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IMPROVING ACCURACY AND REDUCING COSTS OF ENVIRONMENTAL BENEFIT ASSESSMENTS

Volume IV

A Case Study of A Hazardous Waste Site: Perspectives From Economics and Psychology

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CHAPTER1

INTRODUCTION AND SUMMARY

Hazardous waste sites have created intense public concern both for nearby residents and for the general public. For people who live near a hazardous waste site, fears of cancer or other health problems are very real and such fears genuinely reduce the quality of life. Psychologists would argue that many residents around a hazardous waste site have made a subjective risk judgment that the health hazard is substantial. In contrast, experts often judge the risks from a hazardous waste site to be very small. Expert assessments of risk are described as providing measures of objective risk even though such assessments themselves are the result of the subjective judgments of experts. This divergence between the large subjective risk beliefs often held by the public and the small objective risks often indicated by experts creates a policy dilemma for EPA as well as for other institutions concerned with risk management. Should large sums of money be spent cleaning up hazardous waste sites for which objective risks are small? Is the harm to residents near such a site in some sense real even if health is not actually adversely affected? If EPA does not clean up a hazardous waste site because objective risk assessments indicate only a small risk and the local population still believes the site to be harmful, has a disservice been done? Can a community's beliefs change to better reflect what is actually known about possible risks?

The difficult situation described above stems from the fact that many people near such sites feel harmed and consequently they suffer from large subjective damages while, at the same time, scientific evidence suggests that no large current risk to health exists and therefore objective damages are small. The study summarized here attempts to use concepts and methods of analysis drawn from both economics and cognitive psychology to understand the sources of a large drop in property values which has occurred near the Operating Industries Incorporated (011) Landfill in Monterey Park, California.

The Site:

The Operating Industries Inc. (011) Landfill is situated between the communities of Montebello and Monterey Park in the Los Angeles metropolitan area of California (Figure 1). The landfill covers 190 acres and has been used for hazardous as well as municipal wastes. The landfill reached capacity and was closed in October 1984 at which time it was proposed for inclusion on the National Priorities List (NPL). It is estimated that the 011 Landfill contains 30 million cubic yards of refuse which is generating landfill gas. The 011 Landfill reportedly ceased accepting hazardous materials in January 1983. Several underground fires have occurred at the site and methane gas migrating off-site has exceeded the lower explosive limit. In April 1983 the off-site level of vinyl chloride gas, a carcinogen, was measured at 19 ppb which exceeded the State regulatory level of 10 ppb. At this time random samples of air within 12 homes showed no detectable levels of vinyl chloride gas (above 2 ppb). More landfill gas collection wells and better leachate

FIGURE 1

KEN LUBAS and MICHAEL HALL / Los Angeles Times

Aerial view eastward along Pomona Freeway through Monterey Park outlines landfill site nominated for federal Superfund list.

control systems have been installed at the site since 1983 in an attempt to mitigate odors and risks. In early 1985 EPA began initial remedial measure studies and this was soon followed with the start of the remedial investigation/feasibility study.

During the early 1970's, the City of Montebello approved development plans for residential housing along the southern edge of the landfill, Original plans were to reclaim the landfill area and build a golf course and park. This development was accompanied by several land use changes in the area including the construction of the Pomona freeway that bisects the 011 Landfill. During this time activities at the landfill were restricted to the area of the site south of the freeway. Compensating for this loss of area, the height restrictions at the landfill were increased. This increase in the height limitation has been linked to increased erosion problems including slope failure and mudslides which have exposed decaying refuse.

Soon after the newly constructed homes were occupied in the mid 1970's, complaints of odors began to swamp the South Coast Air Quality Management District (SCAQMD) offices. Complaints of rodents and leachate pooling off-site have accompanied odor problems. In 1979, some residents of the immediate area formed a group called HELP (Homeowners to Eliminate Landfill Problems) in order to organize their efforts to fight odor and health and safety problems emanating from the 011 Landfill. HELP, whose dues-paying membership is estimated at 460 families, is governed by a seven member executive committee and a twenty-four member steering committee. Several issues concern HELP: possible health problems associated with the site, leachate disposition, migrating gas, landfill use after closure, and property devaluation. There appears to be a general attitude that the full value of their property can be realized once the major problems at the landfill have been resolved. Media attention at the site appears to have been significant over the past several years. Television, radio and regional newspaper coverage have accompanied intense local coverage from newspapers, community meetings and an EPA newsletter (The 0II Update). The nomination of the 011 for the National Priorities List (NPL) under CERCLA has also been a significant catalyst for media attention.

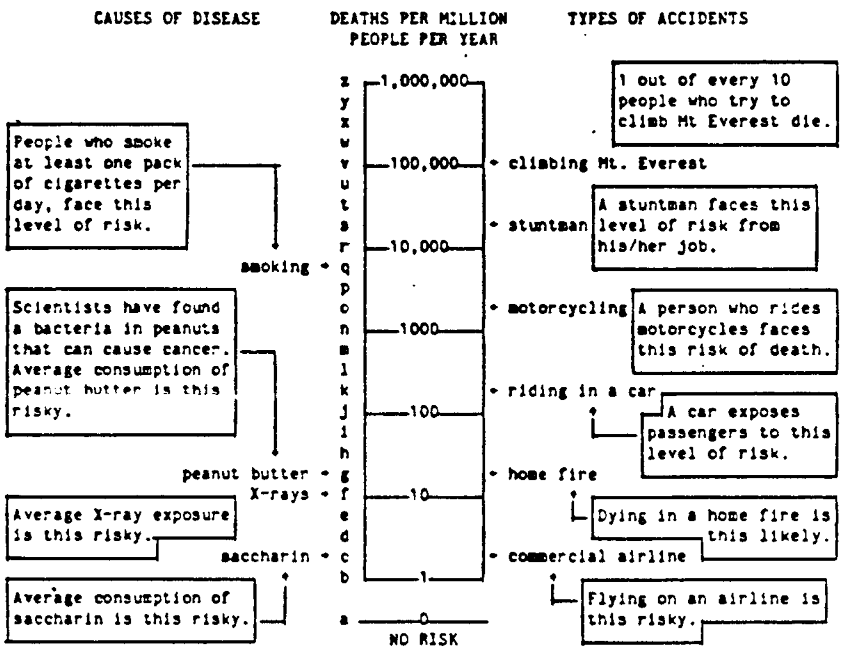
Although 011 has been nominated for the NPL and is eligible for Superfund resources under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), a review of the available evidence suggests that current health risks are small. A new health study about to be released may alter these conclusions and the possibility remains that now unrecognized substances could cause future health problems. Real damages, however, have already accrued to residents in the area in the form of depressed property values. To understand the source of these damages, the study collected data by mail survey (see Dillman, 1978) on such variables as property values, subjective measures of risk to health and safety, odor problems, sources of information about the site, and on attitudes towards local, state and federal government officials, the news media and landfill operators.

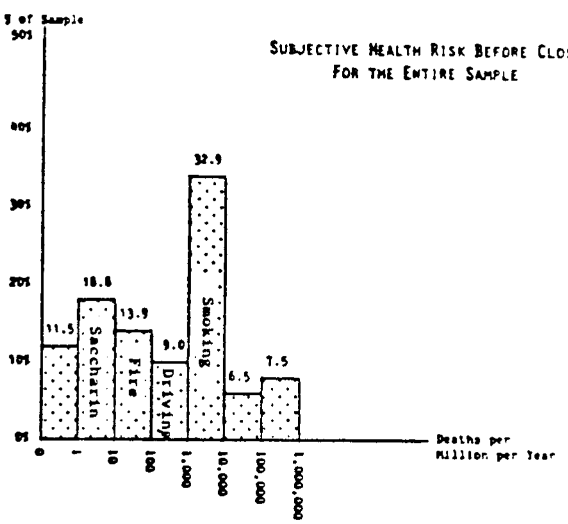
Subjective Health Risk Judgments:

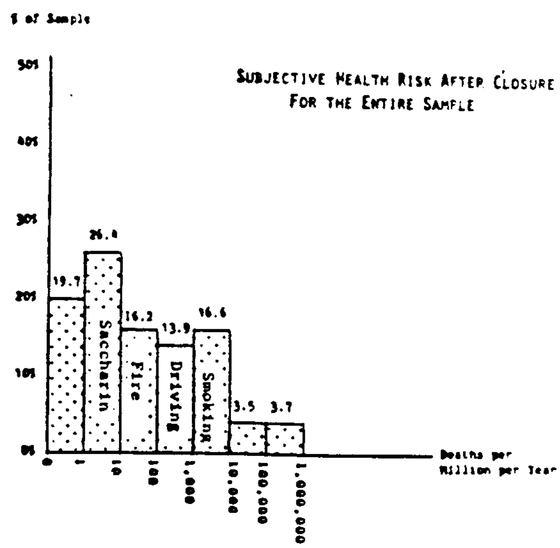
Respondents to the survey were asked to select a level of risk from a risk ladder (shown in Figure 2) which most closely compared to the current health risk they faced from the 011 Landfill. Results indicate that subjective risk to health was bimodally distributed among local residents, i.e.. residents were either very fearful or tended to dismiss the risk as very small. Figure 2, illustrates this bimodality and shows

FIGURE 2

RISK LADDER
(numbers on steps are deaths per million people per year)







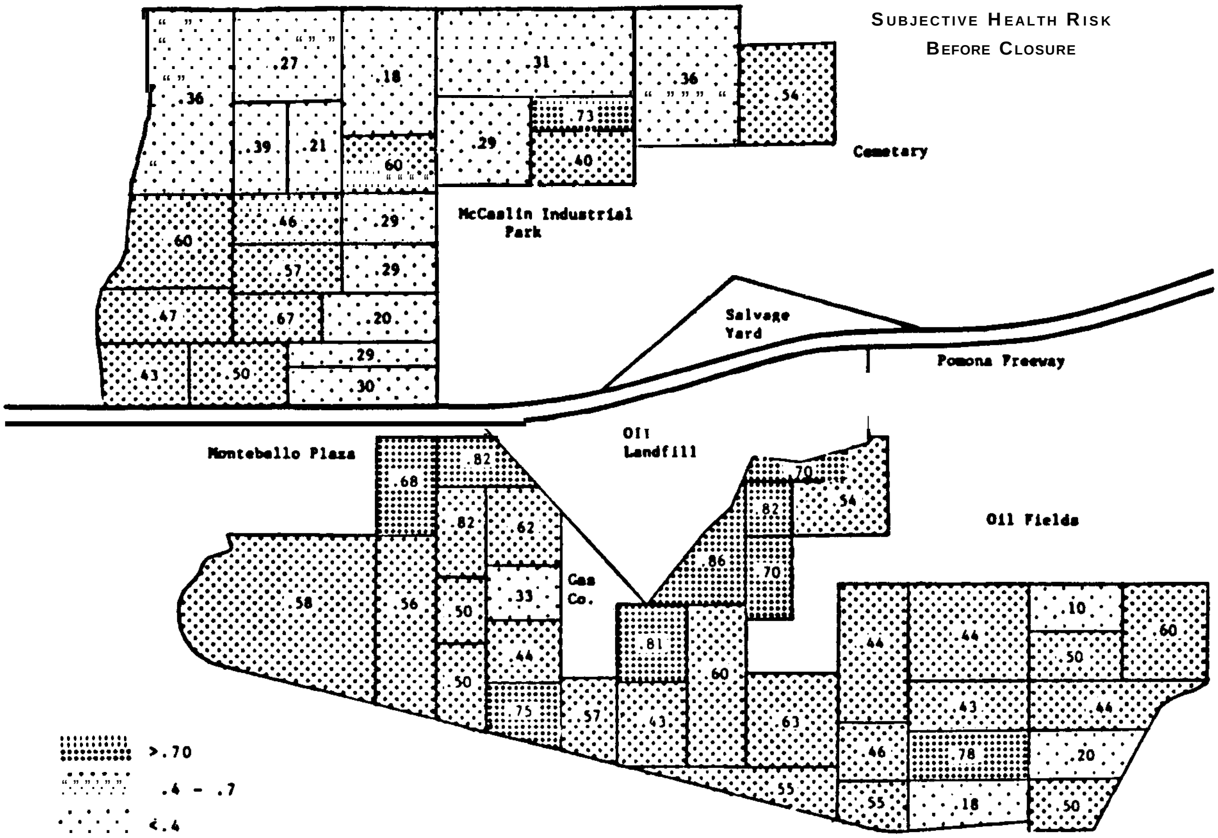
the effect of closing the site on subjective risk judgments.” The bimodal distribution of responses is evidence of the tension which exists within the community between individuals with greatly divergent beliefs about the nature and the magnitude of health risks. This situation would tend to make agreement on remedial measures very difficult. The map in Figure 3 shows how residents in various neighborhoods collectively judged the level of risk they believed they were facing from OII. The numbers on the map represent the fraction of residents who believed the risk to be relatively high within each neighborhood. As is indicated on the map, there was a pronounced shift from before closure beliefs to after closure beliefs.

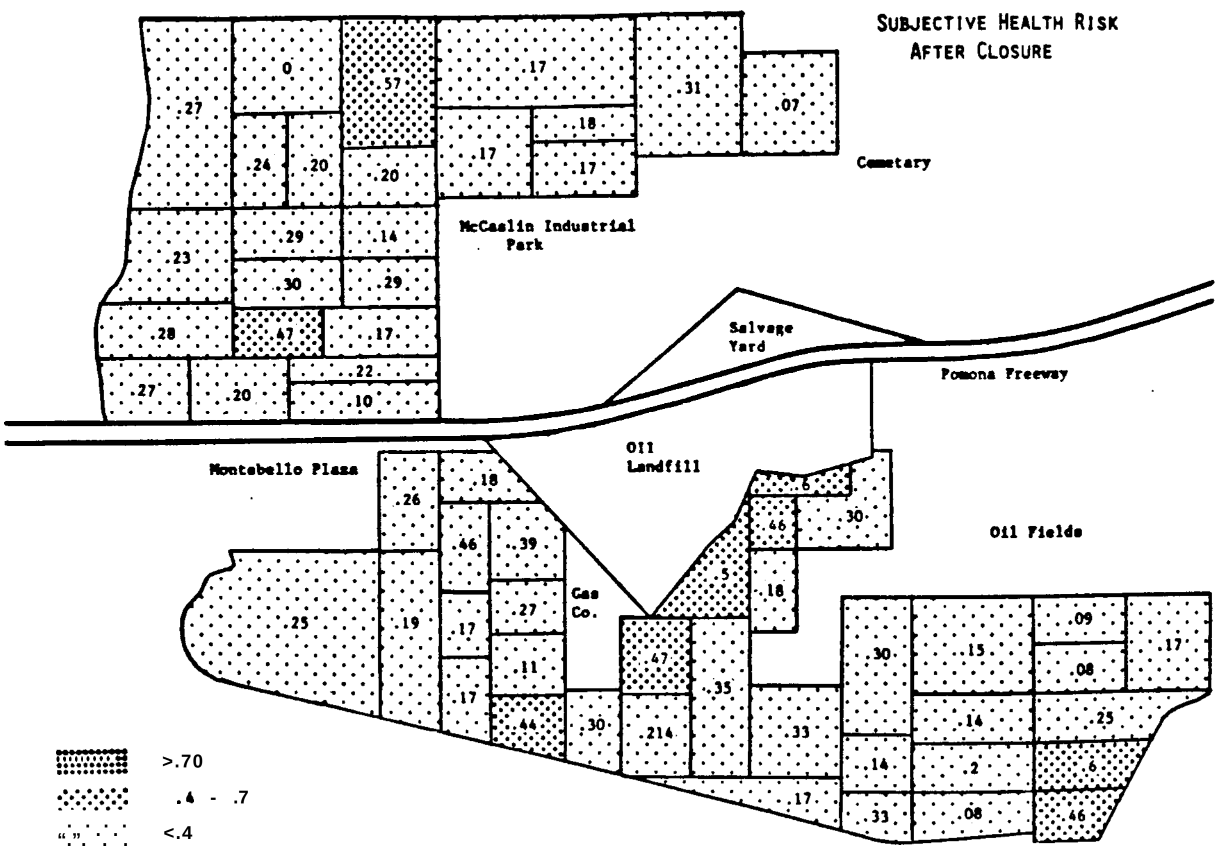
Individual subjective health risk judgments near the OII Landfill were correlated with several perceptual cues including perceived odor from the site, the number of times the respondent had read or heard about the site, the proximity of the respondent to the site and closure of the site. The causal order may, in some cases, be ambiguous. For example, attending to media reports may increase subjective risk or having high subjective risk may increase attention to media reports.

In contrast to the large number of residents who believe that the health risk has been substantial, a study conducted by the Los Angeles County Department of Health Services in 1983 concluded that no consistent pattern of school absences had occurred around the Landfill, and that nearby residents had not suffered excess mortality nor had they suffered from adverse outcomes of conception at a higher rate than in other parts of Los Angeles County. Current epidemiology studies may not, of course, indicate adverse health effects that will arise in the future because of, for example, the long latency periods for certain cancers. However, the

[4] Laboratory experiments carried out in the Psychology Department at the University of Colorado in concert with this study show that this bimodality is a fundamental problem associated with making decisions involving small probabilities.

FIGURE 3


SUBJECTIVE HEALTH RISK
BEFORE CLOSURE
Cemetary
McCaslin Industrial Park
Salvage Yard
Pomona Freeway
Montebello Plaza
Oil Landfill
Oil Fields
Gas Co.
>.70
.4 - .7
<.4


SUBJECTIVE HEALTH RISK
AFTER CLOSURE
Cemetary
McCaslin Industrial Park
Salvage Yard
Pomona Freeway
Montebello Plaza
Oil Landfill
Oil Fields
Gas Co.
>.70
.4 - .7
<.4

results do indicate that health effects are not now apparent. Further, calculations on the cancer risk from possible off-site vinyl chloride exposure (the only cancer causing agent detected off-site) indicate that, even under the most generous assumptions, the risk from this source is likely to be very small (see USEPA, 1985).

Property Values Near the Site:

The loss in property values near the site, although likely based on the subjective beliefs about health risks among residents and potential homebuyers, has resulted in a real welfare loss among residents in the area. As a measure of subjective damages, calculations based on a statistical model of home sale prices show that aggregate property values for 4100 nearby homes were reduced by more than $27 million as a result of the concerns of residents about the landfill prior to its closing in 1984. After the landfill was closed and proposed for the NPL in 1984, property values rose, but remained depressed by more than $13 million. These property value changes were closely related to changes in the subjective risk beliefs of nearby residents. Surprisingly, neither perceived odor problems nor beliefs about explosion risks had statistically significant impacts on property values. This evidence suggests that although the damages that have occurred to property values are real, the damages depend on subjective health risk beliefs which may change in response to factors other than objective risks. With effective risk communication measures and the further reduction of negative perceptual cues, property values may show a further recovery from these subjective damages. The relevant question becomes: Does mitigation of subjective damages require a complete and costly site cleanup or can other measures such as attempts to communicate objective risks along with more limited action to clean up the site provide a satisfactory solution?

Changing Subjective Health Risk Judgments:

It appears that large benefits can be obtained by changing subjective risk beliefs by communicating objective risk information to the public living near Superfund sites, and that these benefits may substantially exceed those from even eliminating objective health risks that may exist. In fact, community agreement that the problem has even been adequately addressed seems unlikely as long as current subjective risk judgments prevail. We concur with the conclusion of Covello, Von Winterfeldt and Slovic (1986) who state

> ... the literature specifically focused on risk communication is relatively small. Substantial progress has been made on some topics, such as psychological research on public perceptions of risk, but large gaps exist in our understanding of virtually every issue relevant to risk communication.

The importance of better risk communication is well understood but the methods are lacking. In a study of public perception and response to EPA warnings concerning the risks of ethylene dibromide (EDB), Sharlin (1986) analyzed and compared what EPA was trying to tell the public about the risks of EDB to the information the public actually received through the media about these risks. He found vivid contrasts between the publics view of the health risks and the EPA's aggregate statistics on health risks. The extent and nature of this contrast is an area that needs further exploration.

Two main conclusions emerge from the 011 study results: (a) subjective health risks are likely to be overestimates of the objective risks and (b) the overestimated subjective health risks are associated with significant property value losses. In many respects it is similar to the situation with earthquake predictions. In several instances the overreaction to such predictions has resulted in economic losses due to property devaluations that far exceeded the economic losses in property damage were the predicted earthquake to occur. When, as in the case of the 011 Landfill, total damages from the overestimates of risk are on the order of $27 million, a program designed to change subjective estimates of health risks can easily be cost effective.

The modeling of subjective health risk judgment described in the technical report, points to two components for possible intervention: perceptual cues and attitudes associated with sociodemographic variables. Of the two, psychological research shows that perceptual cues are much easier to change than attitudes. Managing the perceptual cues which serve to remind people about the risk can be very effective in reducing risk estimates to more appropriate levels. The management of perceptual cues would involve such things as reducing odor, reducing visibility of the site using plantings or screening, reducing activity at the site (e.g., reducing number of trucks entering and leaving), and reducing Sensational media coverage of the site. These are not necessarily easy to implement. Some of these strategies such as reduced media coverage can only be recommended, not mandated. Others such as reducing odor and reducing activity are difficult or impossible to implement short of closing the site. However, if such reductions can be obtained, the management of perceptual cues can have dramatic effects. If subjective health risks for a hazardous site are overestimates of the objective risk, then the perceptual cues about the risk should be managed as extensively as possible. The economic savings obtained by correcting and/or avoiding inappropriate property devaluations are likely to be large.

After major changes in the perceptual cues associated with closing the site, many people maintained high risk estimates. These high risk estimates translate via the property value equation into an estimated remaining loss of about $13 million. This residual loss is due partly to perceptual cues that cannot be easily modified (visibility of the site and the methane plant) and to risk attitudes. Given that further modifications of perceptual cues are probably impossible, further reductions in subjective health risks and their associated effects on property values could only be achieved by credible, effective communications about the objective risk.

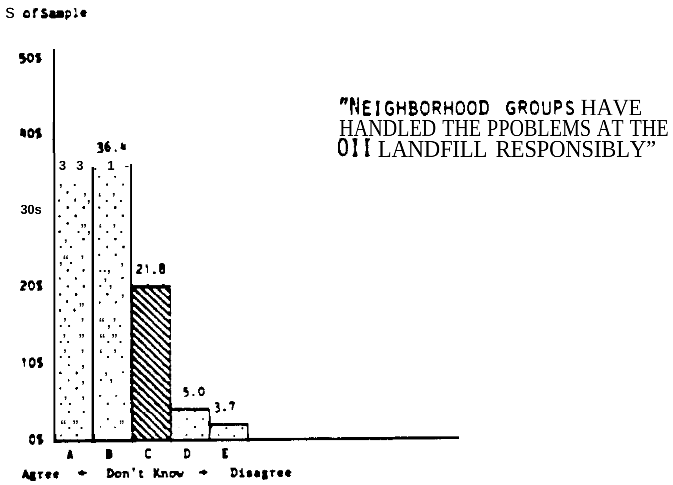
Risk attitudes and beliefs should be changed if health risks are truly small. Changing attitudes is notoriously difficult and there are several factors which compound the problem in this context.

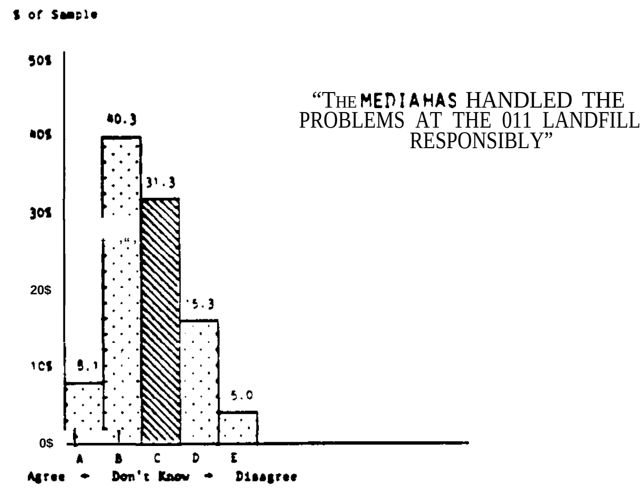
First, many psychological studies (see Tversky and Kahneman 1974; Slovic, Fischoff, and Liechtenstein, 1977) have shown that most people have trouble understanding probabilistic information in general and expert assessments of risk in particular. To be understood, expert assessments are best communicated by comparing new risks to better known risks such as smoking and X-rays rather than presenting technical measures such as mortality rates for a given exposure. No information of the appropriate type on risks has been provided to residents near the 011 Landfill.

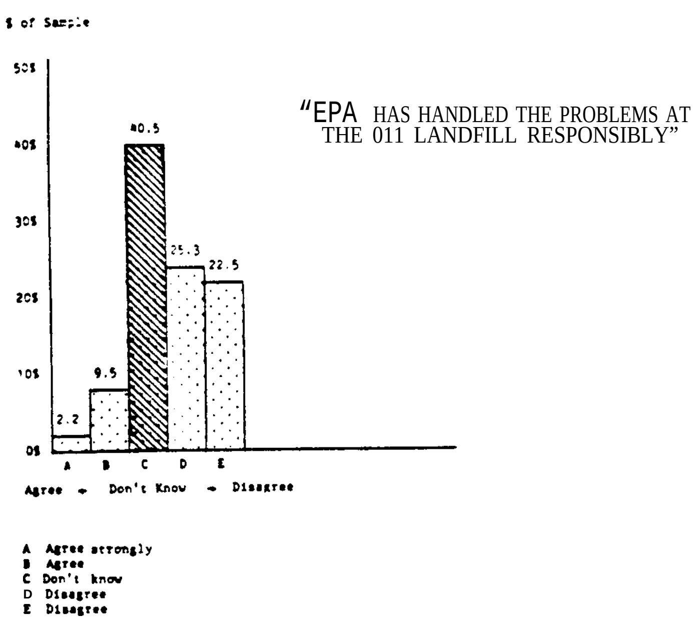
Second, to be effective, risk communications must come from credible sources. Figure 4 shows how credibility is perceived among a few of the important actors at 011. Residents in the area perceive that neighborhood groups have acted the most responsibly with the media also receiving a favorable response. The EPA, however, was not as well perceived, and is now unlikely to be viewed as a credible source since residents ranked EPA nearly as low as the operators of the Landfill in terms of how "responsibly" the agency had dealt with problems at the site.

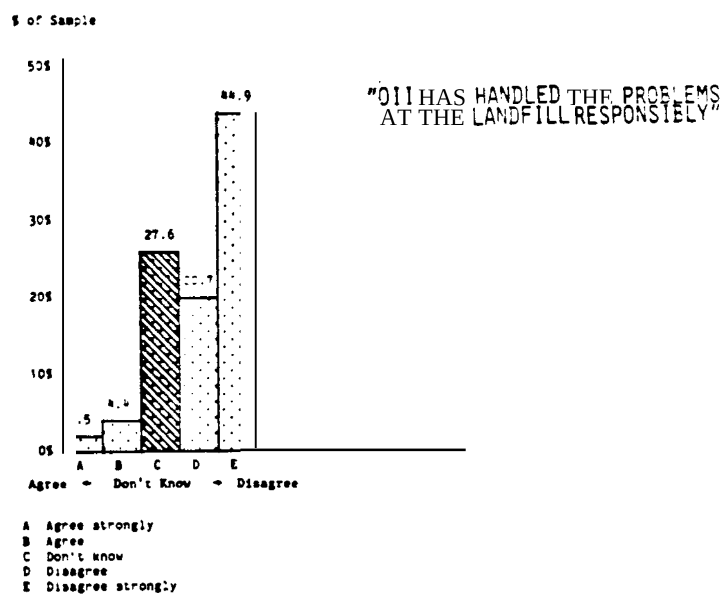
Third, even though it has not been especially effective, much more is known about increasing subjective risk judgments (e.g., risks of smoking, risks of not using seat belts) than about decreasing risk judgments.

FIGURE 4


"NEIGHBORHOOD GROUPS HAVE HANDLED THE PPOBLEMS AT THE OII LANDFILL RESPONSIBLY"
S of Sample
50$
40$
30s
20$
10$
0$
36.4
21.8
5.0
3.7
A B C D E
Agree - Don't Know - Disagree


"THE MEDIA HAS HANDLED THE PROBLEMS AT THE 011 LANDFILL RESPONSIBLY"
$ of Sample
50$
40$
30$
20S
10$
0S
40.3
31.3
5.1
5.0
A B C D E
Agree - Don't Know - Disagree


"EPA HAS HANDLED THE PROBLEMS AT THE 011 LANDFILL RESPONSIBLY"
$ of Sample
50$
40$
30$
20$
10$
0$
40.5
25.3
22.5
9.5
2.2
A B C D E
Agree - Don't Know - Disagree
A Agree strongly
B Agree
C Don't know
D Disagree
E Disagree


"OII HAS HANDLED THE PROBLEMS AT THE LANDFILL RESPONSIBLY"
$ of Sample
50$
40$
30$
20$
10$
0$
44.9
27.6
.5
A B C D E
Agree - Don't Know - Disagree
A Agree strongly
B Agree
C Don't know
D Disagree
E Disagree strongly

Fourth, communications about issues with a high affective component (e.g., the emotionality surrounding a landfill hazard issue) are often misinterpreted and misunderstood. For these and other reasons a quick fix via risk communications for the attitudinal inflation of risk estimates is improbable. The potential elimination of approximately $13 million in property value losses would, however, justify considerable efforts to change subjective risk estimates to more realistic levels.

While changing risk attitudes will not be easy, there are several studies which suggest some optimism. Hammond and his colleagues at the University of Colorado (see Hammond and Adelman, 1974; Hammond et al. 1984) have been successful in reducing disagreements about risk among experts and then communicating the resulting judgment about the risk to the public. Examples include public concern about a new police handgun bullet and about possible plutonium pollution from a nearby facility. Characteristics of these successful efforts to reduce overestimated risks share the following attributes.

First, a citizen panel (such as the HELP group) selects a group of independent scientists to evaluate the risk. The danger at this stage is that, all too often, the citizen’s panel will want to become technical experts themselves in order to make their own risk judgments. Their proper role is representing community values and the procedure generally works best if they stick to that.

Second, the group of scientists uses standard scientific and scholarly procedures (e.g., references to referred journal articles, development and defense of mathematical equations producing the risk estimate) to resolve their differences. Also of use in this stage are psychological techniques for studying judgments and techniques that help identify issues of disagreement that need resolution. Contrary to the danger in the first stage, the danger here is that the scientific experts will make action recommendations for the community. Such recommendations necessarily are based on both risk judgments, which the technical experts should make, and assumptions about community values, which the technical experts should not make.

Third, once agreement on the magnitude of the risk is obtained (and surprisingly such agreement is almost always obtained), the results are communicated to the public via the local media. What is communicated to the public is the experts' conclusion that the risk is either low or high and a comparison of the risk to known, widely-accepted risks. For example, comparing the danger of plutonium emissions to smoking or hospital X-rays.

Although the above approach is not a panacea, it does offer a reasonably inexpensive means for attempting to reduce subjective health judgments which due to attitudes overestimate the true risk. Given the magnitude of potential benefits, the past success and relatively small cost of such procedures justifies their use in an attempt to change subjective health risks.

The study is organized as follows: Chapter 2 reviews relevant past studies and introduces necessary concepts from both economics and psychology. Chapter 3 develops an economic theoretical basis for subjective measures of damages, benefits and costs using concepts drawn from psychology. This provides the economic rationale for benefit cost analysis of remedial actions at Superfund sites including risk communication. Risk communication is likely to be a cost effective way of reducing subjective damage. Chapter 4 presents preliminary property value studies on three hazardous waste sites used to find a suitable site for detailed analysis. The survey design used to collect data on the 011 Landfill is presented in Chapter 5 and the resulting data are described in Chapter 6. Finally, Chapters 7 and 8 present our analysis and conclusions respectively. The non-technical reader may readily omit Chapters 3 and 4.

CHAPTER 2

A BRIEF REVIEW OF THE ECONOMIC AND PSYCHOLOGICAL ISSUES

2.0 Introduction

It is the purpose of the research undertaken here to attempt to resolve, or at least to understand, the problems which have become apparent both in prior efforts to mitigate damages and to estimate the resulting benefits of reducing risks from hazardous wastes. It is our hypothesis that the central source of difficulty results from problems with subjective risk judgments and with application of the traditional model used by economists (as opposed to psychologists) in structuring analysis of hazardous waste risks. This model has focused solely on objective risks. In this Chapter a brief review of the relevant issues and past studies in psychology and economics is presented with respect to the issues of objective versus subjective measures of risk.

2.1 The Impact of Use of Subjective Versus Objective Risks on Economic Analysis

The necessary emphasis on perception and judgement requires understanding of a number of psychological issues. Three arguments developed from the work of Kahneman, Tversky and others may help to explain the intense public concern over hazardous wastes and will prove useful in economic analysis of subjective damages and benefits. (1) People tend to overestimate the odds of low probability events especially for new or unfamiliar risks such as hazardous substances and underestimate the odds of relatively high probability events such as automobile accidents which are associated with old, familiar activities. Thus, there is a serious problem with subjective judgments of probabilities. (2) The perceived consequences of new or unfamiliar risks tend to be exaggerated, inducing dread until experience is accumulated with the new source of risk. (3) Perceived losses are valued much more highly than perceived gains. Thus, people will give up the opportunity for a substantial gain to prevent a small loss. This behavior is inconsistent with economic theory which predicts that the value placed on giving something up should be similar to the value placed on an equivalent gain under most circumstances.

Each of these psychological factors implies that people may initially place a very high value on hazardous waste cleanup. (1) A community may view the discovery that a landfill contains hazardous wastes as a new "disaster" which has befallen residents and thus have an exaggerated perception of the probability of cancer or other harm from a waste site. (2) Since people are very unsure of damages from exposure to hazardous wastes they may also overestimate (dread) the consequences of such exposure. (3) New information that a landfill may cause harm could well be viewed as a loss from the status quo and would consequently receive a very high value.

