ratio of indirect to direct savings is $1.10 to $1.00 for the industry mode and $1.40 to $1.00 for the small business mode. Clients receiving small business technical assistance realized both smaller direct and indirect benefits than the more in-depth industry mode, as might be expected. No trends were evident in the types of indirect savings (research saving, regulatory burden reductions, etc.) achieved for each mode possibly due to the small sample size of clients. The fuzzy numbers in Figure 5.3 indicate a similar degree of uncertainty for both modes' ratios of indirect to direct savings. The analysis by assistance mode indicates that regardless of the scale and complexity of assistance, clients tend to see indirect savings that are of a similar magnitude to direct savings.

Next, ratios of indirect to direct savings were estimated for clients that either reduced hazardous waste generation or only implemented suggestions that reduced non-hazardous waste (i.e., pallet recycling). These ratios of indirect to direct savings are shown by the fuzzy numbers presented in Figure 5.3(b). Clients that reduced hazardous waste generation might have also reduced non-hazardous waste; however, the majority of indirect savings resulted from hazardous waste reductions.

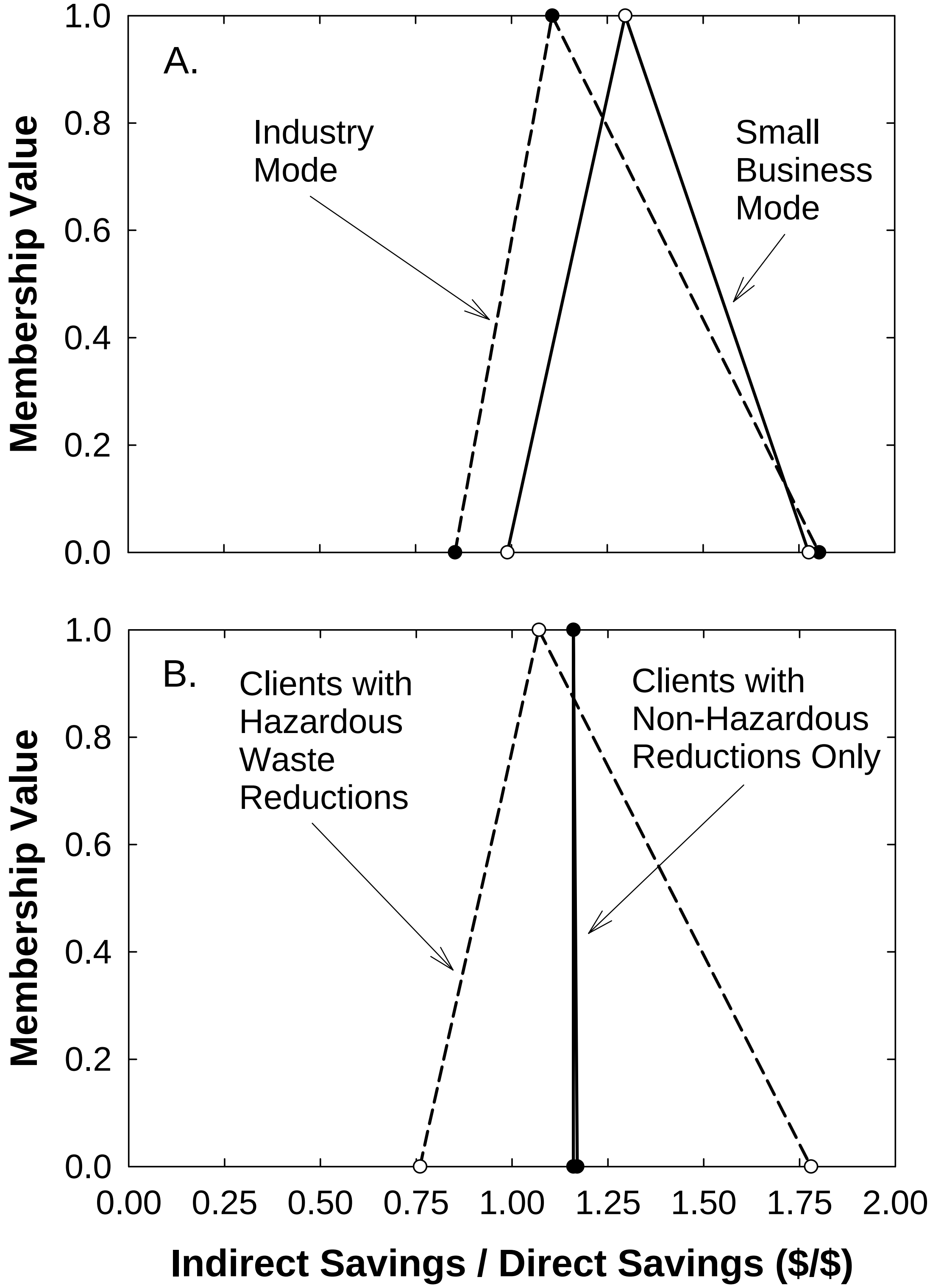

Figure 5.3. Ratio of Indirect to Direct Savings: (A) Assistance Mode Provided to Clients, (B) Type of Waste Reduction

The ratio of indirect to direct savings for both waste reduction cases is $1.20 to $1.00. Although at the most credible level both cases' ratio of indirect to direct savings are identical, the fuzzy numbers in Figure 5.3(b) indicate there is more uncertainty in cases where clients reduce hazardous waste. This uncertainty is likely related to the potential savings that may or may not occur when reducing future liabilities from hazardous waste releases.