Available evidence from studies undertaken by psychologists suggests that, if people have any perception of a hazardous waste problem at all, their subjective risk judgement is likely to be biased upwards.
New unfamiliar risks (such as hazardous wastes) as opposed to old familiar risks (such as driving a car) seem to be especially feared. Thus, our approach focuses on the issue of subjective risk beliefs and we have attempted to find a hazardous waste site which is sufficiently well known to neighboring homeowners so that no question exists as to the awareness of a possible problem.

Given the selection of a site where a recognized problem exists, we have attempted to measure subjective risk judgments through use of a mail survey, following the Dillman Total Design Method (1978). The 0II Landfill was recently closed and the study attempts to measure risk beliefs before and after the closure both near and away from the site. Collection of this information in addition to available real estate market information allows estimates to be made of the subjective benefits associated with reducing hazardous waste risks. Note that subjective benefits are unlikely to be the same as objective benefits which are calculated as an objective reduction in probability of death (usually drawn from the best available scientific evidence) times a dollar value for safety (usually drawn from labor markets).

In contrast to objective benefits, subjective benefits for each individual are implicitly equal to a subjective reduction of probability of death from exposure to hazardous wastes times a perceived value of safety associated with a death specifically brought about by exposure to hazardous substances. The possible divergence between these two measures of benefits raises a fundamental policy problem.

2.2 Subjective versus Objective Benefits

Since subjective benefits and objective benefits are likely to be very different, which measure is appropriate for benefit-cost analysis of hazardous waste problems? Although Chapter 3 takes up this issue in some theoretical detail, a brief summary of the advantages and disadvantages of each measure can be stated as follows: If objective benefits are utilized, and the objective risks are small, benefit-cost analysis will not support expensive hazardous waste cleanup efforts even though people may mistakenly believe that a hazardous waste site is more harmful than objective risk analysis indicates. However, objective benefit estimates will not capture how people actually feel about a hazardous waste site and policies undertaken will likely leave people feeling greatly harmed since the level of hazardous waste cleanup is determined as if people had accurate subjective risk judgments. Alternatively, if subjective benefits are used for benefit-cost analysis, then, since possibly biased judgments are incorporated into the analysis, an additional policy option presents itself. In addition to the level of cleanup at a site, risk bias itself can be the object of social policy. If subjective risks are biased upwards, programs to promote the formation of a scientific concensus and disseminate objective risk information on hazardous waste risks to affected individuals will also create benefits by reducing subjective risk levels in the general population. People will feel better off knowing that risk levels are genuinely not as high as they thought they were.

Reducing objective risk levels through hazardous waste cleanup will, in this framework, not only generate objective benefits, but also generate additional subjective benefits since individuals will likely overestimate the magnitude of the risk reduction as a site is cleaned up. Thus, use of subjective benefits, unless bias can be completely eliminated by information programs, will likely justify more extensive and costly cleanup programs at hazardous waste sites than use of objective benefits alone.

Each approach has considerable appeal as well as some difficulties. Since benefit-cost analysis is a normative (value laden) exercise, choice of objective versus subjective benefits is, in the end, a normative decision. Each approach is logically consistent, but policy outcomes will be different depending on which criterion is chosen. Unfortunately, past economic studies have failed to focus on the issue of subjective risk beliefs and, considerable confusion has resulted. Often the goal in survey analysis has been to manufacture a risk judgement as a basis for people to provide a hypothetical value which agrees with the investigators assessment of objective risk. In contrast, property values as used in this study will reflect pre-existing beliefs or judgments about hazardous waste risks. As a result, property value studies can provide estimates of subjective benefits of hazardous waste cleanup. It is one purpose of this study to attempt to identify measures of subjective benefits for comparison to measures of objective benefits as alternatives for use in benefit-cost analysis so that an informed choice may be based on the implications of each.

2.3 The Psychology of Subjective Risk Judgement

If subjective risks are to be included in benefit-cost analysis, then we need to consider the components and causes of those subjective risks and methods that might be used to reduce the disparity between subjective and objective risks. There are two important components in evaluating subjective risks--a subjective probability or belief component and a subjective damage component. Both components can be very different from their objective counterparts. Below we consider each subjective component separately and then consider the problems of reducing the disparity between subjective and objective risk.

A frequent characteristic of environmental hazards, such as a hazardous wastes, is that there are objectively low probabilities for objectively very high damages. Abundant research shows that most people have cognitive difficulties when dealing with low probabilities. Sometimes their subjective probabilities are serious overestimates of the true probabilities and at other times they are serious underestimates. People tend to underestimate those risks with which they have had much benign experience. For example, all automobile drivers have had many benign driving experiences and so they tend to underestimate the likelihood of an accident involving serious injury or death. As a consequence, few drivers voluntarily wear seat belts which is likely to reduce the probability of death by a factor of 2. Many people have also had benign experiences with respect to potential natural hazards. The attitude expressed by the statement "I've lived here for 15 years and have never had any problems with floods so I'm not going to worry about one now," explains why it is difficult to sell flood control measures or flood insurance. People also tend to underestimate the probabilities of those risks which injure or kill one person at a time and are undramatic. For example, many people seriously underestimate the probabilities of dying in the United States from asthma and home accidents. Finally, people underestimate the risks over which they feel they have at lest some control of the level of the risk. For example about 80% of automobile drivers believe that they drive more safely than the median driver and over 95% of people believe they operate power tools and lawnmowers more safely than the median person.

Not surprisingly, the opposite characteristics are typical of events whose probabilities people tend to overestimate. That is, probabilities are overestimated for events with which people have had little or no experience (or do not realize they have had many benign experiences) and which have the potential for dramatic catastrophes killing many people at one time. These unfortunately are the characteristics of environmental hazards such as hazardous wastes. For example, people who have lived near a newly-discovered hazardous site for many years often do not realize that they have had many benign experiences; as a consequence they tend to overestimate the likelihood of the new problem. Also, a hazardous waste site raises the specter that maybe everyone in the neighborhood might be harmed "just like in Bhopal." Finally, people seldom have any sense of control over the level of risk of a hazardous waste site in the way they believe (often incorrectly) that they have some control over the level of risk in activities such as automobile driving. Feeling that there is no personal action that can be taken to reduce the risk, except moving, people tend to overestimate the magnitude of the risk.

These examples of subjective risk judgments which often dramatically diverge from objective assessments are symptoms of inadequate risk communicating methods and cognitive difficulties in understanding the role of risks in our lives. Both of these problems can be summed under the heading of risk communication, a subject that is greatly in need of further research. We concur with the conclusion of Covello, Von Winterfeldt, and Slovic (1986) who state

> ... the literature specifically focused on risk communication is relatively small. Substantial progress has been made on some topics, such as psychological research on public perceptions of risk, but large gaps exist in our understanding of virtually every issue relevant to risk communication.

The importance of better risk communication is well understood but the methods are lacking. In a study of public perception and response to EPA warnings concerning the risks of ethylene dibromide (EDB), Sharlin (1986) analyzed and compared what EPA was trying to tell the public about the risks of EDB to the information the public actually received through the media about these risks. He found some contrasts between the public view of the health risks and the EPA's aggregate statistics on health risks. The extent and nature of the contrast between these two views is an area that needs further exploration.

Not as much research has been done on subjective damages per se. However, people seem to have clear preferences about ways in which they would want to die. Dying in a plane crash is worse than dying in an automobile accident. Dying from cancer is worse than almost any other way of dying, etc. Again, the risks associated with hazardous wastes tend to be those which people fear the most even though the final consequences of those risks are of course no more nor less fatal than other risks of fatality that people willingly face everyday. It also seems that causes of death that are somehow beyond any possible control are also dreaded more. As the role of exercise and diet and other behaviors in the prevention of heart attacks have become more widely known, the sense of personal control has increased and heart attacks seem to be less dreaded. Cancer and other problems caused by hazardous chemicals are still viewed as "unfair" random events over which the individual has no control and hence they are dreaded more.

The nature of the problem of subjective risk and the problems of reducing the disparity between subjective and objective risks is well-illustrated by the low rates of vaccination for hepatitis B among medical and hospital personnel. Rates of serious illness or death from hepatitis B are very high for medical staffs--4000 to 6000/100,000. The objective risks from the vaccination are about 6/1,000,000. The vaccine is usually offered free to medical staffs. It is therefore difficult to find a situation in which a benefit-cost analysis would point so clearly to one course of action--vaccination in this case. Yet most medical personnel are not opting for the vaccine. The reason is that the hepatitis B vaccine is derived from donor blood plasma and this raises the specter of AIDS. Although there has been no evidence of anyone ever contracting AIDS from the vaccine and although everything known about AIDS indicates that it could not be transmitted by the vaccine, people are still reluctant to take the chance that there might be some unknown means by which they could get AIDS from the vaccine. This situation fits the characteristics described above which cause people to overestimate both the probabilities and the damages. What is especially troubling about this example is that the people involved are more intelligent, more educated, and more used to dealing with scientific information about objective risk than are typical citizens.

Can intervention be used to reduce the disparity between subjective and objective risk? Most of the documented attempts to change subjective risk have been efforts to increase rather than to decrease subjective risk. Examples include attempts to increase the believed risk of smoking, automobile driving, and floods. Although some success has been achieved in raising people's stated estimates of such risks, most of these attempts have been unsuccessful in terms of changing behavior. Attempts to reduce overestimates of risks are harder to find in the literature. Some success has been obtained in situations where the public's overestimate of a toxic hazard was exacerbated by a disagreement among scientists about the level of the objective risk. For example, concern over the hazard of plutonium emissions from the Rocky Flats facility Plant near Denver was increased by sharp disagreement among scientists about the objective risk--a disagreement that was extensively reported in the local press. Hammond, Anderson, Sutherland, and Marvin (1984) used a judgment technique to obtain agreement among a group of scientists representing the range of opinion on this matter. Once the scientists. agreed that the risk of lung cancer due to plutonium exposure was insignificant compared to the risk caused by cigarette smoking, the public concern seemed to abate considerably. Such techniques are not very expensive and might work in other hazardous situations in which some scientists and hence the public overestimates the magnitude of the risk.

2.4 The Calibration of Probability Judgments

In judging a subjective risk, an individual assesses his degree of belief in the likelihood of the occurrence of an event. In other words, he assigns, implicitly or explicitly, a subjective probability to the risk, which reflects his feeling of certainty or uncertainty about the event and his degree of confidence in his subjective judgment. Studies have shown that individuals have difficulty in assessing the risk for rare events due to their preconceptions formed from hearsay and inability to judge the probability of such an event. Slovic, Fischhoff, and Liechtenstein (1980) summarize the need for sophisticated reasoning when judging the risks of rare events:

> Needed are an appreciation of the probabilistic nature of the world and the ability to think intelligently about rare (but consequential) events .. .Unfortunately, although the human intellect is deservedly held in high esteem in many contexts, numerous studies have shown that intelligent people have difficulty judging probabilities, making predictions, or otherwise attempting to cope with uncertainty.

Calibration is concerned not only with the validity of the assigned subjective probability, but also with the appropriateness of the individual's level of confidence. In order to assess the degree of calibration, an individual must encode his subjective probabilities in such a way as to obey the axioms of probability theory. Thus, the subjective probability must take on some value between 0.0 and 1.0, where 0.0 reflects complete uncertainty and 1.0 reflects complete certainty. Suppose an individual assigns a subjective probability of .6 to each event of a set of independent events, whose actual probabilities can later be verified. His assessments of .6 are said to be well-calibrated if 60% of the events do occur. As formally stated by Liechtenstein, Fischhoff, and Phillips (1980), "a judgment is calibrated if, over the long run, for all propositions assigned a given probability, the proportion that is true equals the probability assigned". Thus, an individual's degree of calibration is established by the degree to which his subjective probabilities achieve this property. This is best represented as a calibration curve, where the proportion of the events that actually occur are plotted as a function of the subjective probability and the identity line represents perfect calibration.

In the above example, if only 50% of the events in question actually occurred, then the individual is said to be overconfident which implies he thinks he knows more than he does. If, however, 80% of the events in question actually occurred, then the individual is said to be underconfident. The most pervasive finding in the calibration studies to date is that individuals are consistently overconfident in their subjective probability assessments. In a comprehensive series of experiments, Liechtenstein and Fischhoff (1977) explored the relationship of subjects' level of knowledge (from "know nothing" to "know something") and their calibration performance. They found that all the groups tended toward overconfidence with those who knew nothing showing substantial overconfidence. This suggests that since people know little about hazardous wastes that those who think they might have been exposed will be overconfident, i.e., will overestimate the probability of dying from cancer or suffering other health effects.

A number of studies have examined various correlates with calibration performance. Those relevant to our study are training for the task, type of instructions given for the task, difficulty of the task, and subject's level of knowledge, expertise, and intelligence. Liechtenstein and Fischhoff (1977) as mentioned earlier found overconfidence at all levels of knowledge of the task. They found, however, that as knowledge of the task increased, overconfidence lessened. This improvement in calibration performance, however, did not improve indefinitely. They also found that altering the difficulty of the task affected the calibration performance. As the task got easier, overconfidence was reduced. Interestingly, they found no effects for either subjects' level of expertise (knowledge about the area relevant to the task) or for subjects' level of intelligence on calibration performance. Liechtenstein and Fischhoff (1980) looked at the effects of training for the task on subjects' calibration performance. Their study interspersed a set of training sessions between a pre-test and post-test. After each training session subjects were given comprehensive feedback on their performance. They found improvement in calibration scores for all subjects except for those that were well-calibrated at the beginning. They, however, found that training on a task did not generalize to a similar task. Liechtenstein and Fischhoff (1981) examined the effects of long, explicit task instructions versus shorter task instructions on calibration performance. The longer instructions contained more information explaining how the individual should formulate a probability assessment, as well as a discussion of calibration. They found that the type or length of instructions had no significant effect on calibration performance. They suggested that an individual's miscalibrations are not due to misunderstanding how to formulate explicit subjective probabilities, but are due to what the authors characterize as 'cognitive difficulties which could include limited information processing capacity and inability to integrate different sources of information.

Calibration can be viewed as a measure of how well individuals deal with uncertainty. In general, most people show a tendency toward overconfidence when assigning subjective probabilities to uncertain events. Recent studies have shown that calibration performance can be affected by the subjects' level of knowledge about the task and by the amount of training subjects receive for the task. So far, the studies have shown no effects on calibration performance for more expert or intelligent subjects and for the length and explicitness of the instructions they receive for the task. In assessing calibration performance of individuals, we are examining the accuracy of their subjective probabilities as predictions of events. Although the calibration studies provide more angles on how individuals make (or might make) decisions under risk, they do not seem to offer any revelations on changing people's subjective probabilities about rare events.

2.5 Review of Economic Studies

It should be clear from the discussion above that arguments from psychology have a great deal of relevance in explaining observed behavior with respect to valuing hazardous waste risks. The study of risk judgments and decisionmaking under uncertainty is not limited to psychology. In fact, one branch of economics has addressed several of these issues, laboratory experimental economics. Economists such as Vernon Smith, Charles Plott and others have constructed simulated markets with real financial incentives in the laboratory using students as well as individuals from the community at large as subjects and tested many hypotheses from macroeconomics. These experiments have generally validated the traditional economic theory of individual and market behavior with a few notable exceptions. The most important of these is that the standard economic model of rational behavior under uncertainty, expected utility theory, fails to predict behavior unless individuals are given an extraordinary amount of repetitive experience. Allowing individuals to make many mistaken decisions and suffer the financial consequences, they eventually learn to behave more rationally. These results are consistent with the literature in psychology in that inexperienced decisionmaking under uncertainty is likely to be irrational, but adds the important notion that people may learn to be more rational with experience, especially in a market setting where they inherently will suffer a financial penalty for their irrationality (See Coursey, Hovis and Schulze, 1985, for a discussion of this issue). The implications of this research in psychology and experimental economics is that individuals exposed to new information on possible hazardous waste risks will likely initially respond in an irrational manner placing very high values on avoiding exposure. As part of the research undertaken for this study, a joint economic-psychology laboratory experiment was conducted to attempt to examine behavior at both high and relatively low probabilities with experience in a market environment. This study is presented as the appendix to this report and shows that even with experience in a market environment, most people are unable to develop accurate subjective estimates of small risks. Rather, some overestimate the risk and some underestimate the risk yielding a bimodal distribution of risk judgments. Remarkably, this behavior appears to be similar to that observed around the 011 Landfill as reported in Chapter 6 and is consistent with the large values found in the property value study.

Four recent studies have attempted to directly obtain the economic value of avoiding exposure to hazardous substances by use of the contingent valuation survey method. In three of the studies the attempt was made to communicate objective risk information which may have manufactured risk judgments before values were obtained. The remaining study simply asked people to value the elimination of hazardous waste from drinking water without including any information about possible risks. A serious problem with three of the studies is that, to obtain willingness to pay to avoid a hazardous waste risk, the risk has been described in detail to the respondent. Thus, such studies have typically manufactured a risk perception where none may have existed before. If a larger than intended subjective risk judgment is manufactured, value responses will seem “high” . If a smaller than intended subjective risk judgment is manufactured, value responses will seem "low." These studies are briefly summarized (in chronological order) below:

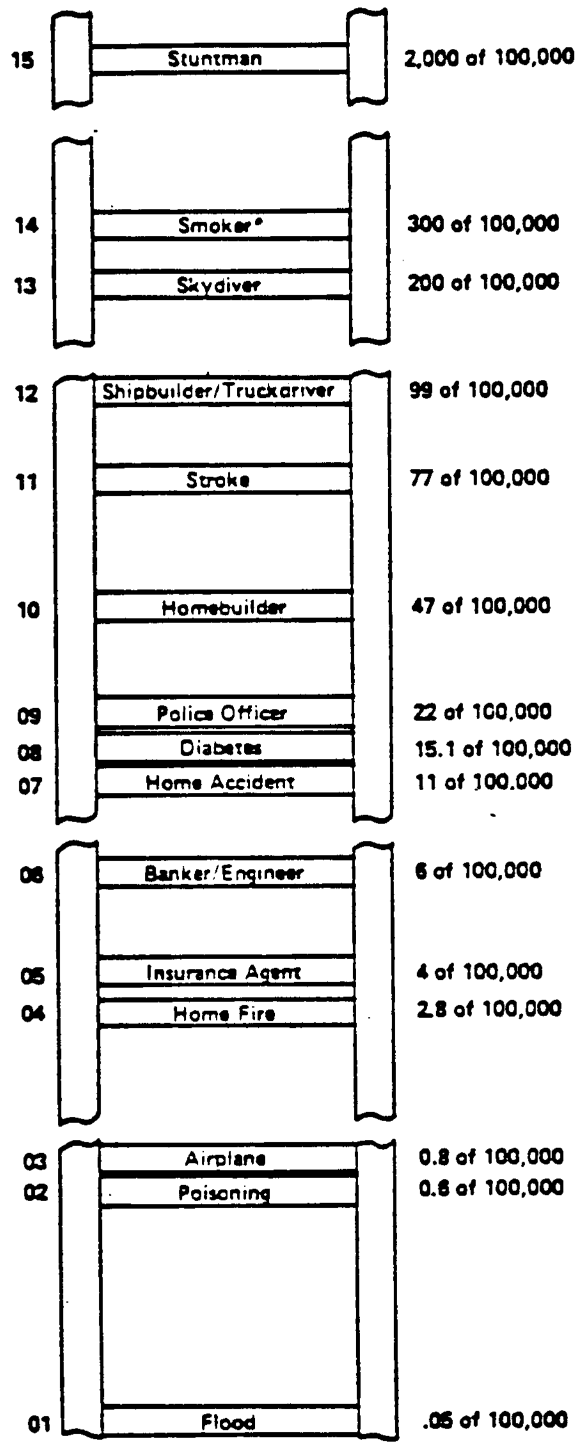
The first study in this series to attempt to value possible hazardous substance exposures was undertaken by Cummings et al. (Chapter IV in Schulze, Cummings et al., 1983) did not attempt either to measure or manufacture risk perceptions. Rather, the argument made that values placed on hazardous wastes in public water supplies “are subject to such uncertainties over probabilities, levels and consequences of exposure, that it is more plausible to ask people for the value they would place on a containment policy to eliminate any chance of exposure. This avoids any attempt at risk communication within the survey procedure. However, the values obtained still necessarily depend on respondents subjective risks. The study surveyed households in three locations: Albuquerque, New Mexico; Houston, Texas; and New Haven, Connecticut; between December 1, 1981 and March 15th, 1983. About 80 households were interviewed in each city. Average household bids per month for eliminating any possible hazardous substance contamination in public water supplies were $21.32 in Albuquerque, $29.62 in Houston and $25.84 in New Haven. Using the established range for the marginal value of safety these bids indirectly imply a presumed average subjective level of risk to be eliminated by the proposed containment policy on the order of 10^{-4}.

This implied level of annual subjective risk is greater than any objective risk analysis of public water supplies based on what the best available scientific evidence would suggest even for incidents of known contamination. In other words, the Cummings et al. study indirectly implies biased risk beliefs. As the first of a series of survey studies to obtain values, it is unfortunate that subjective risks were not measured. However, the study did provide a clear indication that subjective values for risks would likely exceed objective values.

The second study was undertaken by Smith et al. (1985). This study was focused in the Boston area with special emphasis on the suburb of Acton where a number of hazardous waste facilities have polluted local groundwater, including two municipal groundwater wells. Data on subjective risks were collected using a risk ladder (see Figure 2-1) and the median level of subjective risk from hazardous waste exposure in the overall sample was about 6 deaths per million people per year. In contrast, the mean subjective risk of death was about 180 deaths per million people per year, indicating an extremely skewed distribution of subjective risk beliefs. The largest group (31.7%) picked the lowest step on the risk ladder with a risk of .5 deaths per million. The 10% of the sample with the highest subjective risks raises the mean from a level of about 17 deaths per million (if they are excluded) to a level of about 180 deaths per million (if they are included). Thus, 10% of the people sampled raised the average level of subjective risk by about a factor of 10. Clearly a large upward bias in subjective risk is likely to be present among some respondents and, as a consequence, a small percentage of the population suffers from a large percentage of the subjective damages. These

FIGURE 2-1

Risk Ladder: Comparing Annual Risks of Death

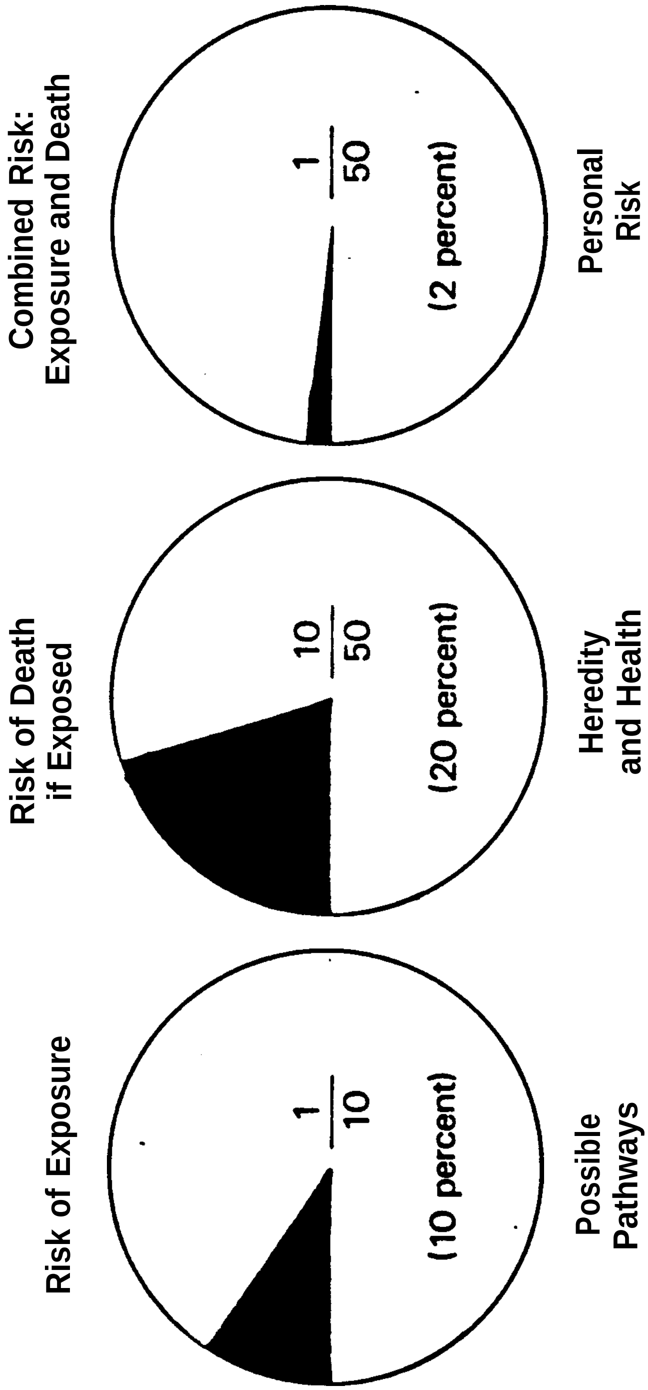


*At least one pack per day.

subjective damages are again likely to be vastly greater than any calculations of objective damages based on scientific risk assessments.

Smith et al. did not follow up use of the risk ladder to measure perception with value questions tied to the ladder. Rather they substituted a presentation of hazardous waste risks based on dials or disks (see Figure 2-2). Further, they presented the overall probability of death associated with exposure to hazardous wastes as a compound probability equal to the risk of exposure times the risk of death if exposed. Given the well documented cognitive difficulties people have in understanding low probabilities, this approach as shown in Figure 2-2, unsurprisingly, had serious difficulties. People did not bid more to avoid risks (defined as combinations of exposure risk and risk of death if exposed) which gave higher overall probabilities of death. In fact, in some instances they bid less to avoid a larger risk. Whereas, a risk ladder as shown in Figure 2-1 allows individuals to find a known risk they feel is similar to their subjective risk from hazardous wastes, the disks shown in Figure 2-2 do not give individuals anything to relate to in subjective terms. The main lessons to be learned from this pioneering study are that risk perceptions for new technological hazards are likely to be highly biased upwards as compared to objective risk assessments, that the distribution of risk perception is highly skewed, and that the use of a risk ladder with familiar subjective risks which people can relate to is a relatively successful way to represent risk as opposed to any quantitative presentation such as use of disks, dials, or other mathematical representations of probabilities.

FIGURE 2-2



Risk of Exposure
1/10
(10 percent)
Possible Pathways
Risk of Death if Exposed
10/50
(20 percent)
Heredity and Health
Combined Risk: Exposure and Death
1/50
(2 percent)
Personal Risk

The third study in this sequence of EPA research efforts conducted a pretest of a survey instrument designed to elicit the value of groundwater protection in two communities; Miami, Florida and Denver, Colorado (see Rowe et al. 1985). Although sample sizes were quite small, the data collected in the Miami pretest, which used a revised and improved survey design, is quite informative. The study tried a number of methods of communicating risks including the risk ladder shown in Figure 2-3, which was also used as the basis for asking value questions on a 90% overall reduction of risk of death from polluted water. Although sample sizes were small (about 10 interviews for each of the categories noted above), the results suggest that risks can be meaningfully represented through use of subjective risk ladders.

The final contingent valuation study reviewed here is now available only in preliminary draft form and was conducted by Mitchell and Carson (1985). The study attempts to value the low level risk of trihalomethanes in the public water supply in Herrin, Illinois. The federal standard for trihalomethanes has been exceeded once there in the summer of 1983 and residents were notified through the radio as opposed to individual notification as required. Residents who participated in the survey did not generally recall the notification. Risks were presented to the respondents using a risk ladder, the lower part of which is shown as Figure 2-4. Respondents were additionally told that in the view of public officials the violation of the trihalomethane standard imposed an inconsequential risk. Bidding for risk reductions from levels D, C and B down to level A, the federal standard, as shown in Figure 2-4, produced implicit value of life estimates of around $300,000, very low by most standards. However, at

FIGURE 2-3

(90% RISK REDUCTION)

HEALTH RISK LADDER

ANNUAL NUMBER OF DEATHS PER MILLION PEOPLE

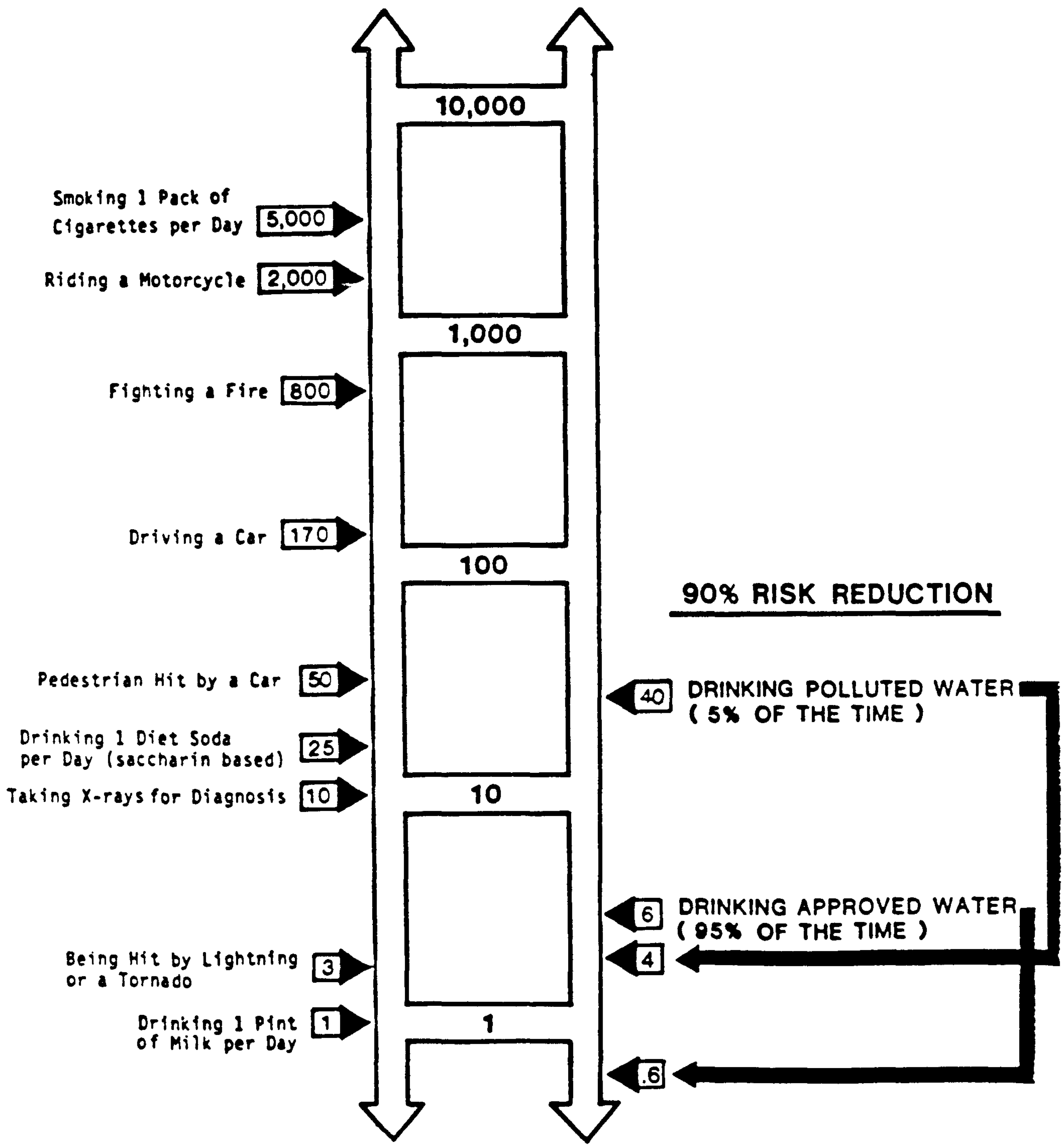
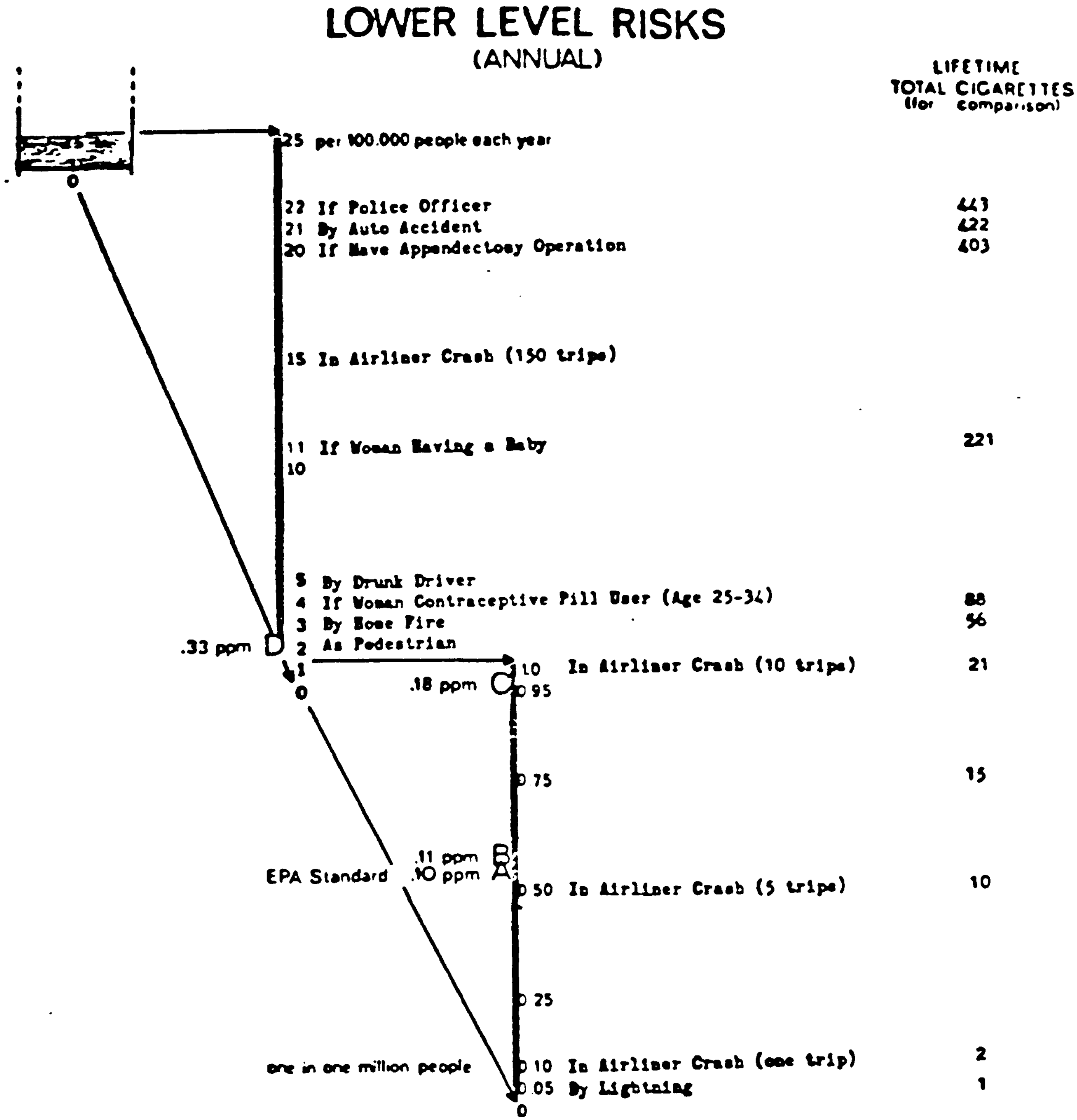


FIGURE 2-4


LOWER LEVEL RISKS
(ANNUAL)
LIFETIME
TOTAL CIGARETTES
(for comparison)
25 per 100,000 people each year
22 If Police Officer 443
21 By Auto Accident 422
20 If Have Appendectomy Operation 403
15 In Airliner Crash (150 trips)
11 If Woman Having a Baby 221
10
5 By Drunk Driver
4 If Woman Contraceptive Pill User (Age 25-34) 88
3 By Home Fire 56
2 As Pedestrian
1
0
.33 ppm D
0
1.0 In Airliner Crash (10 trips) 21
.18 ppm C
0.95
0.75 15
.11 ppm B
.10 ppm A
EPA Standard
0.50 In Airliner Crash (5 trips) 10
0.25
one in one million people
0.10 In Airliner Crash (one trip) 2
0.05 By Lightning 1
0

least the correct order of magnitude of subjective risk was communicated to respondents who, for the most part, had made no risk judgments whatsoever for trihalomethanes prior to responding to the survey. This study suggests that where individuals are not already misinformed, presentation of objective information on low level risks using an appropriate risk ladder may well encourage and enhance an accurate public judgment of risk.

In summary, it appears that in studies where the actual objective risks are understandably communicated (Rowe, et al. 1985, Mitchell and Carson, 1985) that individuals can and do estimate values with a certain degree of accuracy. However, if risk information is not provided (Cummings, et al. 1983) or is not successfully delivered (Smith, et al, 1985) the contingent valuation method fails to provide reasonable estimates because values will correspond to preconceived subjective risk estimates which, as the previous sections noted, can diverge from scientific assessments by several orders of magnitude. Because of this disparity of results arising from contingent valuation studies i.e., some likely obtained subjective benefits and some objective benefits, it is desirable to examine actual behavior taken from a market situation.

By observing behavior and prices within a real estate market, actual value estimates can be obtained for differences in the quality and quantity of an environmental disamenity such as a hazardous waste site. In a study by Cook, Ferguson, Adler and Vickers (1984), property values around two hazardous waste sites were examined. Little association between proximity to the sites and sale prices of homes were found. Likewise, a study by Harrison and Stock (1984) used distance to a number of hazardous waste sites in the Boston area to proxy for associated damages. The results Of this study suggested that benefit values varied significantly from site to site and that the effects were strongest for homes within one-half mile of the site. Benefits per household of cleaning up individual sites range from $9.20 for the relatively small (30 acre) Ashland site to $44.00 for the 400 acre Acton site. Use of distance as a proxy for risk suggested that for a $100,000 house 1.5 miles away from the site the effect of risk on the value of the home was $l,600; if the home was only one-half mile away the estimated effect increased to $13,500.

The evidence indicates that the hedonic property value method can estimate benefits as long as the proxy risk variable (distance in the two studies above) is a good approximation of subjective risk judgments. Drawing upon the evidence in these studies and from the psychological arguments presented earlier, it appears that the direct use of data on subjective risk judgment and perception (which have usually been replaced by distance for lack of better information) can help to clarify the social consequences of hazardous waste sites including economic damage and benefit measures and hopefully provide some policy insight.

CHAPTER 3

THEORETICAL ISSUES IN THE ANALYSIS OF HAZARDOUS WASTE RISKS

3.0 Including Psychological Arguments in Economic Theory

Many important economic theoretical issues in analyzing hazardous waste risks have been fully explored elsewhere (see Smith, Desvousges and Freeman, 1985). However, a traditional economic approach may be inadequate to understand important dimensions of the policy problem or to explain market behavior reflected in property values near a hazardous waste site. Since hazardous waste risks quite generally present new, unfamiliar threats which often evoke fear, the emotional environment near a hazardous waste site may be conducive to deviations from rational decisionmaking as characterized by maximization of expected utility. Psychologists have carefully documented a number of such deviations which will likely be observed, at least for a period of time (until, for example, individuals collect sufficient benign experience to reduce fear and dread), in the behavior of residents surrounding a hazardous waste site. These deviations are not random but, rather, show considerable regularity and may be incorporated into economic theory in a straightforward manner. As noted in Chapter 2, three psychological arguments may have special relevance for analyzing behavior near a hazardous waste site. These are that (1) subjective probabilities of damage may be strongly biased upwards, (2) perceived damages may be overestimated and (3) the perceived marginal utility of a loss may greatly exceed the perceived marginal utility of a gain. This Chapter attempts to draw out the implications of these arguments both for benefit-cost analysis and for property value markets.

3.1 Objective Versus Subjective Risks in Benefit-Cost Analysis

Traditional applications of benefit-cost analysis where uncertainty is present have been based on the usual economic assumptions that consumers maximize expected utility and have perfect information on objective risks. As noted above,- in the case of hazardous wastes, the assumption that consumers have perfect information on objective risks is likely to be highly misleading. This creates a serious policy dilemma: should objective net benefits (based on objective probabilities) be maximized or should subjective net benefits (based on subjective probabilities) be maximized as a social goal in managing hazardous wastes? The former measure of benefits will likely have little to do with values held by the public, while the latter may well imply that large sums of money should be spent reducing very small risks. Is there some escape from this unfortunate situation? The theoretical analysis developed below suggests that some reconciliation may be possible by undertaking public policy measures such as information programs specifically designed to reduce the disparity between objective probabilities and the public's subjective risk judgment of death from exposure to hazardous wastes. This section develops an economic model to explore appropriate efficiency based measures of benefits for hazardous waste management. The sections that follow explore the related issues of subjective damages (consequences) of hazardous waste exposure, how individuals treat perceived losses versus perceived gains, and how risks of possible exposure to hazardous wastes might be capitalized in property values near a hazardous waste site.

We will utilize the following notation throughout this chapter:

r = objective risk of death from exposure to hazardous wastes

R = subjective risk of death from exposure to hazardous wastes

π = risk of death from all other sources (objective risk from other sources is assumed to be equal to subjective risk)

n = number of identical individuals

Y = individual income

U(y) = individual utility, a concave function Of Y.

Given this notation, for a society of n identical individuals, the question for social policy is whether to maximize

$$n\,(1 - \pi - r)\,U(Y), \tag{3.1}$$

the sum of expected utility across individuals defined using objective risk, r, or to maximize

$$n\,(1 - \pi - R)\,U(Y), \tag{3.2}$$

total expected utility defined using subjective risk, R. Note that utility in the death state is ignored here but is treated in the next section. Thus, (3.1) and (3.2) give utility in the life state alone, assuming utility in the death state is zero.

For hazardous wastes it is highly likely that subjective risk exceeds objective risk, so R>r. We can define the degree of risk bias "k" by the relationship

$$R = (1 + k)r \tag{3.3}$$

where it is likely for hazardous wastes that k > 0. Note that R = r if the bias factor, k, equals zero.

Policy options for dealing both with objective risk from hazardous wastes, r, and with bias in perception of that risk, k, can then be defined by the cost function

$$C\ (r,\ k) \qquad (3.4)$$

where $\partial C/\partial r = C_r < 0$ and $\partial C/\partial k = C_k < 0$ so both r and k can be reduced at some increasing social cost. Objective risk, r, can, of course, be reduced by programs to contain or reduce production of hazardous wastes, while the perception bias k can conceptually be reduced by risk communication which entails community relations programs and policies designed to reach scientific concensus on the "true" risks. Also, note that, although we have assumed identical individuals and identical bias in subjective risk judgments for all individuals, both individual utility functions and the risk bias factor are likely to vary widely across individuals. This simple model can be thought of as referring to the "average" individual. However, evidence both from the site studied here and our own experimental work suggests that the distribution of bias across individuals is likely to be bimodally distributed with a large fraction of individuals possibly having very biased subjective risk beliefs.

To introduce the social cost function into the maximization of (3.1) or (3.2) we assume that each individual pays his or her share of such costs so initial individual income Y^0 is reduced by per capita social costs associated with managing hazardous wastes. Thus private per capita income is reduced to

$$Y = Y^0 - \frac{C(r,k)}{n} \quad . \qquad (3.5)$$

If we assume initial levels of r and k are maintained at r° and k°, with no efforts to reduce objective risks and subjective risk bias, then $C(r^o, k^\circ) = 0$ so no social costs are expended. In this case $Y = Y^o$ in (3.5). If policies are undertaken to reduce r and k, so $r < r^\circ$ and $k < k^\circ$, then, since $C_r < 0$, and $C_k < 0$, we will have $C(r, k) > 0$ and social costs for controlling the effects of hazardous wastes will be positive.

If objective expected utility, expression (3.1), is chosen as the criterion for maximization, k is simply set equal to k° in (3.5), and (3.1) is maximized subject to (3.5) over r alone. This maximization of objective net benefits yields as a first order condition for the optimal level of r

$$n\left(\frac{u(Y)}{(1-\pi-r)\ U'(Y)}\right) = -\ C_r\,(r,\ k^\circ)\ . \qquad (3.6)$$

This is the traditional efficiency condition from the public safety literature where the left hand side of (3.6) is the number of individuals, n, times the marginal value of safety to each individual, $U/((l-\pi-r)U')$, or the sum of marginal safety benefits across individuals, and is set equal to the marginal cost of reducing objective risk from hazardous wastes, $-C_r$. Implementation of this efficiency condition requires knowledge of the cost function for reducing objective risk of death from exposure to hazardous wastes and of the marginal value of safety. This latter value is typically drawn from hedonic wage studies of the labor market where higher wages are associated with more risky jobs. Presumably such workers have subjective risk judgments of job related death which closely match objective risks. As implied in the interpretation of (3.6) above, the marginal value of safety, MVS, taken from labor markets can be defined as

$$MVS = \frac{U}{(1-\pi-r)U'} = \frac{U}{(1-\pi-R)U'} \quad \text{(for r, R small).} \qquad (3.7)$$

Objective net benefits may then, based on (3.6), be approximated by

$$\underbrace{n \cdot MVS = (r^{\circ} - r)}_{\text{Objective Benefits}} - \underbrace{C(r, k^{\circ})}_{\text{costs}}. \tag{3.8}$$

The implication of maximizing objective net benefits with respect to r alone is that policy makers are behaving <u>as if</u> consumers had accurate subjective risk judgments. Since benefit-cost analysis is a normative as opposed to a positive exercise, this remains a perfectly plausible approach with considerable appeal, in that, enormous sums of money will not be spent on reducing hazardous waste risks to near zero just because people have large biases in judging risk. However, this approach ignores how people actually <u>feel</u> about hazardous wastes and, since no actions are justified by this approach to do something about bias in subjective risk judgments, people will in fact be worse off than if such actions were taken.

As an alternative, maximization of subjective expected utility, (3.2) subject to the definition of bias (3.3) and the individual level of income (3.5) implies both an optimal level of risk bias, k, as well as an optimal level of objective risk from hazardous wastes, r. The level of risk bias, k, should also be constrained to be non-negative to rule out the peculiar possibility that people are made "better off" by a policy to delude them into thinking that hazardous waste risk is less than it truly is. The first order condition for an optimal level for perception bias, k, (where we do not have a corner solution) reduces to

$$n \cdot \left(\frac{U}{(1-\pi-R)U'}\right) \cdot r = -C_k \tag{3.9}$$

so, remarkably, the total <u>objective</u> damage from hazardous wastes (the number of individuals times the marginal value of safety times the objective risk) is set equal to the marginal cost of reducing perception bias (through information programs etc.). Such policies will, of course, not likely reduce k to zero. Thus, the condition for the optimal level of objective risk derived from maximizing subjective expected utility takes the form

$$\underbrace{n\cdot\left(\frac{U}{(1-\pi-R)U'}\right)}_{(a)} + \underbrace{k\cdot n\cdot\left(\frac{U}{(1-\pi-R)U'}\right)}_{(b)} = -C_r \qquad (3.10)$$

where the terms (a) plus (b) sum to <u>subjective marginal safety benefits</u> of objective risk reduction and these are set equal to the marginal cost of objective risk reduction. Term (a) corresponds to <u>objective marginal benefits</u> while term (b) is <u>residual marginal benefits</u> which result from bias in risk judgment. Clearly for k>O term (b) will be positive and subjective marginal benefits from hazardous waste programs will exceed objective marginal benefits. Thus, more will be likely spent on reducing objective risks from hazardous wastes if the social goal is maximization of subjective net benefits.

Subjective net benefits based on (3.9) and (3.10) can be approximated as

$$\underbrace{\underbrace{n\cdot MVS\cdot(r^0 - r)}_{\text{objective benefits}} + \underbrace{n\cdot MVS\cdot(r^{\circ}k^{\circ} - rk)}_{\text{residual benefits}}}_{\text{subjective benefits}} - \underbrace{C(r,k).}_{\text{social costs}} \qquad (3.11)$$

This definition of benefits and costs has several advantages. First, it provides a motivation for undertaking programs to reduce bias in risk perception. Second, the benefits measured are consistent with publicly held values which are reflected both in the property value study contained in this report and in contingent valuation studies such as that reported by Smith et. al. (1985). The subjective marginal benefits of objective risk reduction are equal to (1+k) MVS from (3.10), reflecting the public's likely bias in subjective risk beliefs, but in the context of efforts to reduce the size of that bias. Both the property value and contingent valuation results mentioned above do not reflect efforts to reduce bias in subjective risk for the population at large which are probably justified if maximization of subjective benefits is the appropriate policy objective.

The principle disadvantage of this approach is that, if subjective risk bias with respect to hazardous wastes cannot be lowered at reasonable cost, then k may "optimally" remain large, implying that "optimal" levels of objective hazardous waste risk, r, may be very low, and will only be achieved at great cost relative to the decision which would obtain if objective net benefits were maximized.

3.2 Subjective Damages and the Marginal Value of Safety

As noted in Section 2.3, perception bias in valuing hazardous waste risk may also be present because people overestimate the damage which occurs if they actually die from exposure to hazardous wastes, presumably from some form of dreaded cancer. In the previous section, utility in the death state was assumed to be zero. In this section we explore the consequences of alternative utilities of death, acknowledging that dying is a process over which people may well have preferences. Thus, people may prefer to die an accidental death over dying 'slowly and painfully" from cancer. To incorporate this possibility we assume, as before, that U(Y) denotes utility in life but add the notion that if death occurs from exposure to hazardous or toxic substances, utility in death is given by UT, while if death occurs from other causes utility in death is given by U_D. Presumably $U_T < U_D$ i.e., individuals would prefer to die from causes other than exposure to hazardous wastes. Both U_T and U_D may take on negative values if individuals derive no positive utility in death (e.g., from bequests to heirs) and only consider possible pain, suffering and fear associated with the process of dying. Objective expected utility is then given by

$$(1-\pi-r)U(Y) + \pi U_D + rU_T \qquad (3.12)$$

so there are three states of the world, life with odds $1-\pi-r$, death by other causes with odds π, and death from exposure to hazardous wastes with odds r. The marginal value of safety applicable for other causes of death is obtained by setting (3.12) equal to a constant, totally differentiating and solving for $dY/d\pi$. This yields

$$MVS_\pi = \frac{U - U_D}{(1-\pi-r)U'} . \qquad (3.13)$$

Alternatively if death occurs from exposure to hazardous wastes, the appropriate marginal value of safety is given by following the same procedure used above and solving for dY/dr. This yields

$$MVS_r = \frac{U - U_T}{(1-\pi-r)U'} . \qquad (3.14)$$

Since we have assumed $U_T < U_D$, i.e., that people feel worse off dying from exposure to hazardous wastes than from other causes, it is apparent by comparing (3.13) and (3.14) that $MVS_\pi < MVS_r$. Thus, the marginal value of safety may well be larger for risk from hazardous substances than for other causes of death. Individuals may, of course, also overestimate the difference between U_D and U_T simply because people dread new and unknown risks.

If one were to suppose that U_D and U_T "should" be identical then, where we assume U_D, $U_T < 0$, bias in subjective estimate of damage can be defined as ℓ where

$$U_T = (1 + \ell)\, U_D \tag{3.15}$$

so for $\ell=0$, $U_T = U_D$. The subjective MVS_r would then be given by

$$MVS_r = MVS_\pi + \ell \cdot \frac{-U_D}{(1-\pi-r)U'} \;. \tag{3.16}$$

If we assume no positive utility in death is derived from sources such as bequests, then the term $-U_D/[(1-\pi-r)]$ can be interpreted as the value an individual places on avoiding the pain and suffering associated with a normal death. If the dread associated with death from exposure to hazardous waste is reduced by public information programs or benign experience then the perception bias for subjective damage, ℓ, should be reduced and MVS_r will fall. However, unlike the case for perception bias for the odds of death, k, which clearly should be brought to zero if possible, it may not be appropriate to bring ℓ to zero in the sense that death by other causes may truly be preferable to death from cancer induced by exposure to hazardous wastes.

3.3 Subjective Losses and Gains and the Marginal Value of Safety

Psychologists argue that people value losses much more highly than gains (See, for example comments by Kahneman in Cummings, Brookshire and Schulze, 1985). This implies that the marginal utility of a loss in income U_L' from an initial level Y^0 is potentially much larger than the marginal utility of a gain in income, U_G'. Where we denote a gain in income as G and a loss in income as L, a linear approximate utility function describing this situation can be written as

$$U \approx U(Y^0) + U_G' \cdot G - U_L' \cdot L \quad (G \geq 0,\ L \geq 0). \tag{3.17}$$

If individuals around a hazardous waste site perceive a new risk to them, r, from hazardous wastes, the compensating variation measure of the gain in income (G) to voluntarily accept this risk is defined using (3.17) as

$$(1-\pi-r)(U(Y^0) + U'_G G) = (1-\pi)(U(Y^0)) \qquad (3.18)$$

where the expected utility of an increase in risk, r, with an increase in income, G, is set equal to the expected utility with no risk and no gain in income. Solving (3.18) for G gives as a willingness to accept measure

$$G = \frac{U(Y^0)}{(1-\pi-r)U'_G} \; r. \qquad (3.19)$$

Thus, the compensation required, G, is equal to the risk, r, times a marginal value of safety defined using the marginal utility of a gain, U'_G.

If, on the other hand, we define a situation where individuals give up an amount of money L to avoid a hazardous waste risk, r, using (3.17) we have

$$(1-\pi)(U(Y^0) - U'_L L) = (1-\pi-r)\, U(Y^0) \qquad (3.20)$$

and the willingness to pay, L, to avoid the risk, r.

$$L = \frac{U(Y^0)}{(1-\pi)U'_L} \; r. \qquad (3.21)$$

Thus, willingness to pay is equal to the risk, r, times a marginal value of safety defined using the marginal utility of a loss, U_L'. Clearly

$$\underset{(a)}{\frac{U(Y^0)}{(1-\pi-r)U_G'}} > \underset{(b)}{\frac{U(Y^0)}{(1-\pi)U_L'}} \qquad (3.23)$$

so the willingness to accept measure of the marginal value of safety (a) will be much larger than the willingness to pay measure (b) if $U_L' > U_G'$. In fact, as shown in Gegax, Gerking and Schulze (1985), contingent valuation estimates of (a) and (b) based on subjective job related risk of death are about 7 million dollars for willingness to accept and 3 million dollars for willingness to pay, respectively. Thus, people may react much more strongly to a subjective new increase in risk than to the opportunity to reduce an existing risk. Clearly, in many cases, hazardous wastes will be perceived as generating a new increase in risk.

3.4 How Subjective Risks from a Hazardous Waste Site Might be Capitalized in Property Values

What does the inclusion of the psychological factors identified above in economic analysis imply about the housing market near a hazardous waste site? How might a property value study provide insights into the nature of subjective benefits? This section attempts to answer these questions and provide a theoretical basis for design of the primary data collection effort reported in Chapter 5 for a specific hazardous waste landfill.

For simplicity, we make the assumption that a hazardous waste site is surrounded by a homogeneous neighborhood of identical homes. Initially, we also assume that both potential buyers and potential sellers (owners) judge no risk to exist from proximity to the site (R=O) and that all homes including those adjacent to the site have an annualized price of PO. In what follows we analyze the impact of new information that the waste site might present a risk to adjacent homeowners.

Potential buyers of homes adjacent to the site are assumed to own homes away from the site which are still worth PO. They face the choice of keeping their current home which has an annualized price of P^0 or buying a home adjacent to the site for an annualized price of PO-G where G represents the annual financial gain of purchasing a home at a lower price than what they are now paying. If the subjective risk of a home adjacent to the hazardous waste site is R, this choice can be represented by

$$(1-\pi)U(Y-P^{O}) + \pi U_D = (1-\pi-R)[U(Y-P^{O}) + U'_G G] + \pi U_D + RU_T \quad (3.23)$$

where the left hand side represents the expected utility of keeping the current home and the right hand side represents the expected utility of purchasing a home next to the hazardous waste site. Clearly, the lower price of the home near the site, G, represents a gain in income which, according to the psychological argument of different marginal utilities on gains and losses presented in Section 3.3 above, should be weighted by the marginal utility of a gain, U'_{G}. This gain must compensate for the perceived risk, R. Solving (3.23) for G yields

$$G = \frac{U-U_T}{(1-\pi-R)U'_G} R. \quad (3.24)$$

Thus potential buyers will lower the price they are willing to pay for a home next to a hazardous waste site by an amount equal to the <u>willingness to accept</u> measure of the marginal value of safety times the subjective risk associated with owning the home.

In contrast, current homeowners adjacent to the hazardous toxic waste site will compare the expected utility of remaining in their current home with the expected utility of selling their home at a perceived finanical loss, L, and purchasing a new home at price PO. This implies

$$(1-\pi-R)U(Y-P^{\circ}) + \pi U_D + RU_T = (1-\pi)(U(Y-P^{\circ})-U'_L \cdot L) + \pi U_D. \quad (3.25)$$

Note that, according to the psychological theory of gains and losses, the annualized value of the loss is weighted with the marginal utility of a loss, U'_L. Solving (3.25) for L yields:

$$L = \frac{U-U_T}{(1-\pi)U'_L} R. \qquad (3.26)$$

Thus, the willingness of homeowners to lower the sale price of their home (take a loss, L) is equal to the willingness to pay measure of the marginal value of safety times the perceived risk, R. Under the assumption that $U'_L > U'_G$ and if it is assumed that buyers and sellers have similar subjective risk judgments, R, then G>L. Thus potential home buyers will only offer PO-G for homes adjacent to the site but homeowners adjacent to the site will demand the larger sum P°-L. Since P°-L>P°-G, supply price exceeds demand price and under these assumptions no homes will be sold adjacent to the site. If we relax our assumptions to include multiple characteristics for homes, including factors such as home location relative to work location (implying variation in miles driven to work) then, initially, a downward sloping demand curve and an upward sloping supply curve will exist for homes adjacent to a hazardous waste site. The impact of new risk information would then result in a much larger downward movement in the demand curve than downward movement in the supply curve according to the theoretical model developed above. Obviously prices of homes adjacent to the site will fall. However, the relative movements of the supply and demand curves should produce a substantial decrease in sales as well. In fact, we verify this decrease in sales for the site chosen for detailed analysis in Chapter 7.

Other theoretical explanations are also consistent with the collapse of the home market near a hazardous waste site. For example, homeowners may suppose that at some future date home prices will recover and withhold homes from the market. However, the psychological interpretation developed here explains why individuals might feel greatly harmed, demand compensation and expensive private or public action to clean up hazardous wastes, but simultaneously refuse to sell their homes and solve their perceived or real problems through private action. The psychological theory of perceived gains and losses would in fact predict this "irrational" response.

The implication for primary data collection for our property value study can be summarized as follows: First, datamust be collected on subjective risk around the site. The market for homes around a hazardous waste site may well be dominated by subjective risk which, psychologists argue, may be very different from objective risk. Prior studies have used distance as a proxy variable for subjective risk. However, this procedure does not allow any exploration of the issue of risk bias, the relationship between subjective and objective risk. Second, through primary data collection, information on recent new buyers (who presumably purchased homes at lower prices knowing that some risk may exist) can be compared to long term residents who purchased homes prior to any subjective estimate of significant risk from the site. Data on past versus recent sale prices and on prices at which homeowners would be willing to sell today near and away from the site will allow tests of the hypotheses developed in this Chapter. As a result of this approach, some notion of subjective damages and benefits developed from observations on actual market behavior can be compared to calulations based on the best scientific evidence on objective damages and benefits. A large divergence would suggest that careful thought needs to be given to the choice of the appropriate objective for public policy i.e.,maximization of subjective net benefits versus maximization of objective net benefits.

CHAPTER 4

PRELIMINARY PROPERTY VALUE STUDIES

4.0 Property Value Studies Using Secondary Data

This Chapter presents results of three applications of the Hedonic Price Method (HPM) to explain property values around hazardous waste sites. There have been several attempts recently to apply the HPM to housing values around a hazardous waste site but most have met with limited success (see for example studies by Cook, et. al. 1984, and Harrison and Stock, 1984). The results of the secondary data analyses presented here suggest that the HPM is an appropriate method under limited circumstances. Fundamental to the successful application of the HPM is the perception of an amenity or, as in the case with hazardous waste sites, a disamenity by the people who live in proximity to the site. This perception is a necessary condition for the HPM to yield useful results. In past studies the role of perception appears to have been overlooked in many instances, but with proper consideration of psychological aspects and through collection of primary data, new studies can gather more information on perception as well as determine the magnitude of subjective damages. Psychological problems with cognition and rationality may greatly affect values placed on potential hazardous waste exposures. A clear understanding of the size and nature of such problems is essential in developing policy to deal with the hazardous waste issue.

The three studies presented in this section use available secondary data and, so, can only use distance measures as a proxy variable for subjective risk judgment. Given the limited success of previous property value studies it was deemed essential to screen sites before proceeding to collect primary data on subjective risk judgments for one of the sites.

4.1 The Data and the Model

The secondary data used in this section was obtained from a real estate market information network which provided near complete home sales information for the immediate area surrounding the sites. The data included basic housing attributes. The data on proximity to the site was gathered from measurements on a map from the home to the boundary of the site. The identity of two of the three sites, at the time of this writing, cannot be disclosed due to pending litigation. The descriptions of the sites and the results presented, however, are accurate accounts of the investigation.

These studies employ a standard hedonic property value equation where community variables (crime rate, school quality, race) have been excluded because little or no variation would be expected within the relatively small geographic area studied around each site. In addition to the standard property attributes, a-proximity or distance-to-site variable was included and a time dependent dummy variable was also used in some regressions to test for the effects of a significant event (i.e. evacuation, closing the site) on the sales price of homes in the area.

The functional form of the equations presented here is linear. The linear specification was preferred over the more conventional semi-log form because the results obtained when both functional forms were compared showed little difference in significance and because of the relative ease of interpreting the results from a linear specification.

Model:

Sales Price = f(standard housing attributes, distance-to-site, significant events in time)

Variable List:

Dependent Variable

Sales price of house ($)

Independent Variables

(standard housing attributes)

Date of home sale by month (month 1 to month 22)
Area of home in square feet
Number of bedrooms
Number of bathrooms
Year home was built (i.e. ’57, ’74, ’82)
Swimming pool
Scenic view
Fireplace
Proximity to freeway (site 2 only)

(distance-to-site)

Inverse of the distance-to-site in feet
Proximity of home to site dummy variable (within 1000 ft. of site)

(significant events in time)

Evacuation of people near the site due to a problem at the site (sites 1 and 3)
Closing of the site (site 2)

4.2 Site Descriptions and Results:

4.2.1 Site Selection

The following attributes were used to select hazardous waste sites appropriate for applying the hedonic property value method:

1) The site should be located near or within a well-populated area.
2) The population around the site must perceive a disamenity which is associated with the location of the hazardous waste site.
3) Community and neighborhood characteristics which may affect property values must be homogeneous or identifiable within the sample.

These criteria provide guidelines which, if satisfied for a site, will likely allow a successful application of the hedonic property value method. As will be shown, relaxing these conditions will lead to negative results.

4.2.2 Site 1

The first hazardous waste site which closely fit the criteria listed above is a landfill located in a highly populated suburban community. The landfill covers more than 500 acres and has been used for hazardous as well as municipal wastes. A number of. problems are associated with the landfill which threaten and annoy the community. These problems include:

1) The build-up and migration of methane gas which prompted the evacuation of a number of families in the area.

2) The presence of vinyl chloride gas (a known carcinogen) in extremely small concentrations.

3) The presence of bothersome odors.

4) Contaminated groundwater which is migrating off-site but which is not currently threatening drinking water wells.

The land abutting the landfill site underwent residential development in the mid '70's as the city yielded to growth pressures. The problems at the landfill have received considerable media attention and although state health agencies do not feel that the community faces any significant health risks, many homeowners have banded together and formed an association to pressure the government into rectifying the problems and compensating for devalued properties.

Results:

The sample size included 185 observations over a twentY-two month period, including the interval when the evacuations occurred. The sample area covered approximately a distance up to one mile from the site with a dummy variable approximating homes within the first 1000 feet from the site.

The results of the study at Site 1 can be found in Table 4.2.1. The first two regressions attempt to explain the sales price of homes as a function of housing attributes and proximity to the hazardous waste site. In the first regression a dummy variable was used to identify homes in the immediate area of the site (within 1000 feet). The results (shown in Table 4.2.1, column 1) indicate that the proximity variable is significant at the one percent level (t=-3.21), suggesting that property values are nearly $9,000 lower within 1000 feet of the site.

The second regression replaces the proximity variable with the inverse of the distance measured in feet from the landfill. This variable which also indicates proximity is significant at the one percent level (t=-3.23). Based upon the results of these first two regressions which test the hypothesis that the waste site depresses local property values, it appears that the hypothesis that an effect is present cannot be rejected.

Regressions 3 and 4 attempt to describe the effect of the site on sales price of surrounding homes over time. Variables were defined to test how property values and perceptions may have changed after the evacuations occurred. In the third regression the original specification used in regression 1 was modified to include an intercept-shifting variable which registered a value of zero unless the property was both within 1000 feet of the site and sold after evacuation, in which case the value of the variable was unity. The results of this regression suggest that property values

Table 4.2.1

SITE 1 HEDONIC PROPERTY VALUE REGRESSION

Variable Name	Mean	Std. Dev.	Estimated Coefficients (t in parentheses) 1	2	3	4	5
Dependent Var. Sale Price ($)	116785	29777.5					
Independent Var. constant			‘60312.2 (-6.45)	-59355.1 (-6.35)	-59983.1 (-6.47)	‘59264.4 (-6.37)	‘59298.2 (-6.44)
distance (feet from home to site boundary)	3192.22	1642.19					
inverse of distance- (1 /distance)				-2643880.0 (-3.23)		-2069300.0 (-2.33)	-2002540.0 (-2.37)
proximity of home to site (0 if greater than 1000 ft. 1 if less than 1000 ft.)	0.10	0.30	-8828.86 (-3.21)		-5724.89 (-1.85)		
evacuation effect on homes near site (0 if sold prior to July 1, 1984, 1 if sold after)	0.03	0.16			-11416.50 (-2.09)		-12730.30 (-2.55)
distance/evacuation indicates effect of evacuation on distance (0 for homes sold before July 1, 1994 l/distance for homes sold after July 1, 1984)						-2649180.0 (-1.63)	
Date of home sale by month (08/83=1+02/85=19)	9.58	5.47	32.2 (0.23)	45.8 (0.32)	107.1 (0.74)	152.5 (0.98)	128.5 (0.89)
area of home in square feet	1592.5	392.5	40.35 (10.2)	40.67 (10.3)	41.42 (10.5)	41.03 (10.4)	41.69 (10.6)
number of bedrooms	3.32	0.60	-4414.1 (-2.6)	-4284.4 (-2.5)	-4610.7 (-2.7)	-4508.0 (-2.7)	-4562.3 (-2.7)
number of bathrooms	2.17	0.58	3414.4 (1.4)	3487.6 (1.4)	3112.4 (1.3)	3608.1 (1.5)	3109.3 (1.3)
year home built (i.e. 77, 84, 56)	75.51	8.43	1473.0 (10.0)	1453.2 (10.0)	1450.4 (10.0)	1437.9 (9.9)	1438.5 (10.0)
swimming pool (0 if no pool 1 of pool)	0.10	0.29	2030.0 (0.7)	2899,9 (1.1)	1881.7 (0.7)	2643.9 (1.0)	2464.4 (0.9)
view from home (0 if no view 1 if view)	0.15	0.35	454.5 (0.2)	441.7 (0.2)	712.1 (0.3)	665.1 (0.3)	1110.5 (0.5)
fireplace in home (0 if no fireplace 1 if fireplace)	0.58	0.49	-5388.9 (-3.0)	-5138.0 (-2.9)	-4971.0 (-2.8)	-4848.7 (-2.7)	-4611.9 (-2.6)
R^2			0.894	0.894	0.897	0.896	0.898
sample size	185						

suffered a decrease in value of approximately $5,700 if within 1000 feet of the site before the evacuation and suffered an additional $12,000 loss if the property was sold after the evacuation.