Table 5.2 presents membership values of 0 (absolute maximum and minimum) and the centroid defuzzified values used to define the ratios of indirect to direct savings illustrated in Figure 5.3. The values in Table 5.2 are ratios (e.g., $0.90 indirect savings to $1.00 direct savings), however, since all ratios are normalized by $1.00 direct savings only the numerators are presented for simplicity. Table 5.2 also presents the minimum and maximum single clients' savings for each analysis category (right-most two columns). Comparison of these values indicates a large amount of variation in this study's data.

Table 5.2. Ratios of Indirect to Direct Savings: Membership Values and Maximum and Minimum Individual Client Ratios.

Type of Client Analyzed	**Number Of Clients**	**Average Membership Value**			**Minimum Centroid Defuzzified Single Client**	**Maximum Centroid Defuzzified Single Client**
		Minimum Possible	**Centroid Defuzzified**	**Maximum Possible**		
Industry	10	0.90	1.10	1.80	0.02	4.10
Small Business	10	1.00	1.40	1.80	0.10	2.80
Hazardous Waste	9	0.80	1.20	1.80	0.10	4.10
Non-Hazardous Only	3	1.20	1.20	1.20	0.02	2.80

Two clients had centroid defuzzified ratios greater than 2.90. An indirect to direct savings ratio of 2.90 is one standard deviation (1.3) above the average ratio ($1.60 to

$1.00) of all studied assistance projects. These clients had two of the three largest future liability reduction totals. One common aspect that may have resulted in higher indirect savings was that they implemented suggestions that were intended to address hazardous waste liabilities of concern to the client before the initial P2 technical assistance.

Two clients had ratios of indirect to direct savings less than $0.20 to $1.00 (one standard deviation below the average ratio). In these cases, the only indirect savings were from research savings. No other indirect savings occurred because the suggestion that were implemented resulted in minimal hazardous waste reduction but a large purchasing or disposal savings.

There is variation in the ratios of indirect to direct savings among clients in this study. Consequently, one must be careful in applying these ratios of indirect to direct savings to specific situations. Based on this sample of clients, it appears that when studying the sum of savings from multiple clients, the indirect savings are roughly equivalent to direct savings (centroid average values).

One should consider that the indirect costs quantified in this study reflect only a portion of the difficult to quantify benefits of P2. If other benefits (e.g., reduced workers compensation, improved corporate image) were added then the ratio of indirect to direct savings would be even larger. Also, the methods used to calculate clients' direct savings attempted to be conservative. A less conservative study would reduce clients' ratios of indirect to direct savings.

5.7. CONCLUSIONS

Although the results presented are specific to twenty projects studied by the P3 program, these results illustrate cases when accounting for indirect savings may prove significant to savings totals. The four indirect savings that were quantified by this study were savings from research by an intern, operating cost reductions, regulatory burden reductions and future liability reductions. One can conclude the following.

1. Indirect benefits often result from suggestions made by P3 interns. Over one-third (37%) of implemented P3 suggestions had health, safety and/or preventative benefits which resulted in financial gains that were not captured by surveys and reassessment interviews.
2. Five of seven clients in this study that implemented P2 suggestions requiring technology change found notable operating cost reductions.
3. Seven of ten clients in this study that implemented P2 suggestions reducing the disposal of hazardous waste found notable regulatory burden reductions.
4. Seven of ten clients in this study that implemented P2 suggestions reducing hazardous waste generation, improving safety and addressing illicit waste discharges observed notable future liability reductions.
5. Regardless of the scale and complexity of assistance, clients tended to see indirect savings that are of a similar magnitude to direct savings. In this study, smaller projects (small business mode) have a centroid method defuzzified average indirect to direct savings ratio of $1.40 to $1.00 and larger projects (industry mode) have a ratio of $1.10 to $1.00.
6. Regardless of the type of waste reduction (hazardous or non-hazardous), clients in this study tended to see indirect savings that are of a similar magnitude to direct savings (centroid defuzzified ratio of $1.20 to $1.00). Assistance projects with hazardous waste reductions were more likely to have indirect savings from future

liability reductions, a type of indirect savings that has more uncertainty associated with it. Consequently, assistance projects that reduce hazardous waste have more uncertainty to the relationship between indirect and direct savings than projects with only non-hazardous reductions.

7. There is much variation between the ratios of indirect to direct savings for clients in this study; one must be careful in applying this study's results to specific situations. Based on this study's sample of clients, it appears that when determining the savings from multiple clients, indirect savings are roughly equivalent to direct savings.