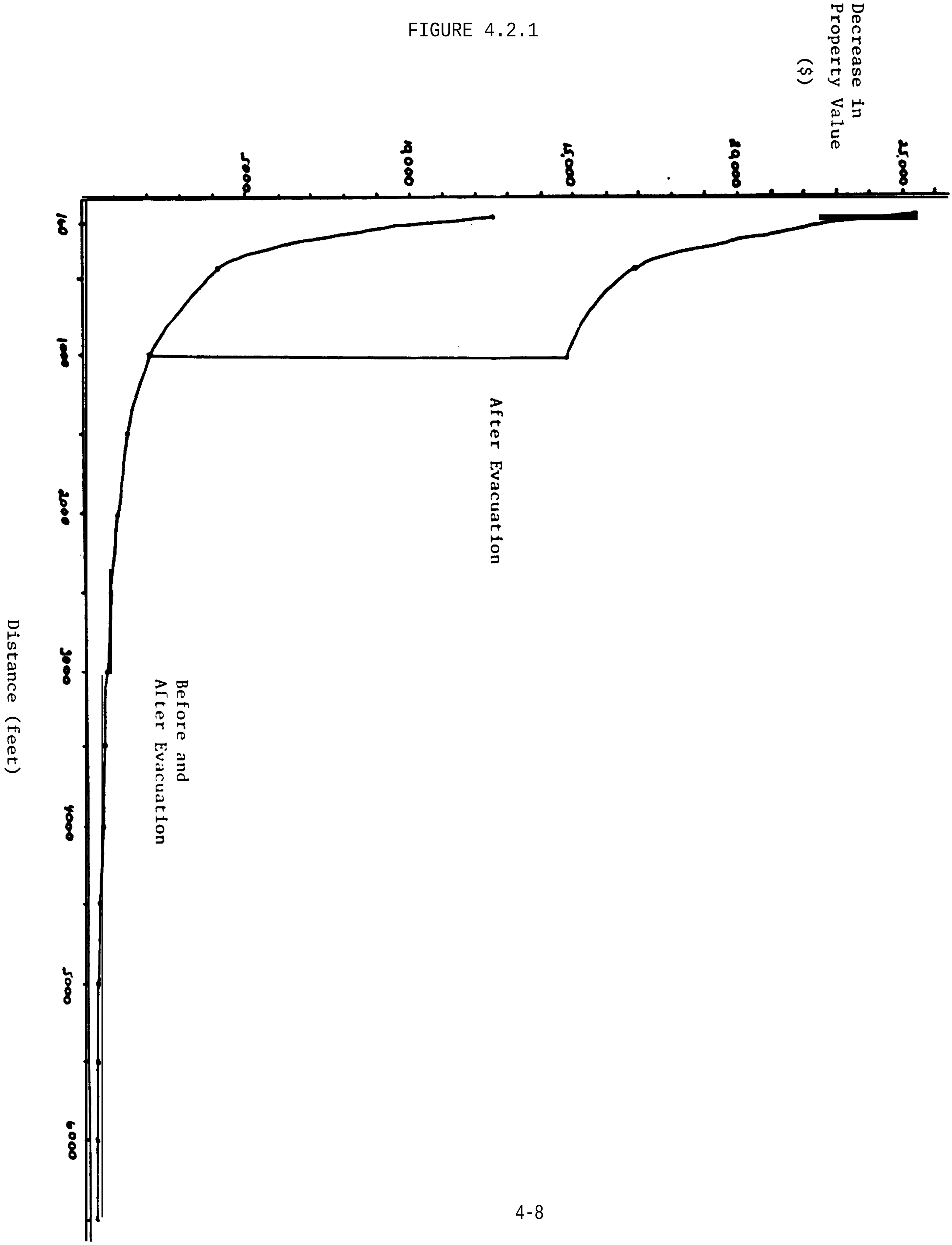
The fourth regression adds a slope-shifting variable to the inverse distance specification. The intent of this regression was to show the effect of the evacuation on the inverse-distance coefficient. The results indicate only weak significance (t=-l .63) for this slope-shifting variable which suggests that the effect of the evacuation did not extend beyond 1000 feet from the site.

The fifth regression attempts to apply yet another specification to illustrate the effect of the evacuation. The inverse-distance equation is combined with use of the after evacuation intercept-shifting variable which registers unity when a home sold was both within 1000 feet of the site and was sold after the evacuation. This regression yields significance of one percent on both the proximity variables.

The results of regression 5 are illustrated in Figure 4.3.1. The inverse-distance coefficient shows how the effect of the hazardous waste site drops away as distance from the site increases. In addition, the second curve (after evacuation) shows the change in the effect for homes within 1000 feet of the site after the evacuation. The curve shows the dramatic affect that the evacuation had on already diminished home values.

This site shows the strongest effect detected at a hazardous waste site of all published results using the HPM. The size of the impact on home values is highly significant for policy analysis. The results suggest that homes in the immediate vicinity of the site (within 1000 feet) have suffered a loss in value on the order of $15,000 per house. This

FIGURE 4.2.1


Decrease in
Property Value
($)
After Evacuation
Before and
After Evacuation
Distance (feet)

devaluation of property values represents a substantial loss to property owners in that area. An assessment of objective risks to life actually faced by people in this area suggests that these damages are far out of line with traditional concepts of damage based on objective risks to health and life. The subjective damages sustained by the owners reflected in sale price of homes is a real loss in the sense that they have been made financially worse off, but the source of this damage appears to be consistent with the notion of subjective damages developed in Chapter 3. Since physical damages in the form of increased risks to health and life appear to be relatively small, subjective damages resulting from cognitive difficulties appear to be very large for this site.

4.2.3 Site 2

The second site identified was also a landfill with many of the same characteristics found at Site 1. The landfill at Site 2 covers a 190 acre area and has been used for both hazardous and municipal wastes. This landfill, however, has reached capacity and has been closed. Potentially explosive levels of methane gas were discovered under several streets but, unlike Site 1, no evacuations were recommended. Likewise, vinyl chloride gas emissions have also been detected in extremely small concentrations (10-20 ppb.), and odor problems also plague members of the communities which surround the site.

During the early '70's, the neighboring cities approved residential development plans for housing along the southern border of the site. A freeway which bisects the site was also constructed during this period of time. Landfill operations were restricted to the area south of the freeway (where the residential construction was proceeding) and to compensate for the decrease in area, restrictions imposed on the height of the landfill were relaxed resulting in increased erosion problems including slope failure and mudslides which exposed decaying refuse. A homeowners association also exists at this site which is also seeking corrective measures from the government. Media attention at the site has been significant including television, radio, and regional newspaper coverage in addition to intense local newspaper coverage.

Results:

In specifying the equation for this site a dummy variable was included to pick up the effects of the highway. If the house stood within 2 blocks of the highway unity was recorded otherwise zero was recorded for the dummy variable. There were 136 observations used within approximately 1 mile of the Site. Excluded from the data set, however, were several observations in a section near the Site which upon visual inspection was discovered to contain a mixture of unquantifiable neighborhood characteristics which tended to significantly decrease the explanatory power of the model.

As with the regressions from Site 1, the first two regressions resulting from Site 2 (Table 4.2.2) test the hypothesis that proximity to the site is a significant factor explaining the sale price of the house. The first regression utilizes a dummy variable which was used to identify homes within approximately 1000 feet from the site. The results (shown in Table 4.2.2 column 1) indicate that proximity is a significant determinant of sales price at the five percent level (t=-l .84). The second regression replaces the proximity variable with an inverse-distance variable measured in feet. This variable, however, appears statistically weak (t=-l .5) in predicting home values (Table 2 column 2). This result suggests that the greatest effect on sales price applies to homes within 1000 feet of the site.

TABLE 4.2.2

SITE 2 HEDONIC PROPERTY VALUE REGRESSION

Variable Name	Mean	Std. Dev.	Estimated Coefficients (t in parentheses) 1	2	3
Dependent Var. Sale Price ($)	132,630	34,238			
Independent Var. constant			5450.3 (0.46)	6132.7 (0.51)	-190.9 (-0.01 5)
distance (feet from home to site boundary)	3401.2	1336.7			
inverse of distance- (1 / distance)				-5,412,610.0 (-1.47)	-6,174,760.0 (-1 . 72)
proximity of home to site (0 if greater than 1000 ft. 1 if less than 1000 ft.)	0.08	0.283	-10,938.9 (-1.84)		
effect of closing the the site (0 f sold prior to October 1, 1984, 1 if sold after)	0.29	0.46			-9082.3 (-1 .63)
date of home sale by month (08/83=1-05/85-22)	12.0	6.19	292.2 (1.14)	271.4 (1.05)	190.9 (1.94)
area of home in square feet	1599.5	469.3	52.9 (7.1)	52.9 (7.1)	51.1 (6.8)
number of bedrooms	3.32	0.77	2513.8 (0.86)	2047.9 (0.65)	2472. (0.79)
number of bathrooms	1.96	0.62	-1775.6 (-0.35)	-1968.4 (-0.39)	-1123.1 (-0.22)
year home built (i.e. 77, 84, 56)	58.6	9.71	578.7 (2.6)	632.4 (2.7)	678.9 (2.9)
swimming pool (0 f no pool 1 if pool)	0.19	0.39	13,182.7 (3.2)	13,638.1 (3.3)	12,230.4 (2.9)
view from home (0 if no view 1 if view)	0.08	0.27	143.2 (0.2)	1019.2 (0.2)	930.6 (0.2)
fireplace in home (0 if no fireplace 1 if fireplace)	0.49	0.49	-1582.6 (-0.4)	-2554.7 (-0.6)	-2202.7 (-0.6)
proximity to highway (1 if within 2 blocks, 0 otherwise)	0.058	0.23	-8393.5 (-1.3)	-8029.2 (-1.2)	-8855.0 (-1.3)
R^2			0.760	0.758	0.763
sample size	136				

The third regression tests the hypothesis that the closing of the landfill was a significant event in the perception of risks. A dummy variable was generated which was recorded as unity for home sales after the month of the closing and registered zero for homes sold before the closing of the landfill. The results are also statistically weak (t=-l .6) but indicate that an effect may still be present.

This site was selected for collection of primary data on property values as well as subjective risk.

4.2.4 Site 3

The third site identified for this study does not closely fit the criteria developed above for application of the HPM, but is presented for contrast. Site 3 is a landfill, but unlike the previous two sites this Site is located on the edge of a fairly large urban area. What is interesting about this site in relation to the other two is that a methane explosion destroyed one of the homes bordering the site forcing the permanent evacuation of a number of families.

The landfill covers 200 acres and is used primarily for municipal wastes. Residential development has been sporadic in the vicinity of the landfill which lies about three miles from the urban development of the city. The terrain around the site is best described as rolling hills with a major river drainage lying within 1500 feet of the site. Some contamination of groundwater has occurred as organic compounds have leached from the landfill. Odor, dust, and smoke problems have plagued the residents immediately bordering the site for several years. The city has accepted liability for the explosion but complaints about operations at the landfill continue to be heard and media coverage continues at the site.

Results:

Only two regressions are presented for Site 3 (Table 4.2.3). The first regression uses an inverse-distance variable to test the hypothesis that proximity to thesite is significant in explaining property values. The result obtained, however, does not have the expected sign. The inverse-distance variable is statistically weak (t=l .55) but suggests that homes closer to the site have higher property values. A reasonable explanation for this result is that property values tend to increase with distance away from the city, it appears that the negative effect of the city is stronger than the negative effect of the landfill. With only 50 observations to work with, this Site is a weak candidate for the hedonic property value model. There were no observations (since the evacuation occurred) within 1000 feet, therefore no proximity dummy variable equation is specified.

The second regression tests for any effect of the explosion/evacuation on home sale prices and the results suggest that no such effect exists (t=O.5). This site is useful for its contrast to the other sites in that the HPM may work at one site but not at another site where events surrounding the site maybe even more dramatic. The results at this site suggest that the HPM may not provide useful results where there is insufficient population in the immediate area of the site. It is plausible that subjective risk judgments are highly localized and this may in fact explain the poor results from earlier studies using the HPM.

TABLE 4.2.3

SITE 3 HEDONIC PROPERTY VALUE REGRESSION

Variable Name	Mean	Std. Dev.	Estimated Coefficients (t in parentheses) 1	2
Dependent Var. Sale Price ($)	51,34.2	29,828.8		
Independent Var. constant			-17,110 (-1.65)	-16,888.3 (-1,68)
distance (feet from home to site boundary)	13,532.4	4116.3		
inverse of distance (1 / distance)			51,683 400 (1.55)	54,216,300 (1.59)
evacuation effect on homes near site (O if sold prior to March 1, 1984, 1 if sold after)	0.48	0.49		5853.7 (0.45)
date of home sale by month (8/83=1+02/5-19)	9.98	7.18	225.4 (0.69)	-161.4 (-0.17)
area of home in square feet	1417.5	455.8	31.2 (4.12)	31.3 (4.14)
number of bedrooms	3.16	0.75	-8176.4 (-2.47)	-8154.7 (-2.43)
number of bathrooms	1.29	0.52	6078.1 (0.81)	6082.1 (0.80)
year home built (i.e. 77, 84, 56)	46.2	18.47	704.8 (4.5)	715.3 (4.5)
view from home (0 if no view 1 if view)	0.20	0.42	-399.9 (-0.67)	446.6 (0.07)
fireplace in home (0 if no fireplace 1 if fireplace)	0.52	0.49	4915.1 (1.0)	4614.3 (0.93)
R^2			0.800	0.801
sample size 50				

Conclusion:

The results of the secondary data HPM studies at hazardous waste sites suggest guidelines which are helpful for identifying candidate sites. The numbers generated in such studies, however, need to be considered carefully because subjective rather than objective damages are obtained. Of course, caution needs to be exercised in the use of subjective damages because without standards to measure subjective welfare (and with serious questions about the development of such standards) there would be no firm ground on which policy should be made. Potential problems with abuse of the notion of quasi-damages in the case of hazardous waste sites appears to be another concern that will need consideration. Such damages are in no way fictitious. However, the remedy for such damages may consist of addressing the problem of bias in subjective risk judgment through information and other programs. Only after such programs have been undertaken would it be efficient (based on Chapter 3) to use subjective damages (as captured either through property values or contingent valuation) to determine the optimal level of objective hazardous waste risk.

CHAPTER 5

SURVEY AND SAMPLE DESIGN

5.0 Introduction

This Chapter presents the procedures and methodologies used in conducting the primary data gathering effort. Examples of the actual survey correspondence along with a description of the sampling area and plan are also included in this Chapter.

5.1 Primary Data Issues

The acquisition of primary data for economic research into the valuation of environmental amenities using the low cost mail survey method proposed by Dillman (1978) allows many new opportunities for gaining insight into regulatory decisions. Primary data collection affords the investigator a great deal of flexibility in seeking answers to questions for which little or no existing data has been compiled.

Quality data for application of the hedonic price method is rarely available, but can be collected fairly cheaply using methods outlined in this Chapter. For this study the Dillman Total Design Method is especially helpful in that it allows collection of data on risk perceptions around a hazardous waste site as well as allowing extension of the initial property value study back through time. The risk perception information collected allows estimation of subjective damages and benefits and the potential impacts of perception biases on policy decisions. By also collecting information on the hypothetical minimum price at which homes would be sold and on contingent values for hazardous waste clean-up additional insights can be gained and a comparison of the Hedonic Price Method (HPM) and the

Contingent Valuation Method (CVM) can be undertaken. A comparison can also be made with results from the secondary data studies presented in Chapter 4. These comparisons will provide further information into the accuracy of benefit estimation methodologies and the usefulness of primary and secondary data.

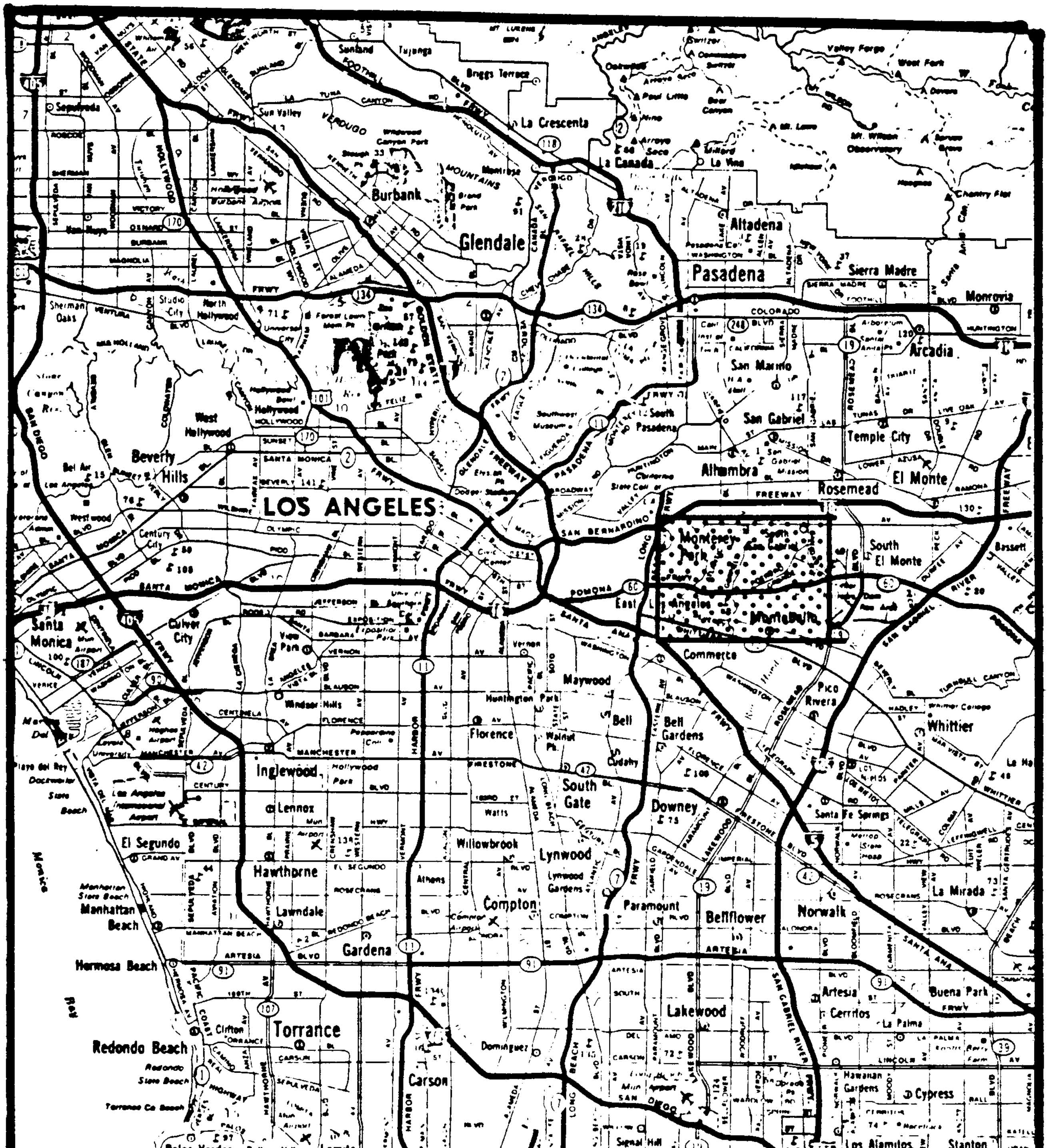
The rest of this Chapter is divided into three sections. The next section (5.2) describes the Site and the population that lives near it. The following sections (5.3 and 5.4) describe the survey design and sampling plan respectively.

5.2 Site Location and Description

The site selected and approved for the primary research effort is the Operating Industries Inc. (0II) Landfill situated between the communities of Montebello and Monterey Park, in the Los Angeles metropolitan area of California (Figure 5.2.1).

The landfill covers 190 acres and has been used for hazardous as well as municipal wastes. The landfill has reached capacity and has been closed since October 1984 at which time it was proposed for inclusion on the National Priorities List (NPL). It is estimated that the 011 Landfill contains 30 million cubic yards of refuse which is generating significant amounts of methane gas. The 011 Landfill reportedly ceased accepting hazardous materials in January 1983, but there is some contention that hazardous wastes have been illegally disposed of after that date. In 1983 several underground fires were detected at the site and in late June potentially explosive levels of methane were detected underneath several streets illustrating the potential problems from high concentrations of methane. More gas collection wells and better leachate control systems have been installed at the site since 1983 in an

FIGURE 5.2.1



Sunland
Tujunga
Briggs Terrace
La Crescenta
La Canada
Sun Valley
Burbank
Glendale
Altadena
Pasadena
Sierra Madre
Monrovia
Arcadia
San Marino
San Gabriel
Temple City
El Monte
Rosemead
South El Monte
Alhambra
South Pasadena
Sherman Oaks
Studio City
North Hollywood
West Hollywood
Beverly Hills
LOS ANGELES
Century City
Santa Monica
Culver City
Monterey Park
East Los Angeles
Montebello
Commerce
Pico Rivera
Whittier
Maywood
Huntington Park
Bell
Bell Gardens
Florence
Cudahy
South Gate
Downey
Inglewood
Lennox
El Segundo
Hawthorne
Lawndale
Manhattan Beach
Hermosa Beach
Redondo Beach
Torrance
Gardena
Willowbrook
Lynwood
Compton
Paramount
Bellflower
Norwalk
Santa Fe Springs
La Mirada
Buena Park
Artesia
Cerritos
Lakewood
Carson
Dominguez
Hawaiian Gardens
Cypress
Los Alamitos
Stanton
Rossmoor
Signal Hill
Wilmington
Lomita
Palos Verdes Estates
Rolling Hills Estates
Rolling Hills
Harbor Hills
Long Beach
Westminster

attempt to mitigate odors and risks. In April 1983 off-site emissions of vinyl chloride were observed (19 ppb) which exceeded the EPA and State regulatory level of 10 ppb. At this time a random sample of air within 12 homes showed no detectable levels of vinyl chloride (above 2 ppb).

During the early 1970's, the City of Montebello approved development plans for residential housing along the southern edge of the landfill. Construction of homes next to the site appears to have been the result of initial plans to reclaim the landfill area and build a golf course and park. The affluent homes that border the 011 Landfill contrast with the presence of lower class housing tracts that exist several blocks further away from the site. This development was accompanied by several land use changes in the area including the construction of the Pomona freeway which bisects the 011 Landfill. During this time activities at the landfill were restricted to the area of the site south of the freeway. Compensating for this loss of area, the height restrictions at the landfill were increased. This increase in the height limitation has been linked to increased erosion problems including slope failure and mudslides which have exposed decaying refuse.

The people who inhabit the area around the site have a diversity of ethnic backgrounds. A significant proportion are of oriental descent, and other ethnic backgrounds include: hispanic, european and southeast asian. The possibility exists that language difficulties of some residents in the area may affect the representiveness of the sample. The homes around the 011 Landfill can be described as modern and suburban. Typical housing prices range from $100,000 to $170,000.

Soon after the newly constructed homes were occupied in the mid 1970's, complaints of odors began to swamp the South Coast Air Quality Management District offices. Complaints of rodents and chemical seepage have accompanied odor problems. In 1979 the residents of the immediate area formed a group called HELP (Homeowners to Eliminate Landfill Problems), in order to organize their efforts to fight odor problems and health safety problems emanating from the 011 Landfill. HELP, whose dues-paying membership is estimated at 460 families, is governed by a seven member executive committee and a twenty-four member steering committee. Several issues concern HELP: leachate disposition, migrating gas, landfill use after closure, and property devaluation. There appears to be a general attitude that the full value of their property can be realized once the major problems at the landfill have been resolved.

Media attention at the site appears to have been significant over the past several years. Television, radio and regional newspaper coverage have accompanied intense local coverage from newspapers, community meetings and an EPA newsletter (The 0II Update). The inclusion of 011 on the National Priorities List (NPL) under CERCLA has also been a significant catalyst for media attention.

5.3 Survey Design

The mail instrument was developed according to Donald Dillman's Total Design method (TDM). The intention of the TDM procedure is to achieve a planned target response rate through careful design and implementation. One of the key components to achieving the target response rate is presentation. Personalizing the presentation, from the cover letter and cover page to the follow up post card and hand-stamped envelopes, is a key factor for encouraging responses.

The survey is divided into four sections and spans ten pages. The cover page of the survey (Figure 5.3.1) introduces the respondent to the topic of the questionnaire, describes who should complete the questionnaire and states who is conducting the research. Visual aids are useful on the cover to grab

You And The OII Landfill

A Survey of Property Owners in Montebello and Monterey Park on an Important Issue Facing your Community.

This questionnaire should be completed by the head of your household,

CENTER FOR ECONOMIC ANALYSIS
University of Colorado, Boulder
Boulder, Colorado 80309-0257

I

I

A N O V E R V I E W

Q-1 When you moved into your current home, were you aware of the OII landfill? (circle answer)

A) NO
B) YES

How much did the OII landfill affect your decision on where to purchase/rent your home in the Montebello/Monterey Park area?

A) NONE
E) LITTLE
C) SOMEWHAT
D) MODERATELY
E) A GREAT DEAL

Q-2 If you were deciding today about moving to the Montebello/Monterey Park area, with what you know now, how much would the OII landfill affect your decision on where within the community to purchase/rent your home?

A) NONE
B) LITTLE
C) SOMEWHAT
D) MODERATELY
E) A GREAT DEAL

Q-3 How far, would you say, is your home from the OII landfill?

A) DON'T KNOW
B) O to 4 BLOCKS
C) 5 to 9 BLOCKS
D) 10 to 14 BLOCKS
E) 15 to 19 BLOCKS
F) 20 to 25 BLOCKS

FIGURE 5.3.3

Q-4 How many times have you read or heard about problems at the 0II landfill?

A) NONE
B) RARELY
C) FEW
D) SEVERAL
E) VERY MANY

Which of the following has provided your best source of news and information about hazardous waste issues at the 0II landfill?

A) NO SOURCE OF INFORMTION
B) RADIO
C) REGIONAL NEWSPAPER
D) COMMUNITY MEETINGS
E) TELEVISION
F) 0II UPDATE
G) LOCAL NEWSPAPER
H) OTHER (specify) ______________

Q-5 How do you feel about the following statement: "the media (newspapers, radio, television etc.) has handled the problems at the 0II landfill responsibly”?

A) AGREE STRONGLY
B) AGREE
C) DON’T KNOW
D) DISAGREE
E) DISAGREE STRONGLY

FIGURE 5.3.4

3

Q-6 For each of the organizations listed below, how do you feel about the following statement: "the organization has handled the problemS at the 011 landfill responsibly"? (circle answers)

ORGANIZATION	AGREE STRONGLY	AGREE	DON'T KNOW	DISAGREE	DISAGREE STRONGLY
FEDERAL GOV'T (EPA etc)	1	2	3	4	5
STATE GOV'T (HEALTH SERVICES etc.	1	2	3	4	5
LOCAL GOV'T (CITIES OF MONTEBELLO AND MONTEREY PARK etc.)	1	2	3	4	5
0 II (OPERATING INDUSTRIES INC.)	1	2	3	4	5
NEIGHBORHOOD GROUPS (HOMEOWNERS TO ELIMINATE LANDFILL PROBLEMS etc.)	1	2	3	4	5

Q-7 Are you a member of HELP (Homeowners to Eliminate Landfill Problems) Or otherwise actively involved with the problems between the 0II landfill and your community?

A) NO
B) YES

Q-8 How much are you bothered by problems at the 0II landfill where you live now?

A) NOT AT ALL (I WOULD NOT THINK OF MOVING AWAY BECAUSE OF THE 0II LANDFILL
B) SLIGHTLY
C) MODERATELY
D) VERY
E) EXTREMELY (I HAVE THOUGHT VERY SERIOUSLY ABOUT MOVING AWAY BECAUSE OF THE OII LANDFILL)

the attention of a potential respondent. In the first section (Figures 5.3.2 -5.3.4), “An Overview,” Questions 1 through 3 attempt to focus respondents on their initial decision to move near the landfill and on their location with respect to the 011 Landfill. These introductory questions are meant to be answerable by every reader to encourage them to continue by getting them immediately involved through answering questions as opposed to reading a lengthy introductory statement. Question 4 elicits information about the readers’ level and sources of information, while Questions 5 and 6 attempt to provide an emotional release so later answers will be less biased as well as an indication of how various actors at 0II are perceived. Questions 7 and 8 finish off the first section by ascertaining how bothered the residents are by problems at 0II and if they are actively involved in efforts to deal with the problems. Question 8 provides a subjective measure on the degree to which people may be bothered by OII Landfill problems. This question provides an alternative variable to measure perception. This question may yield an interesting comparison as to alternative subjective measures of the problem.

Section 2 of the survey (Figures 5.3.5 - 5.3.8), "About Problems and Risks," brings the reader into the substance of the survey. Questions 9 and 10 elicit information about distance and annoyance from the Pomona Freeway that bisects the OII Landfill. This information is necessary for the property value model to explain sales prices which may be affected by the freeway.

Questions 11, 12 and 13 attempt to measure in a more precise fashion the individual perceived affects of odor, cancer risks and explosion risks that may emanate from the OII Landfill. These three factors have been identified as potential sources of problems at the landfill. The survey attempts to obtain subjective measures of each of the three sources both before and after

FIGURE 5.3.5

ABOUT PROBLEMS AND RISK

Q-9 How far is your house away from the Pomona freeway?

A) 0 to 1 BLOCKS
B) 1 to 3 BLOCKS
C) 3 to 5 BLOCKS
D) 5 to 10 BLOCKS
E) 10 to 25 BLOCKS

Q-10 How bothered are you by the Pomona freeway?

A) NOT BOTHERED
B) SLIGHTLY
C) MODERATELY
D) VERY
E) EXTREMELY

Q-11 Have you ever been bothered by odors from the OII landfill?

A) NO
B) YES →

BEFORE the closure of the OII landfill in October 1984 how often were you bothered?

A) RARELY (1-2 DAYS PER MONTH)
B) OCCASIONALLY (3-5 DAYS PER MONTH)
C) MODERATELY (5-10 DAYS PER MONTH)
D) FREQUENTLY (10-20 DAYS PER MONTH)
E) VERY FREQUENTLY (20-30 DAYS PER MONTH)

When you were bothered by the odors, how "bad" were they on a scale of 1 (barely noticeable) to 10 (extremely strong)? (circle answer)

1 2 3 4 5 6 7 8 9 10

NOW after the closure of the OII landfill in October 1984 how often are you bothered?

A) NEVER (NO DAYS PER MONTH)
B) RARELY (1-2 DAYS PER MONTH)
C) OCCASIONALLY (3-5 DAYS PER MONTH)
D) MODERATELY (5-10 DAYS PER MONTH)
E) FREQUENTLY (10-20 DAYS PER MONTH)
F) VERY FREQUENTLY (20-30 DAYS PER MONTH)

When you are bothered by the odors, how "bad" are they on a scale of 1 (barely noticeable) to 10 (extremely strong)? (circle answer)

1 2 3 4 5 6 7 8 9 10

5

The following two questions refer to the figure at the top of the facing page. The figure represents the annual number of deaths per 1,000,000 people attributed to specific sources. Each step on the ladder represents, roughly an increase in risk 10 times the previous step on the ladder, and just like a regular ladder, the higher you climb the greater the risk of death in a given year. The top of the ladder represents certain death in a year and the bottom represents an extremely small risk of death in a given year.

Q-12 There are many possible causes of cancer. Exposure to any one possible cause does not mean that cancer will necessarily result. One possible cause of cancer (vinyl chloride gas) has been detected at the OII landfill.

From the ladder facing this page, select the letter from "a" to "z" which most closely represents the risk of death you faced from exposure to toxics from OII BEFORE the closure of the landflll in October 1984. For example, if you were sure you would die this year because you have lived next to the OII, your answer would be "z". If you felt living near the OII was as dangerous to your health as smoking you would answer "q". If you felt it was as risky as using saccharin you would answer "c". If you felt no risk was present you would answer "a".

LETTER ____________

NOW after the closure of the landfill in October 1984 which letter from the ladder facing this page, best represents the risk of death you feel you face from exposure to toxics from OII?

LETTER ____________

Q-13 Methane (natural gas) is an ordinary by-product of a landfill. The migration of this gas away from the landfill can create a potential for fire and/or explosion.

A fire or explosion at your home can result from a variety of causes including gas stoves and heating systems. From the ladder facing this page, select the letter from "a" to "z" which most closely represents the risk of death you felt you faced from fire/explosion due to methane gas from the OII landfill BEFORE the closure of the landfill in October 1984,

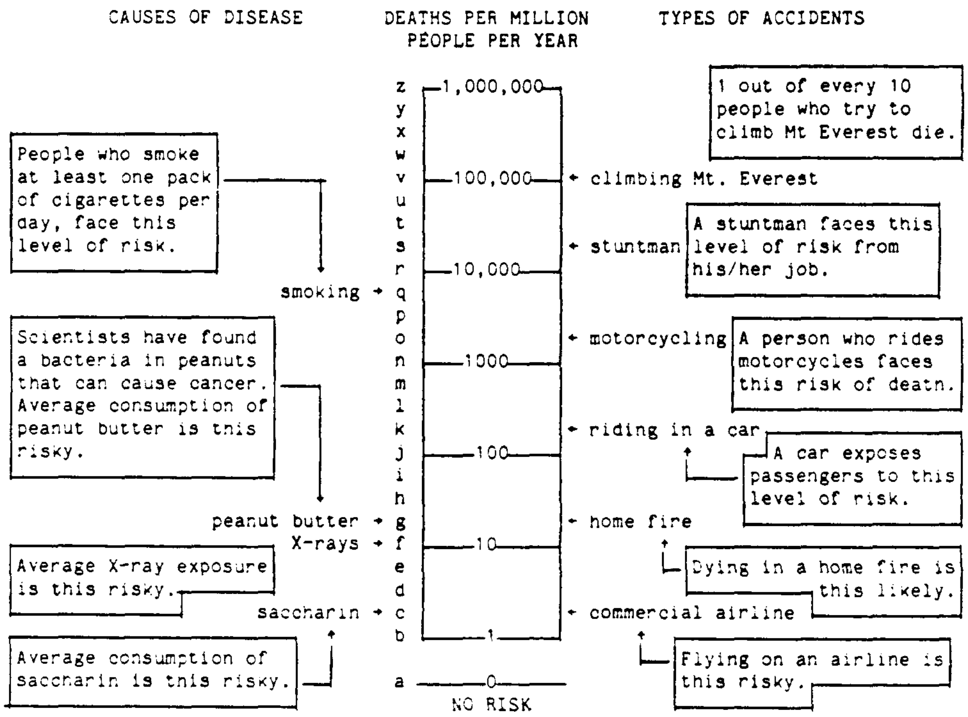
LETTER ____________

NOW after the closure of the landfill in October 1984 which letter from the ladder facing this page most closely represents the risk of death you feel you face from fire/exploslon due to methane gas from the OII landfill?

LETTER ____________

FIGURE 5.3.7

RISK LADDER
(numbers on steps are deaths per million people per year)



Q-14 The landfill is now closed. **IMAGINE** for a moment that OII was planning to reopen the landfill, (this IS NOT the case, however). How much at the most would you be willing to pay each month to prevent the reopening of the landfill, which would expose you to the levels of odors and risks which existed prior to October 1984?

$____________________ PER MONTH

the closing of the OII Landfill in October 1984. Question 11 addresses the problem of odor. Frequency and intensity information is elicited both before and after the closure. The frequency data is collected in terms of how many days during the course of an average month the respondent was bothered. The intensity of odors is much more difficult to measure. Without the aid of a scale on which to rank odors, respondents were asked to rank the intensity of odors on a 1 to 10 scale where 1 is "barely noticeable" and 10 is "extremely strong."

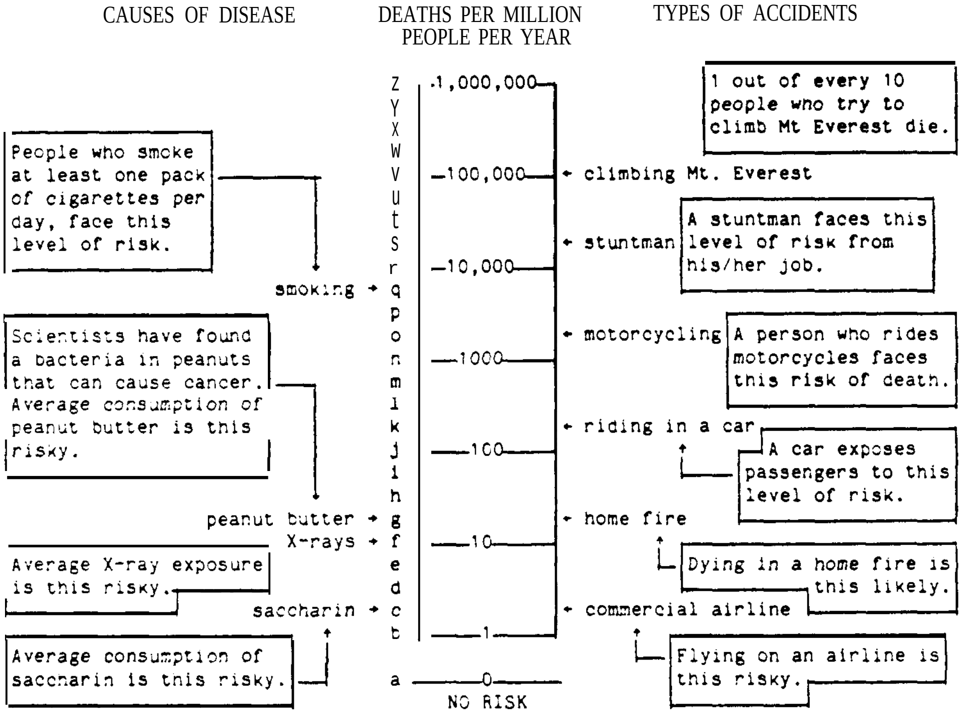
Questions 12 and 13 utilize a risk ladder as a means of identifying subjective risk judgments from the OII Landfill. The risk ladder uses a logarithmic scale to illustrate activities which impose a risk of death from cancer or disease and activities which can increase the likelihood of an accidental death. The ladder is divided by eight rungs which represent the number of deaths per 1 million in population where each step increases risk by a factor of ten. The ladder is further divided by the letters that split each rung into four sections. The risk ladder may provide useful information as to how people subjectively estimate the risks from the OII Landfill. These estimates may correspond to subjective damages present around the OII Site. The subjective damages can then be compared to objective damage assessments around the area resulting in an estimate of quasi-benefits. If such potential benefits are large, increased emphasis on information programs and other policies to form an informed community concensus on objective risks may be justified.

In Question 12, the respondent is asked to choose the letter that corresponds to the level of subjective risk judged, both before and after closure of the landfill, of dying from cancer or other disease as a result of exposure to vinyl chloride gas (or other toxics) present at the landfill. Question 13 parallels Question 12, except that subjective risk of death from

FIGURE 5.3.8

6

RISK LADDER
(numbers on steps are deaths per million people per year)



Q-1 4 IMAGINE yourself back before October of 1984 before the OII landfill was closed with the odor problems and risks that existed at that time. You are given a choice between closing the landfill or being paid some amount of money per month. What is the least amount of money per month you would have accepted rather than closing the OII landfi11?

$________________________ PER MONTH

explosion at the OII Landfill is measured both before and after closure of the landfill.

Question 14 concludes the section on risks and problems with a contingent valuation question. Two versions of this question were sent to people in the area in order to test the effects of framing on the disparity between WTA and WTP measures. Earlier studies have found a significant difference between WTA and WTP measures of value. Based upon theories put forth by Kahneman and Tversky that framing of questions either in terms of losses or gains may yield inconsistencies in preferences, each version of the question is asked with a loss versus loss or gain versus gain tradeoff structure. In the WTP version (Figure 5.3.7), where willingness to pay is viewed as a "loss," the commodity being valued is also structured as a loss. Thus, in the WTP version, people are given a choice between reopening the now closed landfill or paying some amount to prevent the reopening. The respondent is faced with a loss-loss situation, either the landfill is reopened or some amount of money must be given up. In the WTA version (Figure 5.3.8), the respondent is mentally placed back before the closing of the landfill and is then asked what is the least amount of money that he or she would accept in lieu of closing the landfill. In this case, the respondent is placed in a gain-gain situation, where either money is acquired or the landfill is closed. Respondents may however be unable to cope with the peculiar mental gymnastics necessary to avoid trading off gains versus losses which will likely induce the biases identified by Kahneman and Tversky. By framing WTA and WTP questions in the manner shown, it is possible that the traditional large disparity between WTA and WTP measures may diminish. However, the questions asked as much less "natural" than those traditionally employed.

ABOUT YOUR HOME

7

Q-15 Do you own your home?

A) NO → How much is your monthly rent payment $__________
B) YES ↓

What year and month did you purchase your home?

YEAR________ MONTH__________

What was the purchase price of your home?

$________________

If someone wanted to buy your house today, what is the lowest selling price you would be willing to accept for it?

$________________

Q-16 Approximately how many square feet does your home have?

____________________SQUARE FEET

Q-17 Do you have a scenic view?

A) NO
B) YES

Q-18 Do you have a swimming pool?

A) NO
B) YES

Q-19 Do you have a fireplace?

A) NO
B) YES

FIGURE 5.3.10

Q20 How many bathrooms does your home have?

________________ BATHROOM

Q-21 How many bedrooms does your home have?

________________ BEDROOMS

Q22 Approximately when was your home originally built?

YEAR> __________

C-23 IMAGINE you live in an identical house in an identical neighborhood with the same monthly house/rent payments you now pay but without the OII landfill in the community. What is the largest amount of money per month that you would be willing to pay to prevent the OII landfill from locating at the same distance it is now from your home?

$____________ PER MONTH

Q-24 How would you describe the quality of the schools in your area?

A) DON'T KNOW
B) POOR
C) AVERAGE
D) GOOD
E) EXCELLENT

Q-25 Do you expect to move within the next 5 years?

A) NO
B) YES
C) DON'T KNOW

FIGURE 5.3.11

Q-20 How many bathrooms does your home have?

______________________BATHROOMS

Q-21 How many bedrooms does your home have?

______________________BEDROOMS

Q-22 Approximately when was your home originally built?

YEAR______________

Q-23 **IMAGINE** that you were given the opportunity to live in an identical house in an identical neighborhood with the same monthly house/rent payments you now pay but without the OII landfill in the community. What is the smallest amount of money per month you would have to be paid to turn down that opportunity?

$__________________PER MONTH

Q-24 How would you describe the quality of the schools in your area?

A) DON'T KNOW
B) POOR
C) AVERAGE
D) GOOD
E) EXCELLENT

Q-25 Do you expect to move within the next 5 years?

A) NO
B) YES
C) DON'T KNOW

FIGURE 5.3.12

ABOUT YOU AND YOUR FAMILY [9]

Q-26 What is your age?

YEARS ____________

Q-27 What is your sex?

A) FEMALE
B) MALE

Q-28 Including yourself, how many people live in your home?

NUMBER ____________

0f those people how many are under the age of 18?

NUMBER ____________

Q-29 Circle the letter for your family's gross income (before taxes) in 1984?

A) UNDER $10,000
B) $10,000-20,000
C) $20,000-30,000
D) $30,000-40,000
E) $40,000-50,000
F) $50,000-60,000
G) $60,000-70,000
H) $70,000-80,000
I) $80,000-90,000
J) $90,000-100,000
K) MORE THAN $100,000

Q-30 How much formal education have you completed?

A) 0-5 grades
B) 6-8 (finished Grade School)
C) 9-11 grades (Some high School)
D) 1-2 grades (finished high School)
E) Trade school
F) Some college
G) College Degree (BA or BS)
H) Some graduate work
I) Advanced College degree

G-31 Are you retired?

A) NO
B) YES

FIGURE 5.3.13

Q-32 What is your occupation?

JOB ____________________

Q-33 How far is your commute to work?

A) LESS THAN 1 MILE
B) 1-5 MILES
C) 5-10 MILES
D) 10-15 MILES
E) 15-20 MiLES
F) MORE THAN 20 MILES

Q-34 How would you describe your ethnic background?

A) NATIVE AMERICAN
B) WHITE
C) ORIENTAL/ASIAN
D) BLACK
E) HISPANIC
F) OTHER (specify) ____________

Q-35 Which of the following best describes your native language?

A) ENGLISH
B) SPANISH
C) JAPANESE
D) CHINESE
E) KOREAN
F) FILIPINO
G) VIETNAMESE
H) OTHER (specify) ____________

Q-36 When you travel in an automobile, do you generally wear a seat belt?

A) NO
B) YES

Q-37 Do you smoke?

A) NO
B) YES

The third section of the survey (Figures 5.3.9 - 5.3.11) consists of the property value information required for the hedonic property value study. Questions 15 through 22 elicit basic housing characteristics such as price, number of square feet, view etc. Question 23 is very similar to Question 14 in eliciting WTA and WTP information. In this question the commodity being traded off is the opportunity to live in an identical house and in an identical community without the OII Landfill. In the WTP version (Figure 5.3.10), a loss-loss situation is presented, where the reader is mentally placed in an identical house in identical neighborhood without the OII Landfill and is then asked what is the most amount of money that they would be willing to pay to prevent the landfill from locating in the community. In the WTA version (Figure 5.3.11), the reader is again placed in a gain-gain situation, where either financial compensation will be provided for living near the OII or an identical house in an identical neighborhood without the OII Landfill will be provided. This question will provide an interesting contrast to Question 14 where the commodity being valued is the closing of the landfill.

Question 24 asks about the quality of schools in the area, which may be a factor in determining property values in the area. Question 25 completes section 3 by inquiring whether the respondent expects to move within five years, again to obtain information on the location decision.

The final section of the survey (Figures 5.3.12 - 5.3.13) "About You and Your Family," is comprised of questions about the characteristics of the respondent and the respondent's family. Questions 26 through 33 inquire about age, sex, family size, income, education and occupation. Questions 34 and 35 ask about ethnic background and native language, which may be important because of the existing cultural diversity of the area. The final two

FIGURE 5.3.14

Is there anything we may have overlooked? Please use this space for any additional comments you would like to make concerning you and the OII landfill.

Your contribution to this effort is very greatly appreciated. If you would like a summary of results, please print your name and address on the back of the return envelope (NOT on this questionnaire). We will see that you receive it.

questions ask whether the respondent uses seat belts in automobiles and whether the respondent smokes. These two questions relate to the risk section of the survey and may provide useful information on behavior of respondents with respect to other risks.

The final page of the survey (Figure 5.3.14) provides space for additional comments and thanks the respondent for cooperating in the effort.

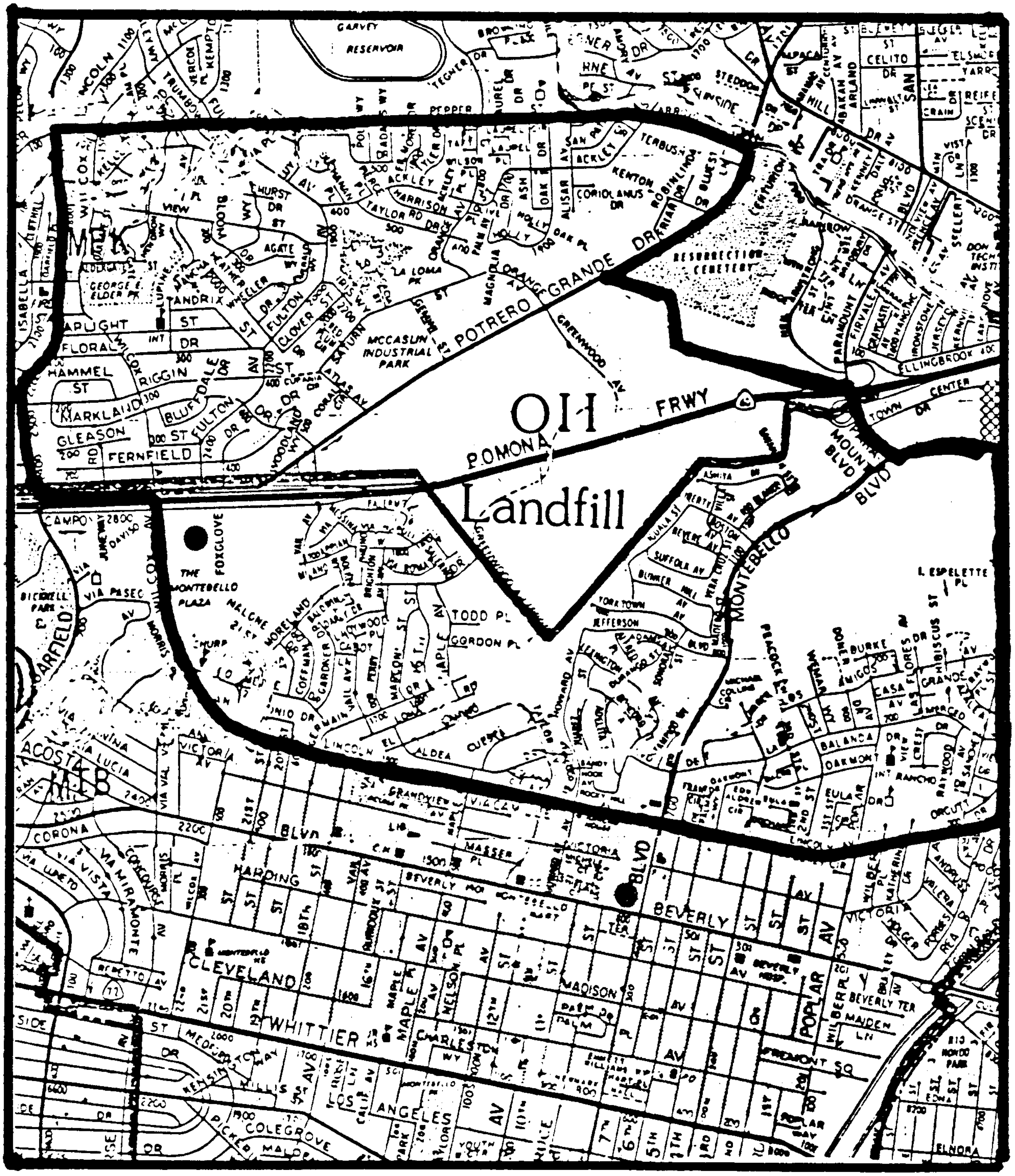
5.4 Sample Design and Plan

The Operating Industries Inc. (OII) Landfill is located between the communities of Montebello and Monterey Park, California (Figure 5.4.1). In implementing the secondary data property studies (Chapter 4), the initial sample area included home sales within an approximate one mile radius of the site.

The results of an initial attempt at a secondary data study around the OII Landfill were unable to show any significance for the regressors on the sales price other than the square footage of home, which was only marginally significant. The R-square statistic of the initial test was 0.60, suggesting that the explanatory power of the model was insufficient to detect effects from variables which are much less pronounced such as the effect from the landfill on property values.

Upon closer inspection of the data, it was found that in one section of the sample in Montebello, homes in the same neighborhood (and distance from the OII Site) had a large variance in sales price. For example, homes within the same block ranged in price from $60,000 to $240,000. A plot on a map of homes greater than $200,000 and less than $100,000 showed that in the older section of the city there were a large fraction of homes in each of those categories were intermixed within a relatively small area. Other sections of the city showed much more homogeneous housing prices. The area of concern is

FIGURE 5.4.1


OII
Landfill
POMONA FRWY
POTRERO GRANDE DR
MCCASLIN INDUSTRIAL PARK
GARVEY RESERVOIR
RESURRECTION CEMETERY
THE MONTEBELLO PLAZA
FOXGLOVE
MONTEBELLO
BLVD
BEVERLY
BLVD
WHITTIER
CLEVELAND
HARDING
VICTORIA
CORONA
ACOSTA
GARFIELD
WILCOX
FULTON
BLUFFDALE
GLEASON
FERNFIELD
MARKLAND
HAMMEL
FLORAL
RIGGIN
TODD PL
GORDON PL
MADISON
POPLAR
COLEGROVE
LOS ANGELES
GREENWOOD
TOWN CENTER DR
ELLINGBROOK
TERBUSH
KENTON
ACKLEY
HARRISON
TAYLOR RD
CAMPO
PARAMOUNT
ELNORA

highlighted in Figure 5.4.1. Photographs of the area verified this disparity by showing a large disparity in unquantifiable variables such as upkeep of homes, lawns etc.

It was hypothesized that eliminating this section from the sample would increase the R-square value and the significance of a number of the explanatory variables. A subsequent test with the problem section eliminated confirmed the hypothesis. The results of this test are presented for Site 2 in Chapter 4. With the explanatory power of the model brought up to an R^2 of 0.76, the effects of many of the explanatory variables became significant including the effect of the distance-to-site variable.

The sample area for the primary data collection study mimics the sample area used in the secondary data study presented in Chapter 4 (e.g., the problem section is removed). Reverse telephone-address books were obtained from the Pacific Bell which listed the names, addresses and phone numbers of people in the area according to street address. Within the sample area, 1006 homes were identified in the Montebello region and 806 homes were identified in Monterey Park, yielding a total sample size of 1812. Using a 100% sample of homes within approximately one mile from the OII Site eliminates many problems associated with defining a sampling plan.

In the secondary data study at the OII Landfill, a dummy variable was defined for proximity to the site. This proximity variable identified home sales within approximately 1000 feet of the site and showed a possible decrease of about $10,000 for homes within 1000 feet of the site. With only 12 homes sales in a twenty-two month period within 1000 feet, it appears that the market demand for homes in proximity to the site has fallen dramatically. According to the reverse phone-address listings, the number of homes with listed phones and addresses is 546 within 1000 feet of the site. Therefore, only twelve homes sold, the rate of home sales was approximately 2.2%. Within the sample area, but beyond 1000 feet of the site, there were 124 home sales over the same period of time out of approximately 1266 homes, yielding a home sales rate of about 9.8%. Both of these percentages are, however, biased upwards since houses with unlisted numbers were excluded from our estimates of the total number of homes. This result suggests that the real estate market has been substantially affected by the OII Landfill. Demand for housing appears to have fallen to a much greater degree than the supply has increased near the site, resulting in both lower sale prices and quantities of homes exchanged. This result is consistent with the theory outlined in Chapter 3 describing the effects of perceived gains and losses on supply and demand for homes. Even though the two estimates of home sales rate may be biased upwards, the difference between the 2.2% rate within 1000 feet and the 9.8% rate for homes outside of 1000 feet is likely to be significant and suggests a collapse of the home market near the site.

The sampling procedure follows the process described in Donald Dillman's Total Design Method (TDM). The survey is printed and folded into a booklet that measures 8 inches by 6 inches. The survey, a cover letter (Figure 5.4.2) and a self-addressed stamped envelope are then folded and mailed to the entire sample area. An important component of the Dillman method to maximize response is the follow-up procedure. One week after the initial mailing a post card is sent reminding the respondent of the importance of completing and returning the survey (Figure 5.4.3). If, after the initial mailing and the postcard, a response is not received from a respondent a second survey, cover letter (Figure 5.4.4) and self-addressed stamped envelope is sent 3 weeks after the initial mailing. This third mailing again emphasizes the importance

FIGURE 5.4.2

UNIVERSITY OF COLORADO, BOULDER

Center for Economic Analysis
Campus Box 257 l Boulder, CO 80309-0257

August 29, 1985

Safety near hazardous waste sites is a matter of concern to everyone. Yet little is really known about how much people value the benefits of landfill clean-up. In order to get this Information, we need your help.

The OII landfill was chosen as representative of similar waste sites around the country. Because your home is close to the OII landfill, you have been sent a questionnaire. To truly obtain the opinions of the entire community, it is important that each questionnaire be completed. Your answers and those of others from surrounding neighborhoods will be summarized to form a profile of the community's concern for public safety.

Since this survey concerns the value of landfill cleanup, we ask that the enclosed questionnaire be filled out by the head of your household. You can be assured of complete confidentiality. Your name will never be associated with the information you provide. The number on the questionnaire is only so your name can be checked off the list when it is returned.

Since your responses are so important to the study, we hope that you will fill out the questionnaire and return it in the enclosed stamped envelope. If you do not wish to respond please let us know by returning the blank questionnaire.

If you would like a summary of the survey results (they are free), please write "send results" on the back of the envelope. I would be happy to answer any questions you might have. Please call or write. My telephone number is (303) 492-5242.

Many thanks for your help with this important effort.

Sincerely,

Bill Schulze
Project Director

FIGURE 5.4.3

September 5, 1985

Last week a questionnaire was mailed to you seeking information which is crucial in evaluating the effects of the OII landfill in and around your neighborhood.

If you have already completed and returned the questionnaire, accept our sincere thanks. If not, please do so today. The OII landfill was chosen as representative of similar waste sites around the country. Because your home is close to the OII landfill, you were sent a questionnaire. Therefore, it is extremely important that your answers also be included in the study.

If by some chance you did not receive the questionnaire, or it was misplaced, please call me collect (303) 492-5242, and I will get another one in the mail to you immediately.

Sincerely,

Bill Schulze
Project Director

FIGURE 5.4.4

UNIVERSITY OF COLORADO, BOULDER

Center for Economic Analysis
Campus Box 257 • Boulder, CO 80309-0257

September 24, 1985

About three weeks ago I sent you a questionnaire concerning safety near hazardous waste sites. As of today, I have not yet received your completed questionnaire. If you have already completed and returned the questionnaire, accept our sincere thanks and disregard this letter.

This study has been undertaken as a national project in the belief that citizens' attitudes towards safety should be incorporated into policies concerning landfill cleanup programs. Your opinions will be extremely valuable towards evaluating the worth of such programs.

I am writing to you again to encourage you to complete the questionnaire. In the event that your questionnaire has been misplaced, a replacement is enclosed.

Your cooperation is greatly appreciated.

Cordially.

Bill Schulze
Project Director

of completing and returning the survey. Although Dillman describes further follow-up techniques which increase the overall response rate such as using registered mail and telephone follow-up, this study terminated after the third mailing which produces a target response rate of forty to fifty percent.

CHAPTER 6

DATA COLLECTION AND DESCRIPTION

6.0 Introduction

In this Chapter data collection procedures and general results of the Operating Industries Inc., Landfill primary data study are presented. Data analysis and discussion are presented in Chapter 7 which will develop statistical models for subjective risk and property values respectively. Our interpretation of the evidence and conclusions are presented in Chapter 8.

6.1 Data Collection

The first mailing of the surveys commenced on September 4, 1985 and subsequent mailings proceeded according to the schedule outlined by Dillman (1978) and discussed in Chapter 5. Responses began to arrive quickly after the first mailing. Figure 6-I shows the percentage of daily response as a percent of total response over the data collection period and shows three peaks resulting from the three mailings. Figure 6-2 shows the cumulative response which flattens out just above 45 percent of the original mailing sample after adjusting for bad addresses. A fourth mailing would have been very desirable to increase the response rate since the response rate fell below the targeted 50%. The lower than expected response rate may be due to the inherent difficulty of some of the questions asked of respondents as well as suspicions that the survey was sponsored by the Landfill operators. A number of inquiries about sponsorship were received. We carefully examine the data for possible biases in Section 6.3.

After about 6 weeks when survey response had fallen nearly to zero, all surveys collected to that point were screened to check for reasonable

Figure 6-1

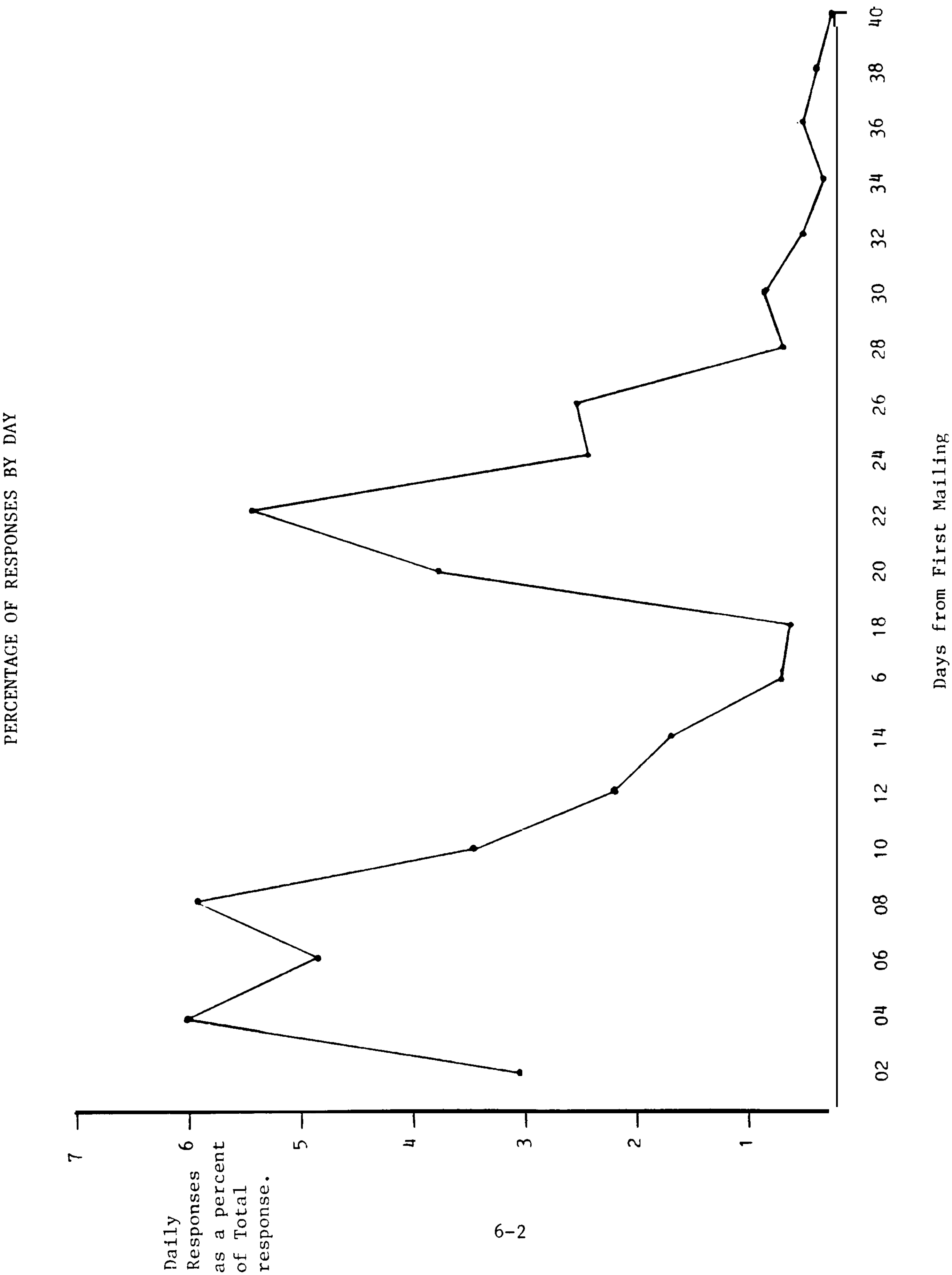
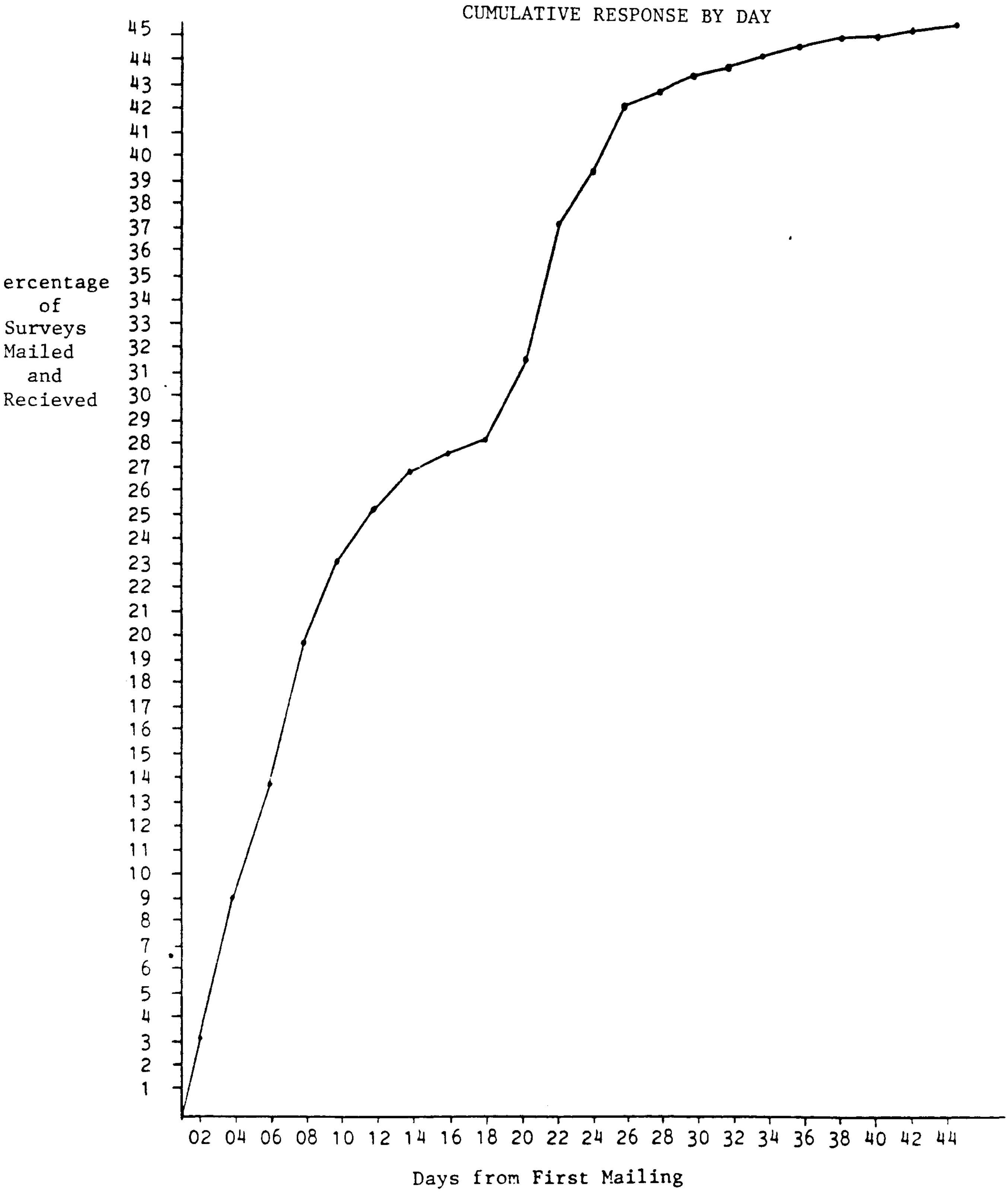

PERCENTAGE OF RESPONSES BY DAY
Daily Responses as a percent of Total response.
7
6
5
4
3
2
1
02
04
06
08
10
12
14
6
18
20
22
24
26
28
30
32
34
36
38
40
Days from First Mailing

Figure 6-2


CUMULATIVE RESPONSE BY DAY
ercentage of Surveys Mailed and Recieved
45
44
43
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
02 04 06 08 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Days from First Mailing

completeness, and surveys found insufficiently complete were excluded from the data coding process. A commerical firm was contracted to code the survey data onto a magnetic tape which could then be computer analyzed. The SPSS statistical software package was used for the majority of the data analysis and description.

After an initial screening of the data it was found that the actual sample of recent home sales numbered less than 50. This prompted a closer look at the existing secondary data to determine which homes had been recently bought but did not already appear as part of our sample which was based on reverse phone directories that do not document residents with unlisted telephone numbers. The addresses of homes that were found to be recently sold and not a part of the initial sample were identified through the L.A. County Property Assessors office and our existing secondary data set. Approximately 100 additional homes were identified and were also surveyed following the same sampling procedures as before (See Chapter 5; Dillman (1978)). This additional sampling resulted in 43 additional completed surveys which could be analyzed. The total number of surveys available for analysis then totaled 768.

6.2 General Results

The first two questions of the survey introduce the respondent to the subject matter of the survey by asking how the OII Landfill may have effected and hypothetically would effect their location decision if they were moving to the area today. Although the landfill was present before most homes in the area were constructed, only 35 percent of the respondents said that they were aware of the landfill when they moved to their current home and only 38 percent of homebuyers since 1983 were aware of the landfill. Of those aware of the landfill, 42 percent said that the

TABLE 6-1

How Did/Would the OII Landfill Affect the Respondents Decision on Where to Purchase/Rent Their Home in the Montebello/Monterey Park Area?

	When they purchased*	Now
	%	%
None	42	8.5
Little	22	9.2
Somewhat	16.0	16.2
Moderately	10.9	15.5
A Great Deal	8.7	50.7

*of the 32.2 percent responding that they were aware of the landfill when they moved into their home.

TABLE 6-2

Respondents Perceived Distance From the OII Landfill.

	%
Dont't Know	9.4
0 to 4 Blocks	16.2
5 to 9 Blocks	19.7
10 to 14 Blocks	21.9
15 to 19 Blocks	15.3
20 to 25 Blocks	17.4
mean	11.1

landfill had no affect on their decision (see Table 6-l). However, over 50 percent responded that the landfill would affect their decision "A Great Deal" if they were deciding today about moving to the Montebello/Monterey Park area today.

Table 6-2 shows how respondents subjectively assessed their distance to the landfill with an average stated distance of about 11 blocks.

Question 4 asked the respondents about the frequency and sources of information about problems at the OII Landfill. Over 70 percent responded that they had read or heard about OII problems "several" or "very many" times with only 6 percent saying that they had not heard or read anything. The local newspaper was selected most often as the “best” source of news and information concerning hazardous waste issues regarding the site (see Tables 6-3 and 6-4).

Questions 5 and 6 asked the respondent to rate the performance of various actors involved with problems at the OII Landfill. Figures 6-3 through 6-8 show how these various actors faired. The homeowners group which is very active in the area (Homeowners to Eliminate Landfill Problems, H.E.L.P.) received the highest ratings and the owners and operators of the OII Landfill received the lowest. The media, local government, state government and EPA filled in the intermediate ratings from relatively high to relatively low respectively.

In response to question 7, 13 percent of the respondents said that they were members of H.E.L.P. or otherwise actively involved with the problems between the OII Landfill and the community. This figure compares with the overall H.E.L.P. membership in the area of 11.2 percent.

Table 6-5 shows the results to Question 8 which asked how bothered the respondent was by problems at the OII Landfill. On the average, residents said they are slightly to moderately bothered by these problems with 27 percent saying they are "very" or "extremely" bothered and 19 percent saying they are not bothered at all.

Questions 9 and 10 asked respondents about their distance to and degree of bother from the Pomona freeway which bisects the OII Landfill. Over 75 percent of the respondents said they were "not bothered" by the highway and their average subjective distance to the highway was about 9 blocks.

Questions 11, 12 and 13 address perceived odor and subjective risks both before and after the closure of the OII Landfill in October 1984. Table 6-6 shows the perceived frequency and intensity of odor problems around the OII Landfill. Both measures of show a decline in perceived odor problems after the closure of the landfill. Question 12 addressed the subjective potential for adverse health effects arising from the OII Landfill. Respondents were asked to view a risk ladder (see Figure 6-9) that identified a number of causes of death and their relative probability of occurrence within the general population. They were then asked to select a letter from the ladder corresponding to the level of risk they subjectively estimated they faced from the OII Landfill both before and after closure. Figures 6-10 and 6-11 show on a bar graph both the subjectively estimated levels of risk and the shift in subjective risk after closure of the OII Landfill.

Question 13 addressed the problem of explosion risk faced by residents due to the natural production of methane gas at the OII Landfill. Respondents were asked to use the risk ladder to identify this subjective risk both before and after closure of the landfill. Again bar graphs (Figures 6-12 and 6-13) are used to show both the magnitude of subjective risk and the effects of closing the landfill on subjective risk.

TABLE 6-3

Frequency of Reading or Hearing About Problems at the OII Landfill.

	%
None	6.4
Rarely	7.0
Few	15.6
Several	32.4
Very Many	38.6

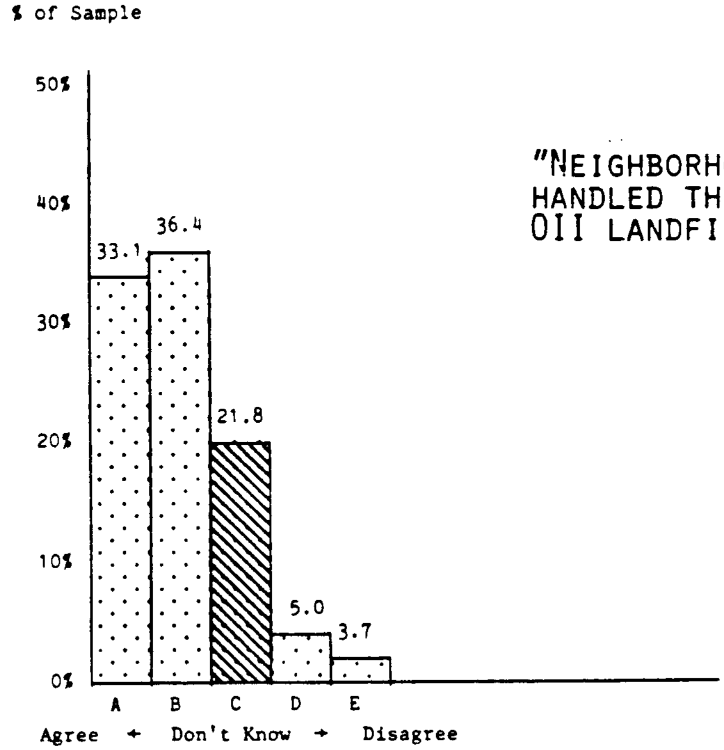
TABLE 6-4

Best Source of News and Information About Hazardous Waste Issues at the OII Landfill.

	%
No Source of Information	2.0
Radio	1.0
Regional Newspapers	8.6
Community Meetings	6.2
Television	12.8
OII Update	.1*
Local Newspaper	62.5
Other	6.9

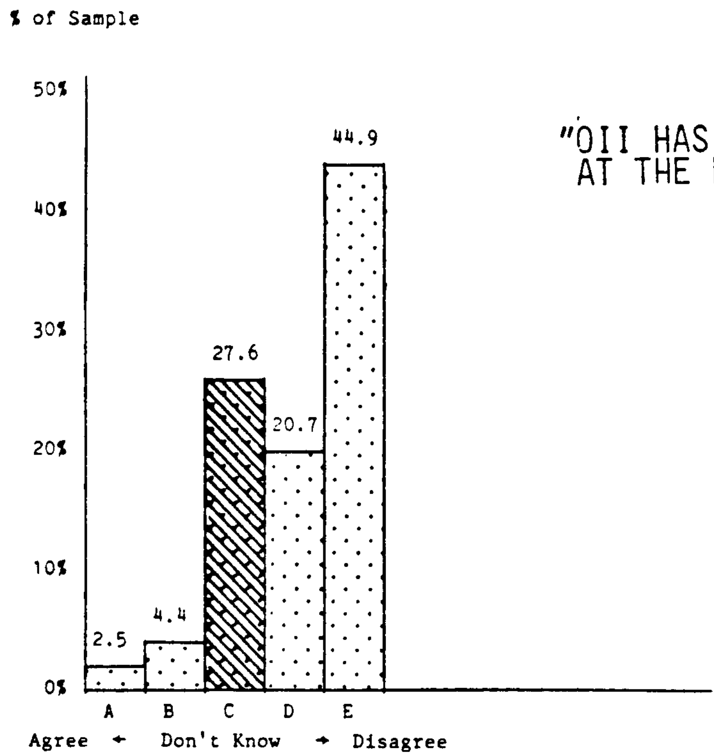
*survey was conducted prior to the first release of the OII update.

FIGURE 6-3



"NEIGHBORHOOD GROUPS HAVE HANDLED THE PROBLEMS AT THE OII LANDFILL RESPONSIBILY"

FIGURE 6-4



"OII HAS HANDLED THE PROBLEMS AT THE LANDFILL RESPONSIBLY"

A Agree strongly
B Agree
C Don't know
D Disagree
E Disagree strongly

FIGURE 6-5

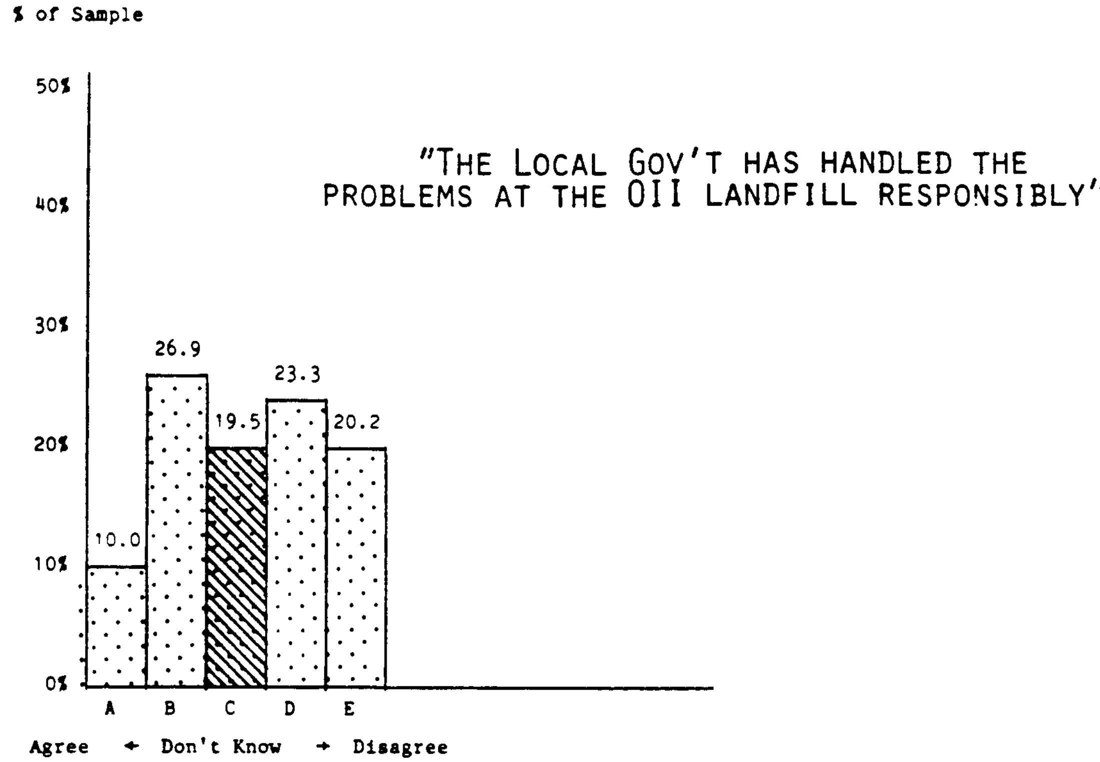
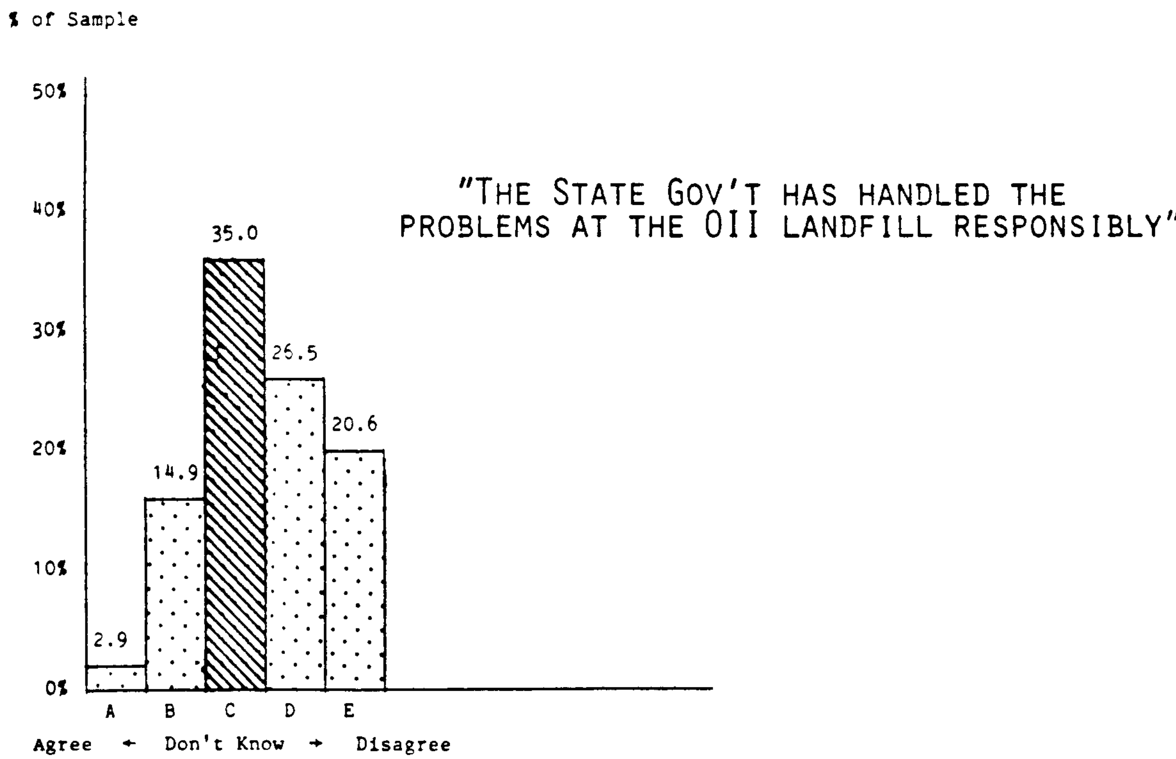


FIGURE 6-6



A Agree strongly
B Agree
C Don't know
D Disagree
E Disagree strongly

FIGURE 6-7

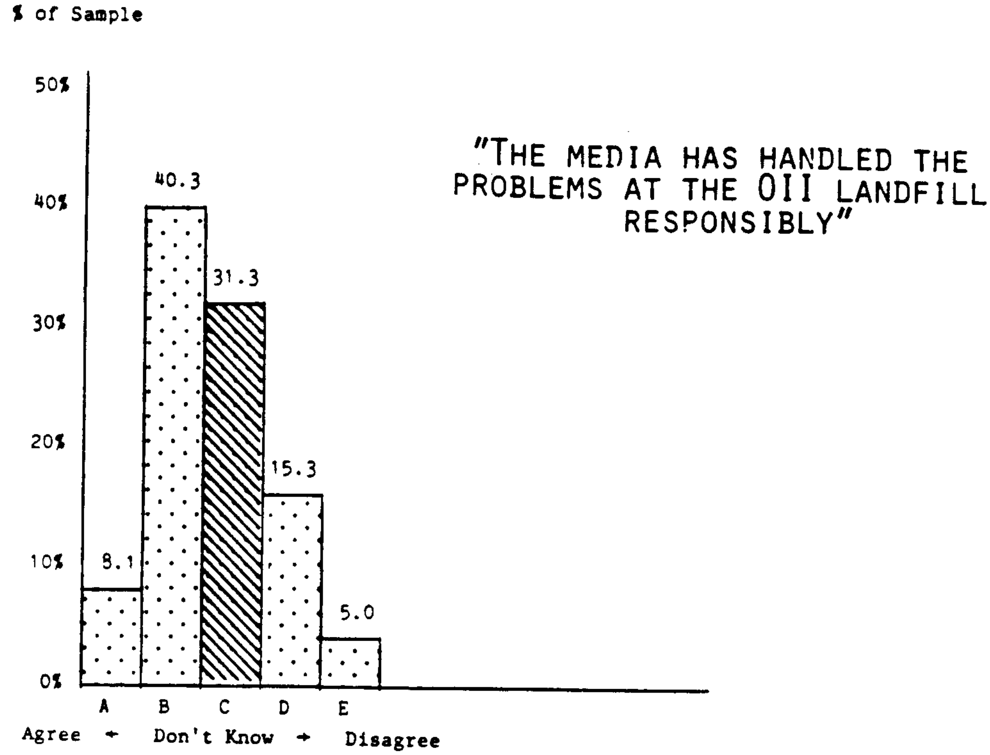
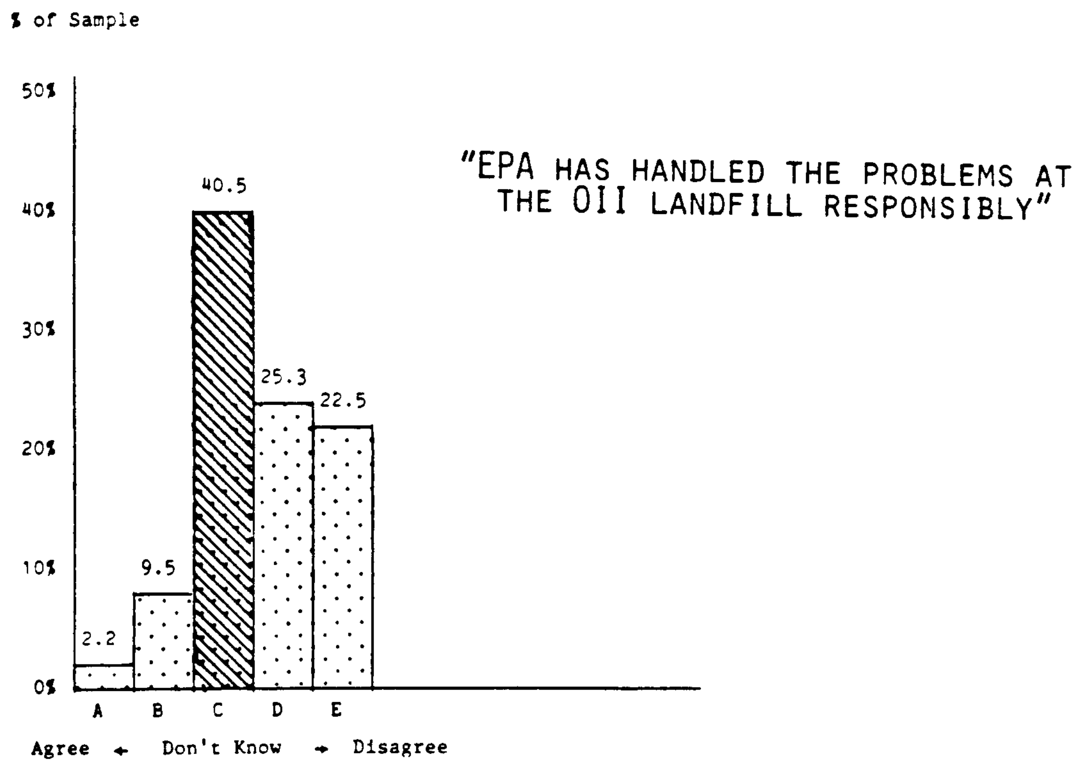


FIGURE 6-8



A Agree strongly
B Agree
C Don't know
D Disagree
E Disagree

TABLE 6-5

How Bothered are Residents by Problems at the OII Landfill

	%
Not at All	19.7
Slightly	28.3
Moderately	24.7
Very	13.9
Extremely	13.4

TABLE 6-6

Perceived Odor Problems Around the OII Landfill

Frequency of Odors	% Before	% After
Never (O days per month)	9.9	17.2
Rarely (l-2 days per month)	16.8	37.5
Occasionally (3-5 days per month)	20.4	24.1
Moderately (5-10 days per month)	21.6	13.5
Frequently (10-20 days per month)	18.8	**5.9**
Very Frequently (20-30 days per month)	12.5	1.7
mean	4.0 days/mo.	1.5 days mo.
Intensity of odors		
barely noticeable 1	4.2	10.7
2	3.6	9.4
3	8.2	15.4
4	7.5	12.2
5	11.6	12.3
6	4.9	10.9
7	12.7	7.5
8	17.1	8.8
9	8.2	3.5
extremely strong 10	21.9	9.3
mean	6.7	5.0

FIGURE 6-9

RISK LADDER
(numbers on steps are deaths per million people per year)

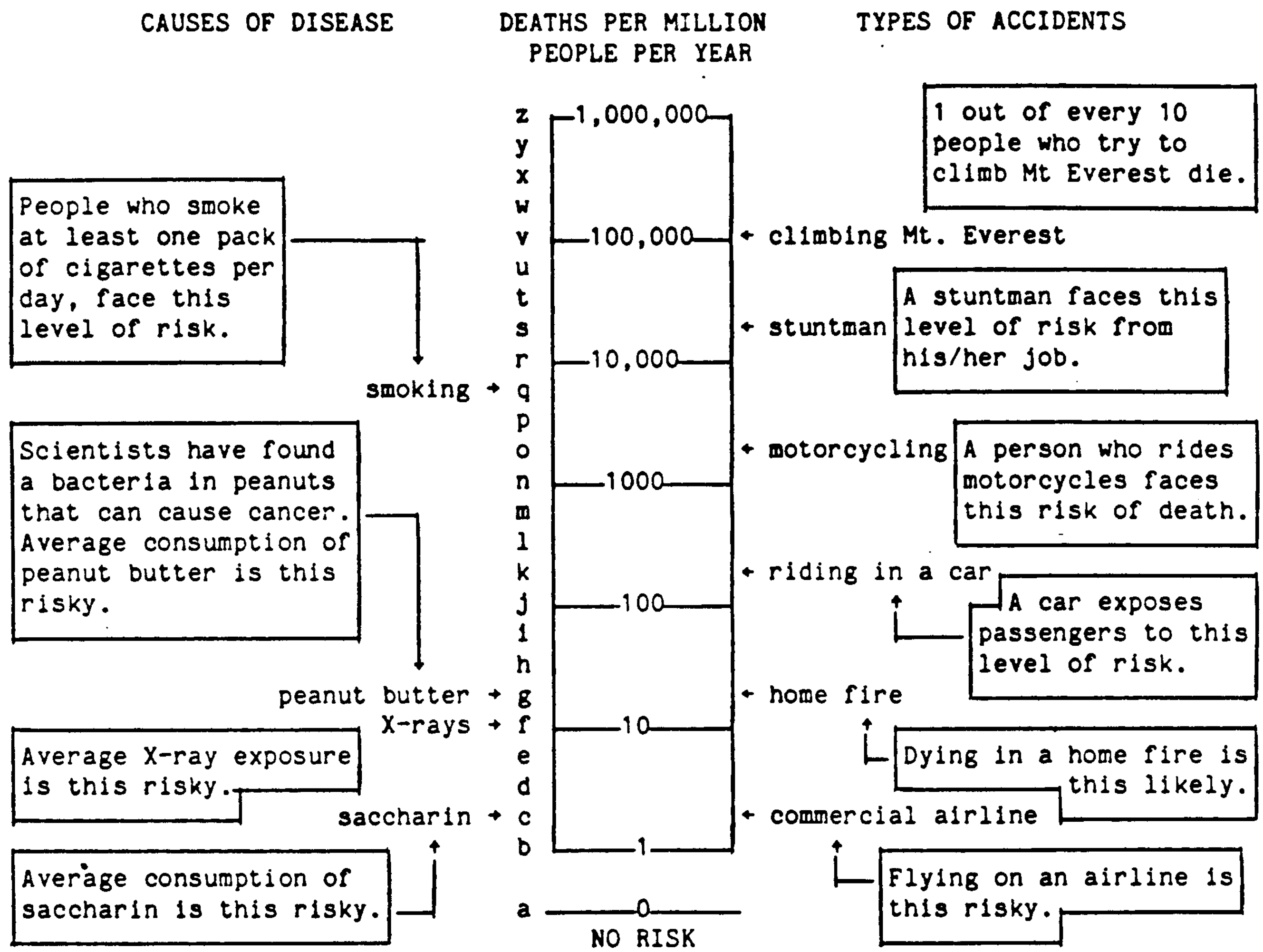


FIGURE 6-10

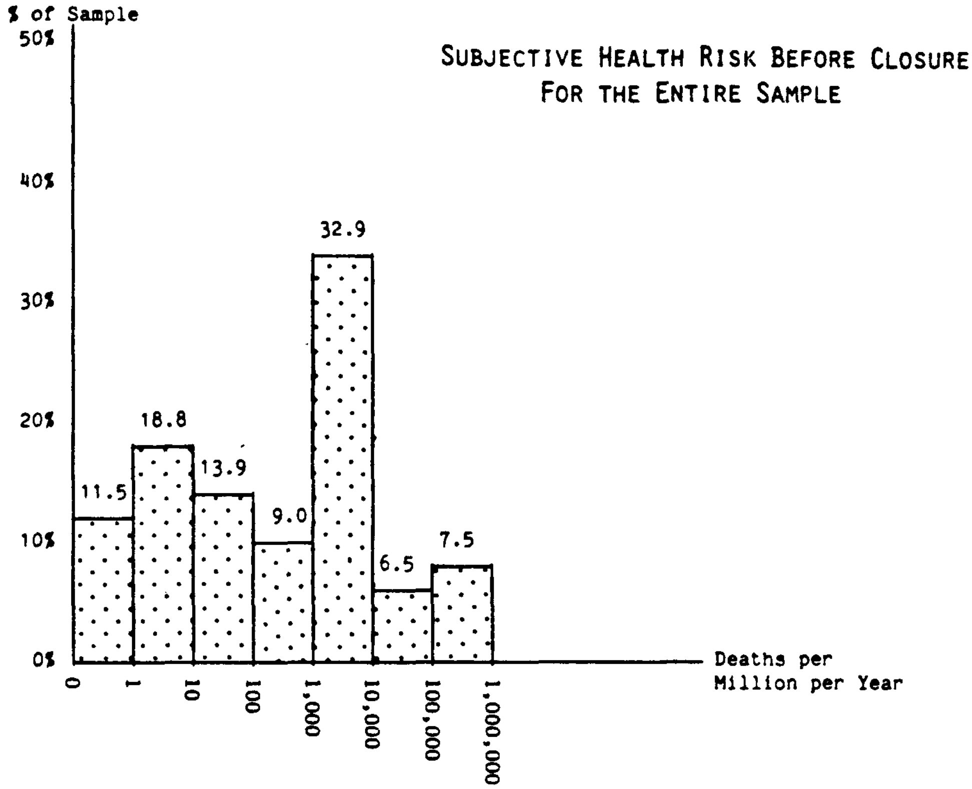


FIGURE 6-11

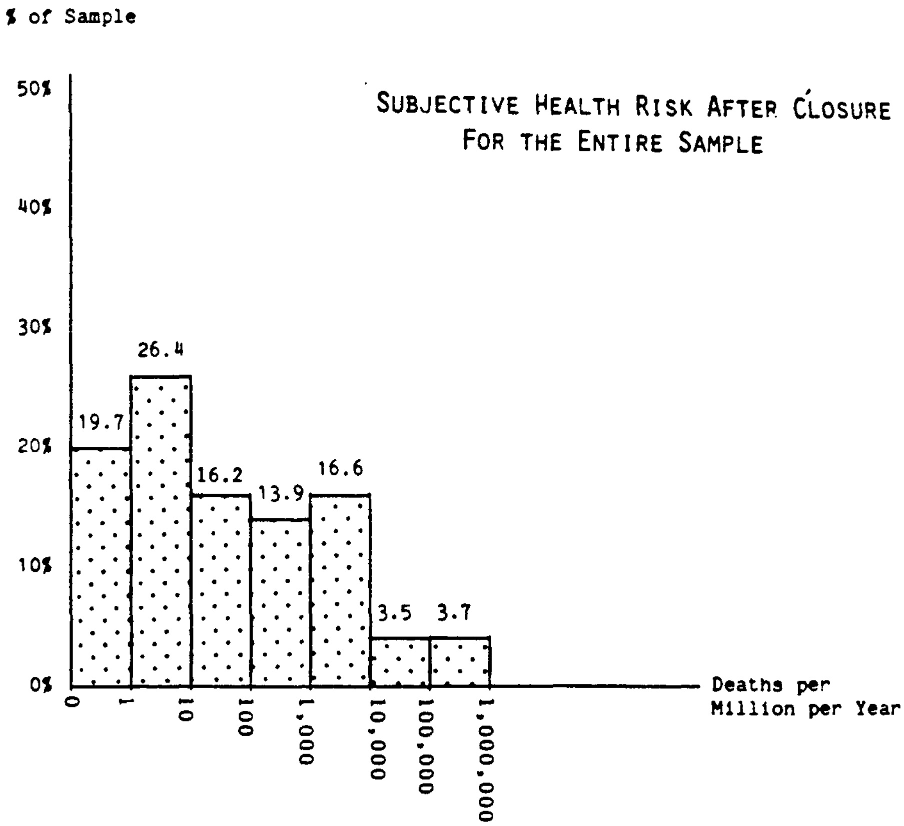


FIGURE 6-12

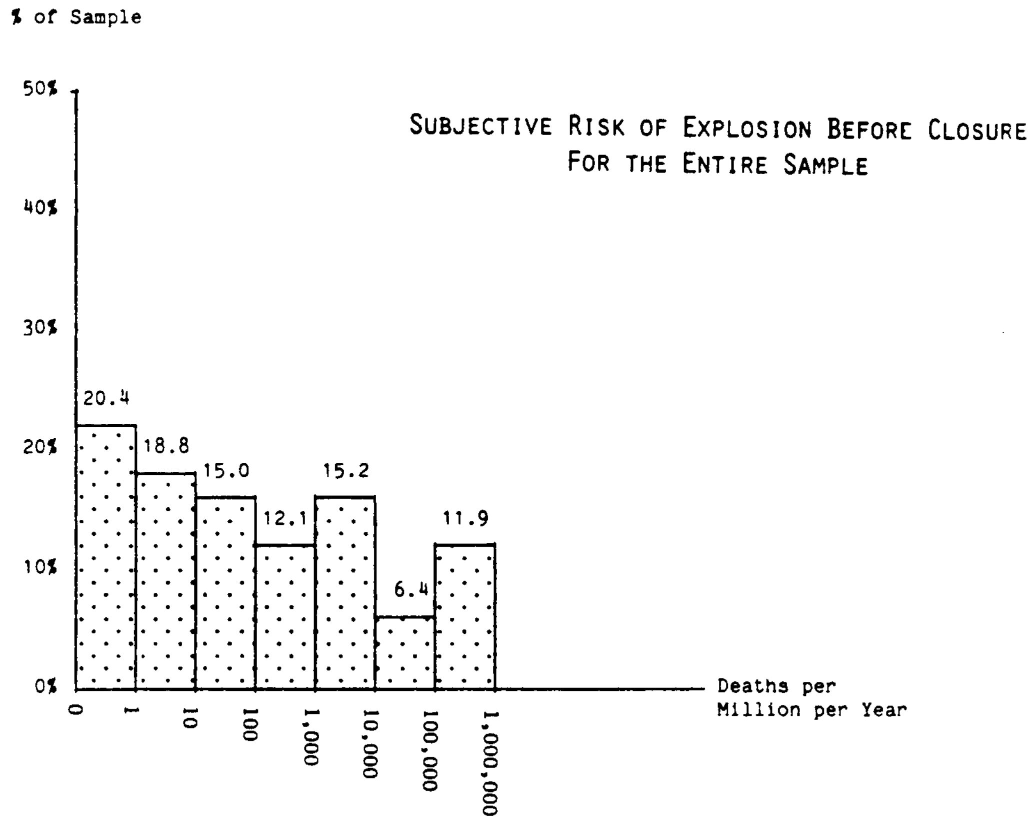
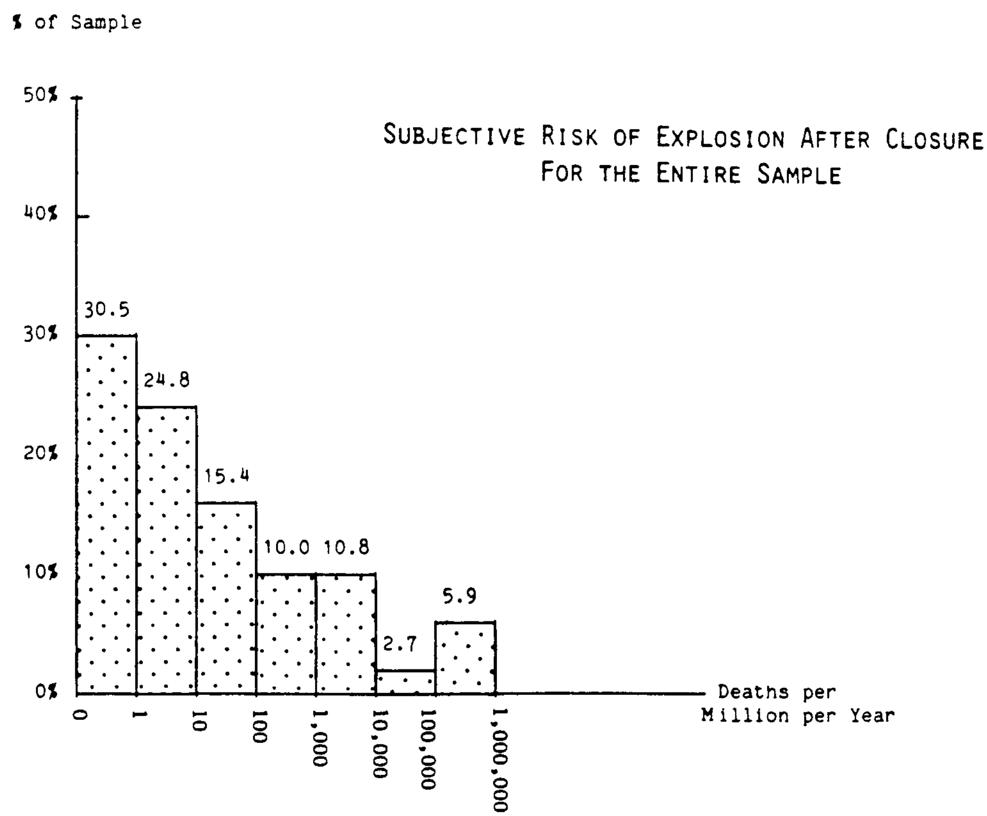


FIGURE 6-13



Questions 14 and 23 asked for contingent values for the closing of the OII Landfill and the presence of the OII Landfill respectively. Two versions of these questions were asked with 50 percent of the sample receiving a willingness to pay (WTP) version and 50 percent receiving a willingness to accept (WTA) version. The two measures of value were chosen in order to further illuminate the disparity between the two measures, which may have psychological or strategic origins, and for comparison with property value effects. Table 6-7 presents a summary of the answers to the two contingent valuation questions.

Questions 15 through 25 elicited information on property values and housing characteristics. Responses included 33 renters with an average monthly rent payment of $709.58. Table 6-8 shows the mean responses to the housing questions.

Questions 26 through 37 gathered socio-economic information and individual behavior data, these results are summarized in Table 6-9. In response to Question 36, 62 percent of the respondents said that they generally wear seatbelts when they travel in cars, and 77 percent said they did not smoke. These questions were asked in order to obtain information on behavior towards risk in contexts other than the OII Landfill problems.

6.3 The Question of Bias in the Survey Response

Hazardous waste issues facing communities and governments are quite divisive and it may be suspected that people who are more strongly active and concerned about problems would be more inclined to respond to a survey. In the case of the OII Landfill, results indicate that the results may not be biased by residents who are H.E.L.P. members and are actively involved with the OII Landfill problems. Members of H.E.L.P. comprise 11 .2% of the residents in the area, which is only slightly less

TABLE 6-7

Valuing the Closure and the Presence of the OII Landfill: Contingent Valuation $ BID/Month

Valuing the closure of the OII Landfill

	mean	SE mean	median	N	#$0Bids
WTP bids	$88.02	18.34	10.00	250	67
WTA bids	$835.20	99.66	299.80	179	43

Valuing the Presence of the OII Landfill

WTP bids	$221.73	24.25	24.72	272	69
WTA bids	$751.38	63.62	499.93	218	29

TABLE 6-8

Mean Housing Characteristics of Homes Near the OII Landfill

Year home was purchased	1970.3
Month home was purchased	6.9
Purchase Price of home	$118,593
Purchase price of home adjusted by CPI	$152,479
Hypothetical List Price if home were put on market today	$161,170
Mean Square feet	1983
% with a scenic view#	42.3
% with a swimming pool	13.4
% with a fireplace	77.3
Avg. # of bathrooms	2.23
Avg. # of bedrooms	3.39
Year home was built	1961.7
Avg. perceived quality of schools	Average (2.37 on a 4 point scale)
% expecting to move within 5 years	22.0

This number is a subjective estimate of the presence of a scenic view from the property and does not necessarily reflect a real estate appraisers assessment as presented in the secondary property value data.

TABLE 6-9

Socio-economic Characteristics of Residents Near the OII Landfill

	Population(%)	Sample($)
ETHNICITY		
White	34	27
Black	0	0
Native American	0	6[1]
Oriental/Asian	29	42
Hispanic	26	21
Other	11	4

[1] respondents may have interpreted as simply meaning born in U.S.A.

EDUCATION		
0 - 8 Grades	13.2	3
1 -3 Years High School	10	6
Finished High School	31	18
Some College or Trade School	22	30
4 or More Years College	24	43
OCCUPATION		
Managerial	22	29
Technical	37	21
Service	9	15
Farm, Forestry, Etc.	0	1
Precision	12	6
Laborer	22	4
Retired	NA	24
INCOME*		
Under 10,000	12	4
10,000 - 19,999	24	9
20,000 - 24,999	14	8
25,000 - 34,999	22	18
35,000 - 49,999	17	26
50,000 +	10	34
Mean	28,130	40,700

*1979 data

TABLE 6-9 (Con't)

AGE			
Total Population	12,449	751	
0 - 24		39.3	39.#
25 - 34		16.6	8.4
35 - 44		13.4	12.2
45 - 54		12.8	13.4
55 - 64		10.5	14.9
65 - 74		5.4	9.3
75 +		2.2	2.2
Mean		32	36

#Assumed to be equal to population figure because survey did not sample this age group.

SEX*		
Male	49	77
Female	51	23

*surveys were completed by heads of households who were predominately male.

than the proportion of completed responses received from this group. We received 100 survey responses from H.E.L.P. members, equal to 13% of the sample. This corresponds well with the expected number of responses suggesting that an over-response from H.E.L.P. members did not bias the results.[1]

We now turn to possible bias in sampling procedures. We obtained the names and addresses of residents in the sample area using reverse telephone directories. In this area of California, however, unlisted phone numbers are quite common and may represent up to 50 percent of the homes. This leads to a potential bias due to the oversampling of homes with listed telephone numbers relative to homes with unlisted telephone numbers. There is no a priori indication that this situation should lead to biased estimates, but the data collected allows this question to be explored. Through the secondary data obtained for the home sales near the OII Landfill, we were able to identify approximately 100 recently sold homes which had unlisted phone numbers. Obtaining the names and addresses of these residents from L.A. County property records, we followed the same Dillman mail survey sampling procedure previously described in order to sample residents of recently bought homes with unlisted telephone numbers. As previously noted, we received 43 completed responses through this additional sampling.

In comparing responses from residents with listed telephone numbers to responses from and residents with unlisted telephone numbers,

[1] 460 Households belong to H.E.L.P of the 4,100 homes located in the sample area. This implies that

$$\frac{460}{4,100} \times 100 = 11.2\%$$ of responses should be from H.E.L.P. households. In comparison, 100 H.E.L.P. households gave complete reponses out of 768 complete surveys which were returned. Thus, $\frac{100}{768} = 13.0\%$ of complete responses were obtained from H.E.L.P.

we selected a subsample of recent home buyers who purchased their home since 1983 including 28 responses from residents with unlisted telephone numbers. Table 6-10 shows that there appears to be very little variation in response due to the status of the telephone listing. There are only slight differences in the perception of odor and subjective health risks. Table 6-10 compares socio-economic characteristics between the two subsamples. In this comparison there appears to be some significant differences. Oddly enough both subsample sex ratios differ significantly from the ratio from the entire sample where male respondents contributed to 76 percent of the response. However, in the cases of these recently bought homes, female respondents outnumbered their male counterparts. In addition, there appears to be significant differences in the ethnic composition. The first notable difference appears in the shift in the composition in recent homes buyers from the overall survey response figures. Minority groups (e.g., oriental and hispanic) appear to be moving into the area at a higher rate than Caucasians. The second notable difference is that minority groups appear to have a higher incidence of unlisted telephone numbers among recent home buyers. However, the presence of the socio-economic differences appears not to have greatly affected responses for subjective risks, an issue we explore in the following Chapter.

TABLE 6-10

Comparison of Recent Homebuyers (since 1983) with Listed and Unlisted Phone Numbers

$Mean/SE_{mean}$	Unlisted Phone	Listed Phone
Subjective distance (Blocks)	7.3/0.30	7.2/0.29
Frequency of Hearing or Reading about problems at the OII Landfill	3.36/.27	3.32/.22
Perception of various agents involved with problems at the OII Landfill (the lower the number the better the agent is perceived)		
Media	3.07/.9	3.00/.15
EPA	3.57/.20	3.58/.15
State Gov't	3.50/.22	3.59/.13
Local Gov't	2.96/.23	3.03/.20
Operating Ind.	3.81/.23	4.03/.19
Neighborhood groups	2.35/.24	2.54/.18
How bothered are residents by OII Landfill problems (scale 1-5)	2.43/.24	2.21/.19
Perceived Odor Problems[1]		
Before Closure	18.33/3.18	16.96/2.96
After Closure	11.27/2.82	7.36/1.89
Perceived Health Risks[2]		
Before Closure	9.12/1.54	12.23/1.24
After Closure	8.32/1.59	7.43/1.03
Perceived Methane Explosion Risk[2]		
Before Closure	9.09/1.93	8.68/1.45
After Closure	6.08/1.51	7.00/1.47
NOBS	28	36

[1]means based on the product of frequency and intensity on a scale of 1 to 50.

[2]mean of reported risk level from "Risk Ladder" on a scale of 1 to 26.

TABLE 6-11

Socio-economic Comparison of Recent Homebuyers (since 1983) with Listed and Unlisted Telephone Numbers

	Unlisted Phone	Listed Phone
Mean age of respondent	37.1	38.8
Sex Ratio (male/Female	35.7/64.3	11.1/88.9
Ethnic Composition (%)		
White	3.7	20.0
Oriental/Asian	59.3	48.6
Hispanic	33.3	22.9
Native American	0	2.9
Other	3.7	5.7
Mean income ($)	47,962	45,000
NOBS	28	36

CHAPTER 7

DATA ANALYSIS

7.0 Introduction

This Chapter analyzes the data obtained on the Operating Industry, Inc. Landfill both from primary and secondary sources. The goal of this analysis is to understand the source of the substantial drop in property values observed near the landfill from the perspective of both economics and psychology. However, most interpretation is deferred until the next Chapter where the implication of the various component analyses of this Chapter are drawn together. We begin with an assessment of objective health risks from the landfill so that these may be compared to the analysis of the residents' subjective assessment of health risk. The effects on property values around the site are then explored with the use of an econometric model incorporating measures of subjective health and explosion risk and odor as possible causal factors impacting property values. Since it appears that the primary impact of the site on property values is associated with subjective health risk, we then undertake a detailed statistical analysis of factors which may effect health risk judgments. Values for cleanup and closure of the landfill (economic benefits) obtained from the property value study are then developed and compared with the corresponding survey bids to further help understand the psychological factors underlying the initial property value decline.

7.1 Objective Risks from the Operating Industries Inc. Landfill

Two approaches can be used to assess health risks facing residents in the area around the OII Landfill. An estimate can be made directly of the possible excess cancer risk based on measured offsite levels of vinyl chloride gas. Alternatively, existing data on the health status of residents near the site can be examined. Application of each of these approaches shows that health impacts to the residents near the site are now likely to be small. However, unknown health risks may exist for the site which we cannot now quantify or observe. This may be the case for some unknown agent which has long term health impacts.

First, the presence of vinyl chloride gas which has been monitored in association with offsite landfill gas could produce a significant health risk to residents in the area. A review of the literature on the effects of vinyl chloride indicates that a rare form of liver angiosarcoma is associated with exposures to vinyl chloride. In 1976, EPA included vinyl chloride on its list of hazardous air pollutants that required regulation under the Clean Air Act. The highest concentration of vinyl chloride that has been reported to date in a residential area adjacent to the OII Landfill occurred on July 22, 1983 and measured 19 ppb.[1] However, no detectable concentrations of vinyl chloride (above 2 ppb) have occurred over the Past Year (Roberts) 1986). The USEPA Carcinogen Assessment Group estimated in 1985 that the unit risk for exposure to vinyl chloride over a 70 year lifetime at a concentration of 1 micro-gram per cubic meter is 2.6×10^{-6} (USEPA, 1985). Thus, if a population were exposed to vinyl chloride at a 1 micro-gram per cubic meter concentration over a 70 year period, the incidence of cancer would be expected to increase by 2.6 cases per million people. This figure corresponds to a concentration of .38 ppb, which, if adjusted linearly from a 70 year exposure to a one year exposure, is equivalent to 26.9 ppb, 140 percent of the highest monitored level. Dividing the EPA unit risk for exposure by 1.4 gives an estimated annual risk of $1.86 \times 1O^{-s}$ for residents exposed at 19 ppb for one year. This roughly corresponds to step "c" on the risk ladder presented to respondents (a risk of about two in a million) on the assumption that all cases result in death. However, residents nearest to the OII Landfill have lived there as long as nine years (since 1977). The maximum cumulative risk might then be as much as nine times higher or 16.7×10^{-6}, about step "g" on the risk ladder. It should be noted that these risk calculations are likely to be grossly exaggerated since the 19 ppb level used represents the highest 24 hour average value ever obtained near the site and since vinyl chloride concentrations have been below detection for the past year (Roberts, 1986). EPA has taken random air sample in 12 homes in the area and has found no detectable levels of vinyl chloride gas. Thus, our assumed exposure of 19 ppb cannot be characterized as typical for any individual living near the site but rather represents an extreme upper bound assessment on possible exposure.

The second approach to assess objective health risks has been undertaken by the L.A. County Department of Health Services in a health study performed in 1983. This study utilized existing health data available by census tract to examine conception outcomes, mortality and morbidity in the vicinity of the OII Landfill and to compare the results with expected rates from the rest of L.A. County.

Data on conception outcomes for the years 1978 through 1981 was examined. The data included the number of births, ethnicity, birthweight, and the number of fetal deaths. The fetal, neonatal and infant mortality experience of the study area, after adjusting for ethnic composition, was compared to the rest of L.A. County. The ratios of observed to expected rates are as follows: fetal death 0.72; neonatal death 0.49; infant death 0.90 and low birthweight 0.76.

Mortality data from the years 1978 through 1981 included age, sex, race, year and cause of death. When the data is adjusted for age, none of the observed/expected ratios were greater or equal to 1. For most cancer sites, even the unadjusted number was less than that expected except for colon/rectum, breast and ovary cancers where the ratios were 1.17, 1.23 and 1.19 respectively. After adjusting for age and ethnic composition these ratios fall below one, suggesting that current health has not been significantly affected by the landfill.

School absenteeism data was examined for the 1981-82 and 1982-83 school years as a check for increased morbidity. In elementary schools the excused absence rate in 1981-82 was slightly higher in the control area schools than in the study area schools. This pattern was reversed during the 1982-83 school year. The evidence does not suggest excess illness in the area.

It should be also noted that the California State Department of Health Services has conducted a door-to-door health survey in the area. However, the results of this new study which makes a detailed examination of morbidity will not be made available until June of 1986.

In summation, it appears from the existing evidence that the health risks facing the community surrounding OII are likely to be small. However, the new health study now underway may force a revision in this conclusion. Finally, it should be noted that since the latency period between exposure and onset of cancer is often greater than 10 years, a degree of uncertainty must surround these studies.

7.2 Subjective Risk and Problem Assessment

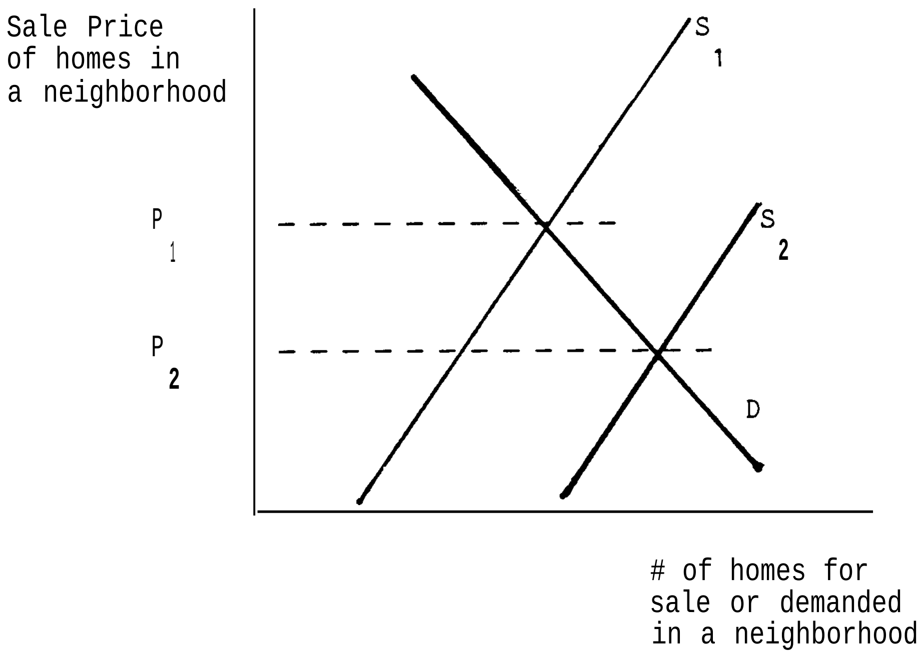
Questions 11, 12 and 13 of the survey inquire quantitatively about the respondents' perception of odor, health and explosion problems arising from their proximity to the OII Landfill. In this section, the responses to these questions on perception and judgments of risk are analyzed.

Neighborhood Groups and Spatial Characteristics

Since the primary focus of this study is use of the property value approach to determine damage estimates, we have attempted to analyze the role of perception and risk judgments by residents on the real estate market in the area around the OII Landfill. In the previous section we reported mean characteristics and responses of individuals to the perception and subjective risk questions from the survey. However, in analyzing the real estate market near the OII Landfill, individual perceptions and attitudes are of less importance than the collective perceptions and attitudes of individuals residing in various neighborhoods.

Although, as shown in Chapter 3, residents may well be willing to sell at a price adjusted downward by their willingness to pay to avoid any subjective risk associated with proximity to the OII Landfill, they are likely to list homes, after consulting a realtor, at the "going" market rate. Thus sellers will attempt to obtain a price higher than their actual willingness to sell. In effect, sellers will try to obtain some consumer surplus as is normal in all competitive markets. In fact, as shown in Figure 7.1, in a neighborhood, the supply curve will be shifted to the right to the extent that homeowners within a neighborhood feel that the OII poses a risk.

Figure 7-1



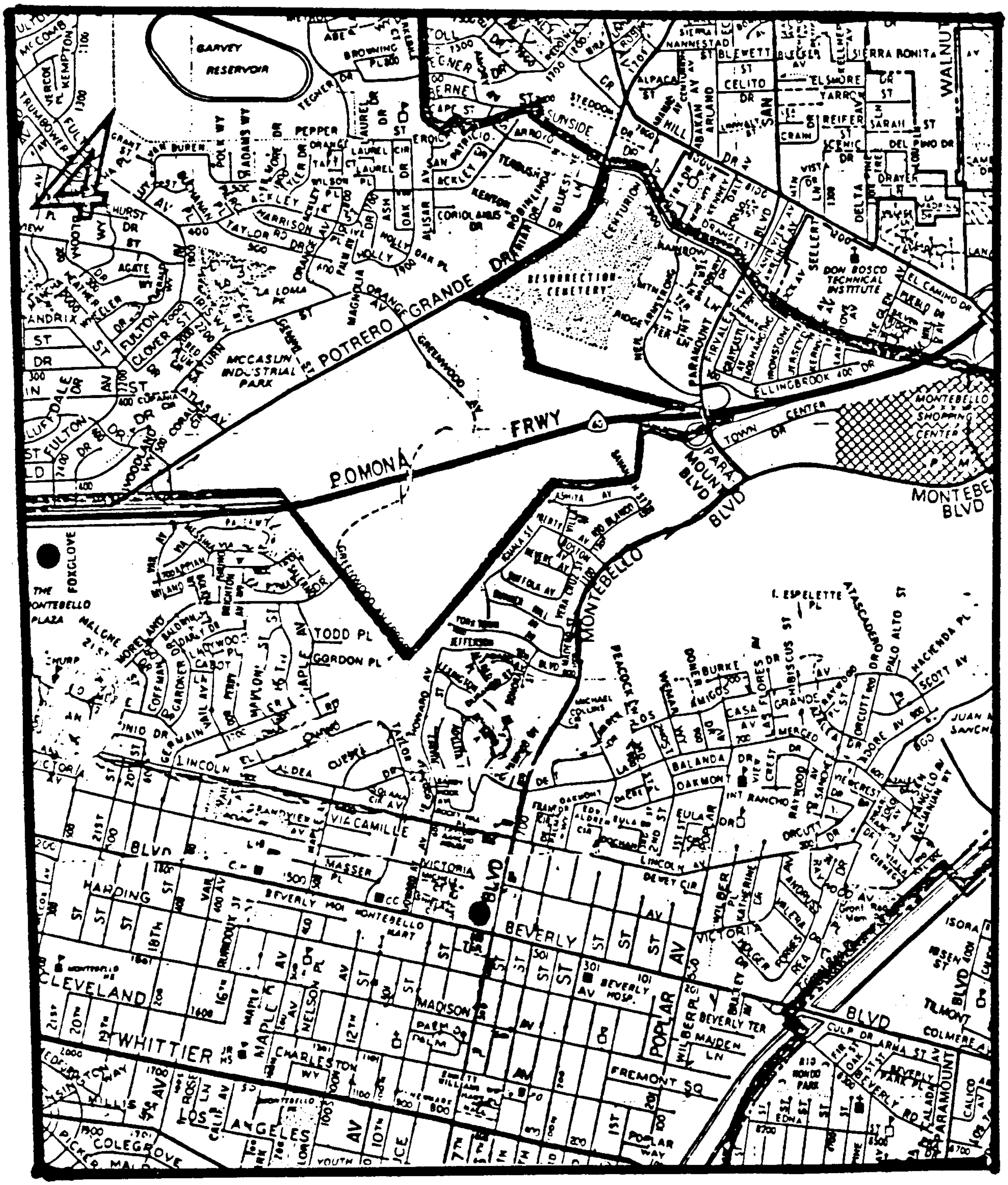
Thus, the greater the percentage of homeowners in a neighborhood who feel that the OII Landfill poses a threat, the further the supply curve S_2 will be shifted to the right relative to supply curve S_1, which is drawn on the assumption that no homeowners in the neighborhood feel threatened by the site. Thus, the observed price for homes in a particular neighborhood, P_2 in Figure 7-1, will fall relative to P_1 as more homeowners in a neighborhood feel threatened. Note also, that individual homeowners who lie along the supply curve S_2 below P_2 will likely list their homes at price P_2, not at their minimum willingness to accept. Unfortunately, we have no information on the subjective risk beliefs held by potential purchasers who make up the demand curve, but note that sixty-two percent of recent purchasers were not aware of the site when they bought their homes, despite local requirements for information disclosure to new buyers. Those that were aware may, of course, have lowered their offered bids, shifting the demand curve downward to the left, causing a further decline in observed prices. Since we have no data on subjective risks by neighborhood for prospective purchasers, we must assume that the subjective risk of residents measured for each neighborhood around OII can proxy for that of purchasers in our reduced form estimated property value equation. Thus, we focus on the development of neighborhood rather than individual measures of perceived odor problems subjective health risk and explosion risk.

In order to provide the spatial distribution of these variables for the property value study, households responding to the survey were plotted on an aerial photograph of the area. Using the aerial photograph, the area around the site was then parcelled into neighborhoods with about 10 to 15 data points in each neighborhood (see Figures 7-2 and 7-3). Having identified responses within a given neighborhood, perception characteristics can be attributed to homes sold in neighborhoods and used as independent variables in the property value study presented in Section 7.3. These neighborhood characteristics are described below.

Odor

Odor problems have been associated with the OII Landfill since the mid 1970's when homesites near the landfill were developed. Figures 7-4 and 7-5 show frequency distributions of perceived odor problems both before and after closure of the landfill for the whole sample and by distance for the before closure odor perception. These results show a decreasing problem with distance from the landfill. Figures 7-6 and 7-7 show how odor problems were perceived in both neighborhoods around the OII Landfill

FIGURE 7-2


GARVEY RESERVOIR
POTRERO GRANDE DR
POMONA FRWY
McCASLIN INDUSTRIAL PARK
RESURRECTION CEMETERY
DON BOSCO TECHNICAL INSTITUTE
MONTEBELLO SHOPPING CENTER
TOWN CENTER DR
MONTEBELLO BLVD
PARAMOUNT BLVD
THE MONTEBELLO PLAZA
FOXGLOVE
TODD PL
GORDON PL
LINCOLN AV
BEVERLY BLVD
CLEVELAND
WHITTIER BLVD
WALNUT
GREENWOOD AV
FREMONT SQ
COLEGROVE

NEIGHBORHOODS USED IN THE OII STUDY

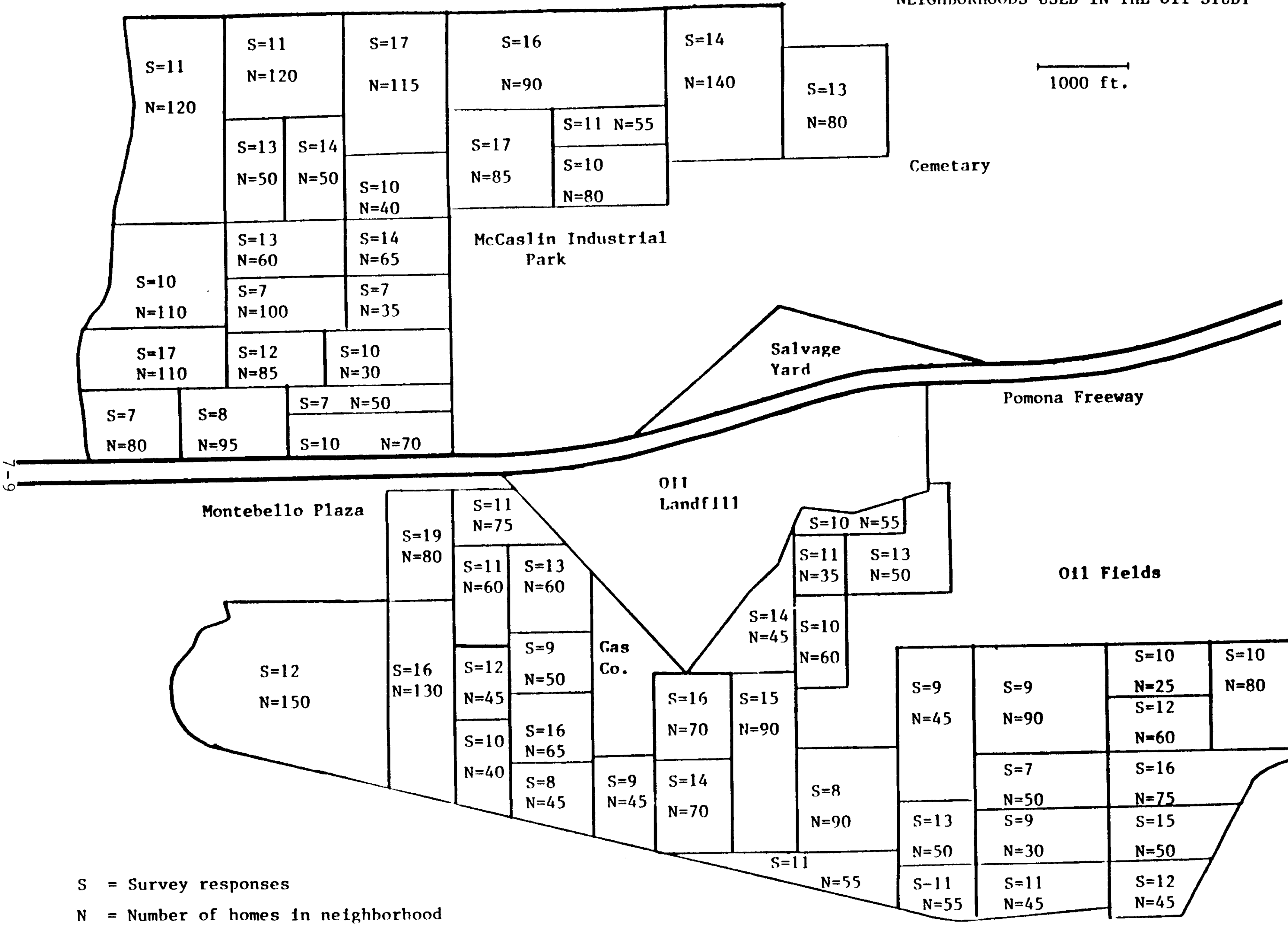
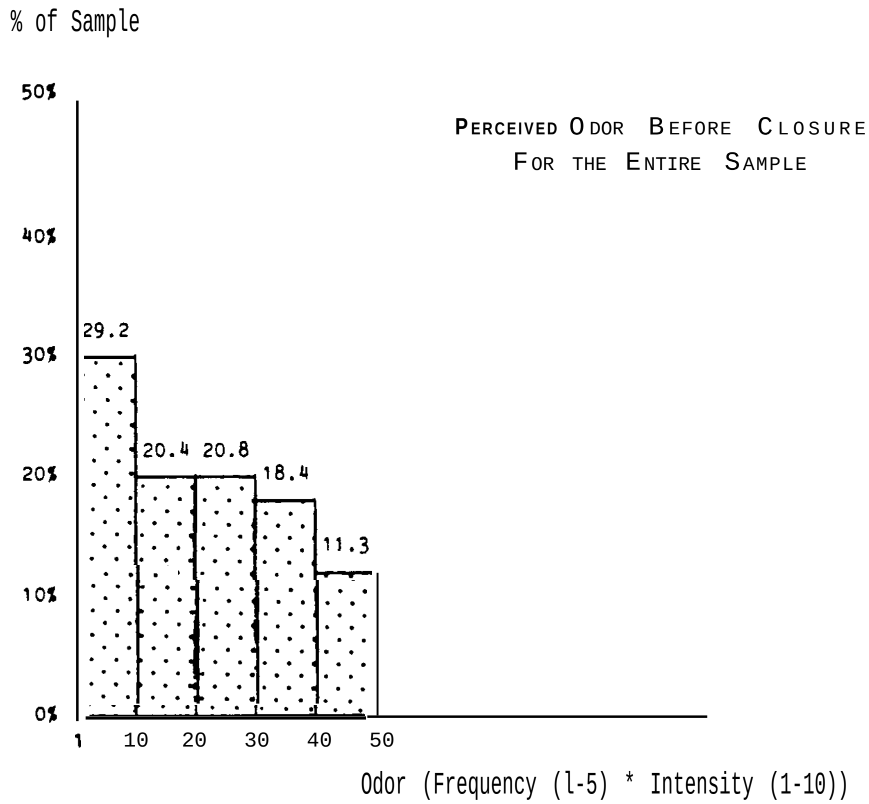


FIGURE 7-5

FIGURE 7-4


% of Sample
50%
40%
30%
20%
10%
0%
PERCEIVED ODOR BEFORE CLOSURE
FOR THE ENTIRE SAMPLE
29.2
20.4
20.8
18.4
11.3
1
10
20
30
40
50
Odor (Frequency (l-5) * Intensity (1-10))

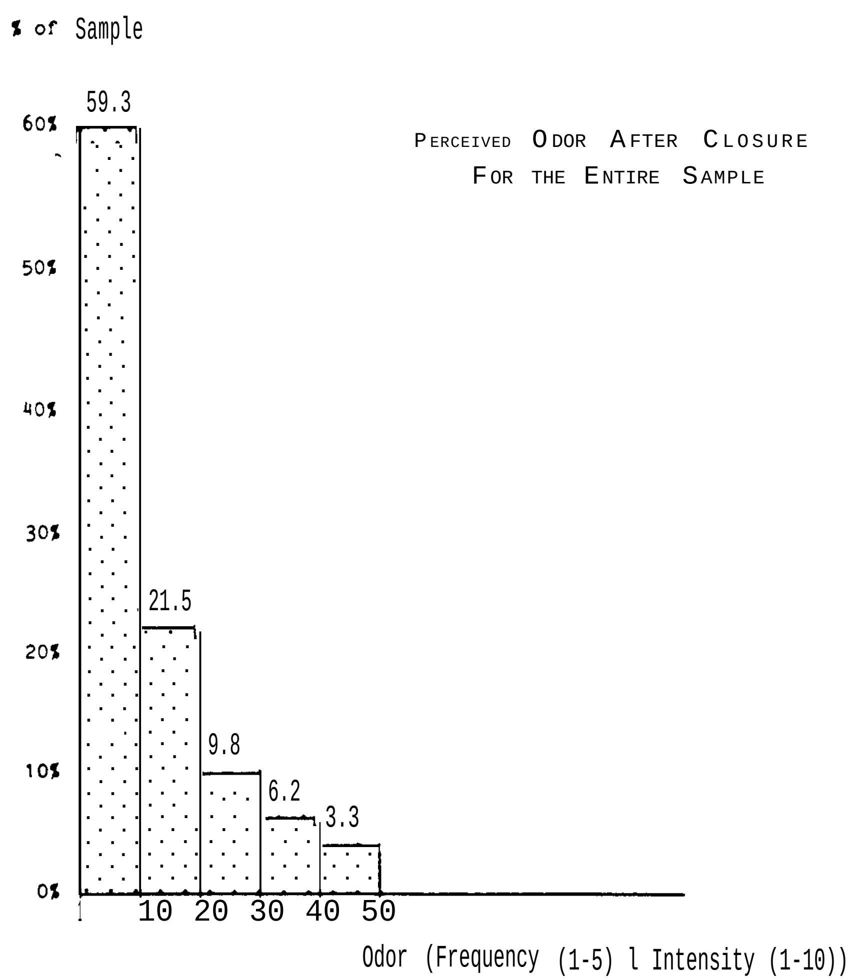
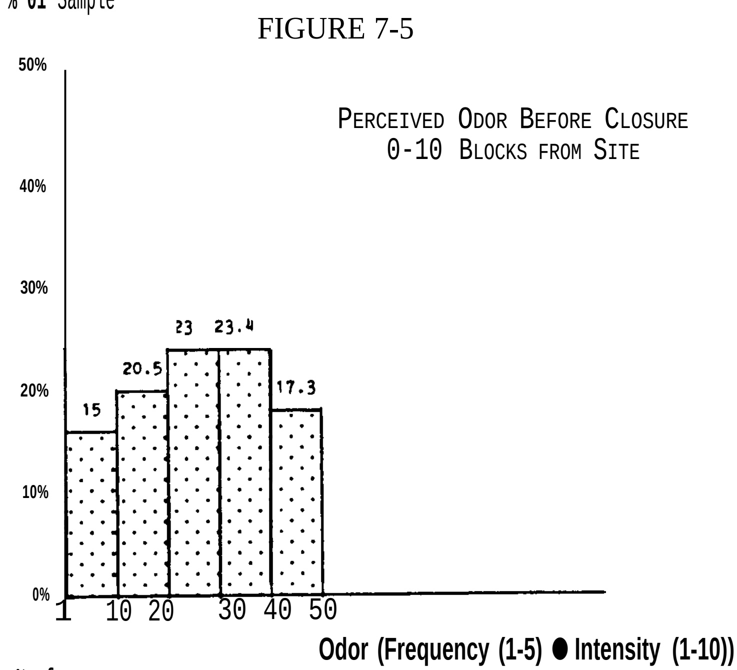
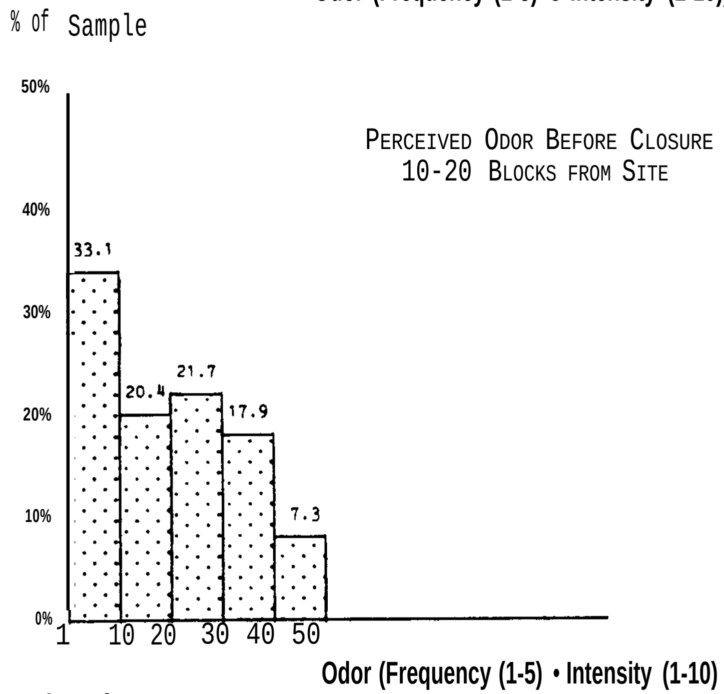

% of Sample
60%
50%
40%
30%
20%
10%
0%
PERCEIVED ODOR AFTER CLOSURE
FOR THE ENTIRE SAMPLE
59.3
21.5
9.8
6.2
3.3
1
10
20
30
40
50
Odor (Frequency (1-5) l Intensity (1-10))

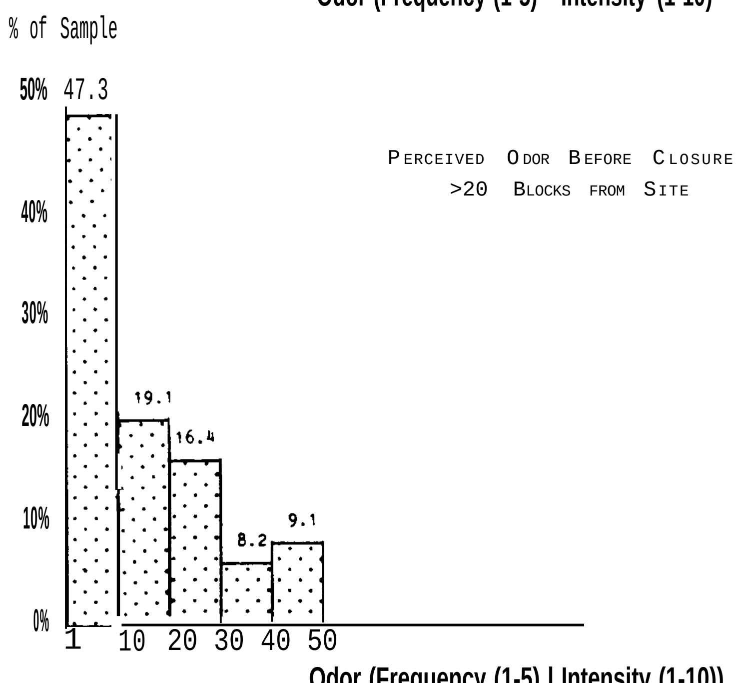
FIGURE 7-5



% of Sample
50%
40%
30%
20%
10%
0%
PERCEIVED ODOR BEFORE CLOSURE
0-10 BLOCKS FROM SITE
15
20.5
23
23.4
17.3
1
10
20
30
40
50
Odor (Frequency (1-5) ● Intensity (1-10))



% of Sample
50%
40%
30%
20%
10%
0%
PERCEIVED ODOR BEFORE CLOSURE
10-20 BLOCKS FROM SITE
33.1
20.4
21.7
17.9
7.3
1
10
20
30
40
50
Odor (Frequency (1-5) • Intensity (1-10)



% of Sample
50%
40%
30%
20%
10%
0%
PERCEIVED ODOR BEFORE CLOSURE
>20 BLOCKS FROM SITE
47.3
19.1
16.4
8.2
9.1
1
10
20
30
40
50
Odor (Frequency (1-5) I Intensity (1-10))

Figure 7-6

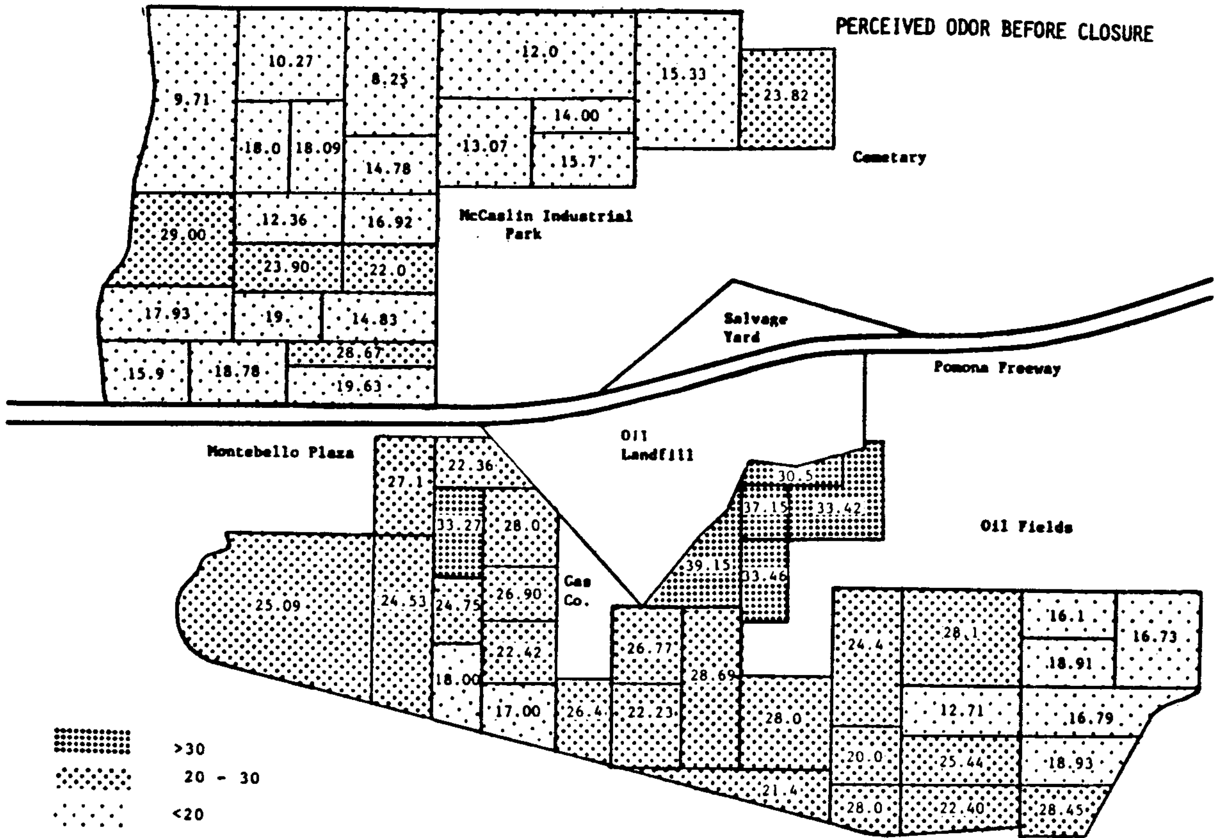
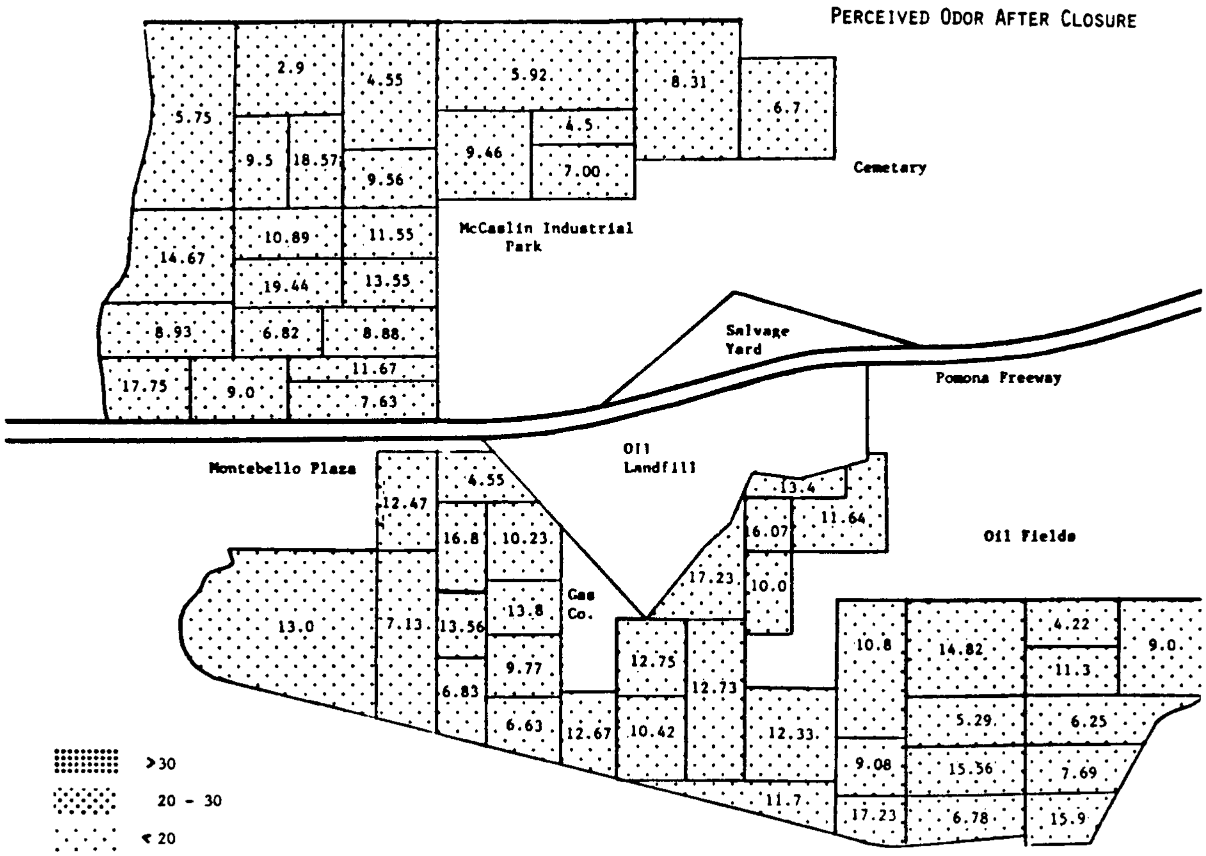


Figure 7-7



before and after closure. Each neighborhood was assigned the mean value from residents in the neighborhood of a single odor variable constructed as the product of frequency and intensity of odor problems. From these Figures it is apparent that proximity to the landfill is the primary factor influencing perceived odor problems. The shift in perceived odor from before to after closure is also readily apparent suggesting that closure did have a large impact on perceived odor near the site.

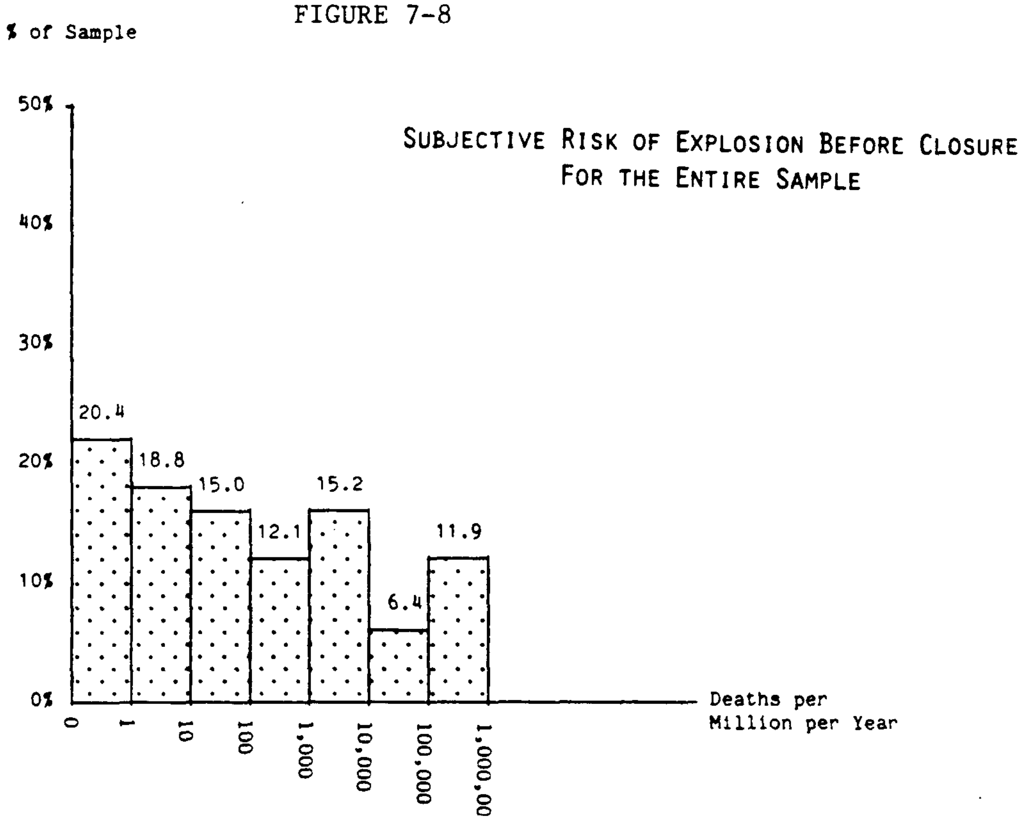
Explosion Risk

The production of methane gas is a natural process of landfill aging. The buildup of methane gas has led to several underground fires at the OII Landfill and methane gas has been measured offsite leading to concerns that possibly explosive levels might collect near the site. This has led to an extensive methane gas monitoring effort and the development of a gas collection and recovery system around the site. Figures 7-8 and 7-9 show the quantitative distribution of subjective explosion risk around the site both before and after closure of the landfill and by distance before closure. The results show a significant downward shift with the closing of the site. Figures 7-10 and 7-11 show how this risk is judged both before and after closure of the landfill around the site. The number associated with each neighborhood represents the mean level of risk identified from the risk ladder for residents living in that neighborhood. Again, the spatial distribution and the effect of closing the landfill is readily apparent.

Health Risk

The presence of vinyl chloride gas, as well as other possibly unknown hazardous substances has led to concern among residents about

FIGURE 7-8


% of Sample
50%
40%
30%
20%
10%
0%
SUBJECTIVE RISK OF EXPLOSION BEFORE CLOSURE
FOR THE ENTIRE SAMPLE
20.4
18.8
15.0
12.1
15.2
6.4
11.9
Deaths per
Million per Year
0
1
10
100
1,000
10,000
100,000
1,000,00

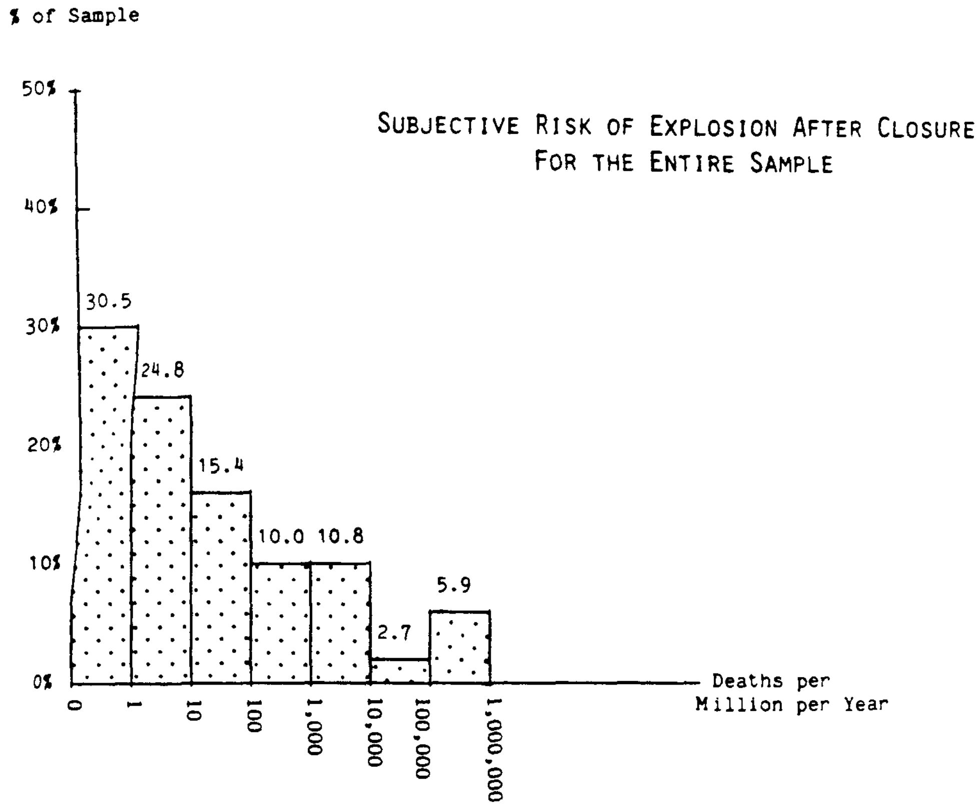
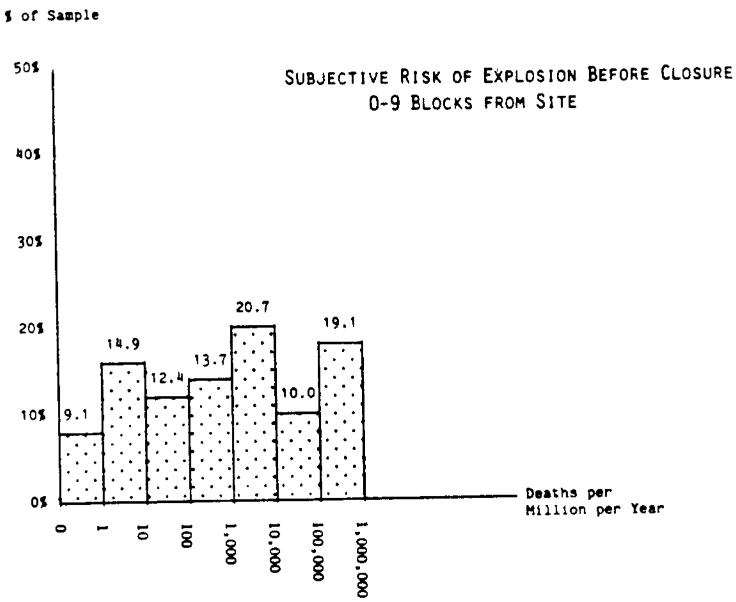
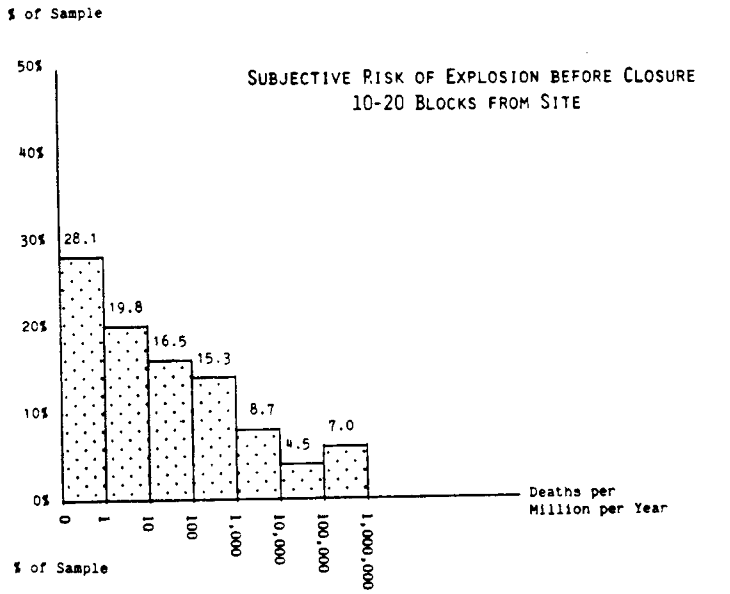

% of Sample
50%
40%
30%
20%
10%
0%
SUBJECTIVE RISK OF EXPLOSION AFTER CLOSURE
FOR THE ENTIRE SAMPLE
30.5
24.8
15.4
10.0
10.8
2.7
5.9
Deaths per
Million per Year
0
1
10
100
1,000
10,000
100,000
1,000,000

FIGURE 7-9


% of Sample
50%
40%
30%
20%
10%
0%
SUBJECTIVE RISK OF EXPLOSION BEFORE CLOSURE
0-9 BLOCKS FROM SITE
9.1
14.9
12.4
13.7
20.7
10.0
19.1
Deaths per
Million per Year
0
1
10
100
1,000
10,000
100,000
1,000,000


% of Sample
50%
40%
30%
20%
10%
0%
SUBJECTIVE RISK OF EXPLOSION BEFORE CLOSURE
10-20 BLOCKS FROM SITE
28.1
19.8
16.5
15.3
8.7
4.5
7.0
Deaths per
Million per Year
0
1
10
100
1,000
10,000
100,000
1,000,000

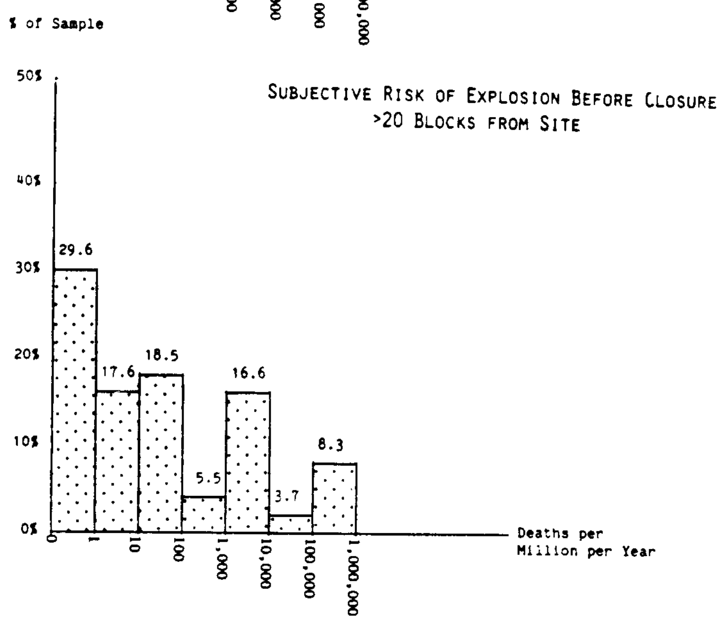

% of Sample
50%
40%
30%
20%
10%
0%
SUBJECTIVE RISK OF EXPLOSION BEFORE CLOSURE
>20 BLOCKS FROM SITE
29.6
17.6
18.5
5.5
16.6
3.7
8.3
Deaths per
Million per Year
0
1
10
100
1,000
10,000
100,000
1,000,000

Figure 7-10

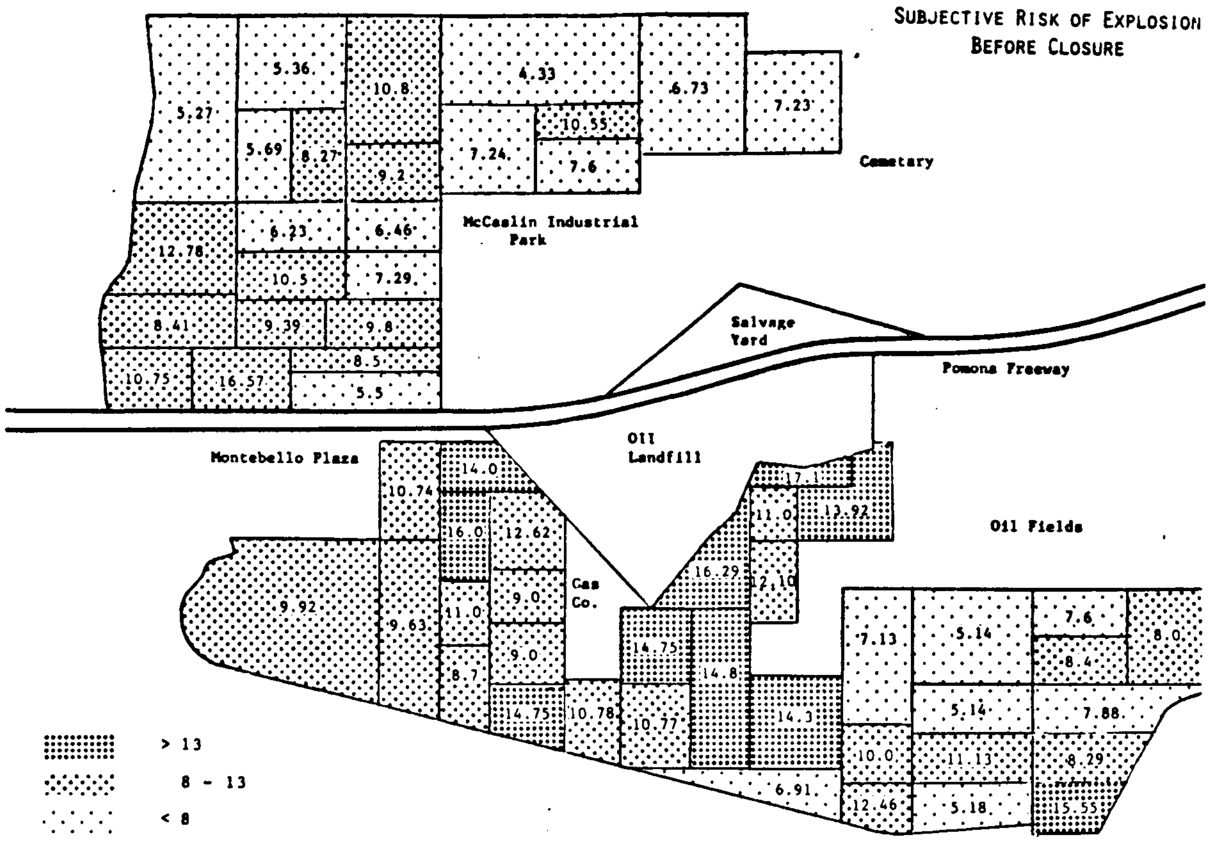
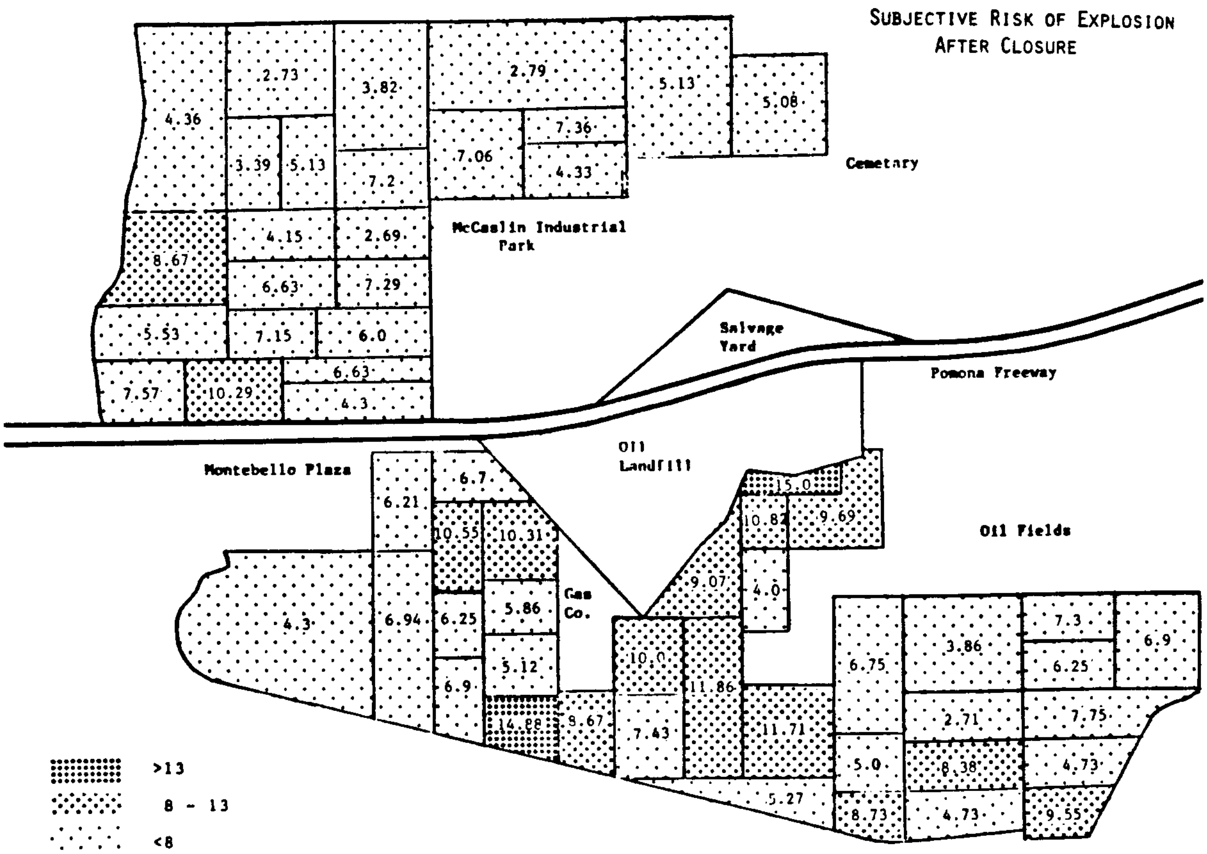


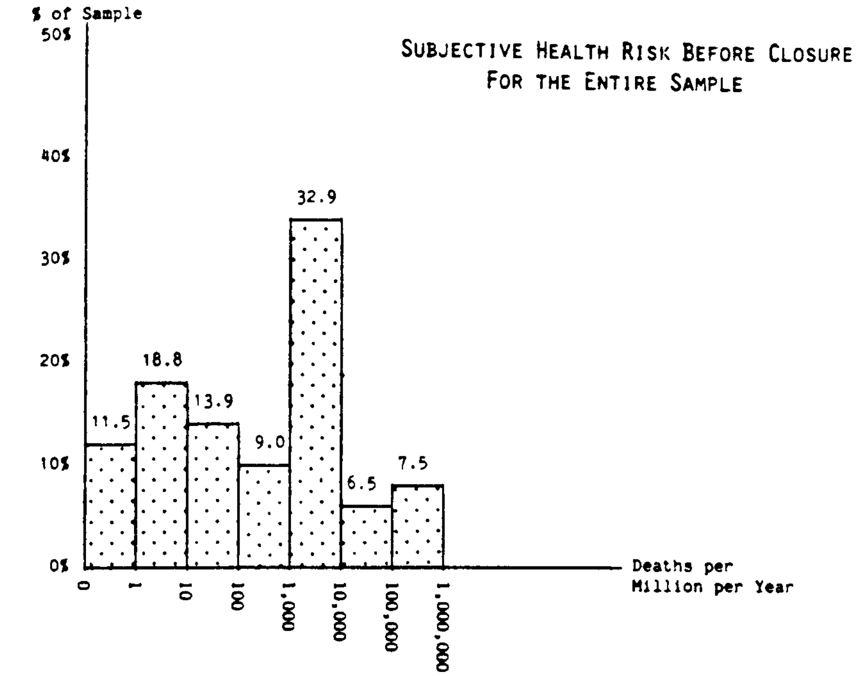
Figure 7-11



adverse health effects. Although monitored levels of vinyl chloride gas exceeded EPA standards of 10 ppb on twelve occasions in 1983, current measurements have been below the level of detection (2 ppb).

Figures 7-12 and 7-13 show the frequency distributions of subjective health risk both before and after closure. Both distributions clearly show bimodality in the judgment of risk with one mode at a relatively low risk and the other mode at a relatively high risk. This bimodal result is consistent with the results of an economic-psychology laboratory experiment conducted as part of this research. This study shows that when individuals are confronted with small risks, one group of subjects will respond with a higher than "Expected Value" assessment of the risk while another will select a value below "Expected Value". In other words the bimodality shown for residents around the OII Landfill can also be reproduced in the laboratory (See Appendix A). Because of this bimodal distribution, it is inappropriate to characterize judgments of health risk with a mean value. Thus, we have constructed a measure to account for the judged level of risk for neighborhoods around the site as follows: The midpoint between the two modes in the distribution of health risk corresponded to the letter "L" on the risk ladder (about 500 deaths per million people per year), therefore, this level was selected to separate individuals into high risk and low risk modes. Those individuals who selected a risk equal to or greater than "L" were identified in the upper mode and those who selected a risk level less than "L" were identified as filling in the lower mode. Figures 7-14 and 7-15 show how judgment of health risk is spatially distributed around the site both before and after closure of the landfill. The number used for each neighborhood

FIGURE 7-12


% of Sample
50%
40%
30%
20%
10%
0%
SUBJECTIVE HEALTH RISK BEFORE CLOSURE
FOR THE ENTIRE SAMPLE
11.5
18.8
13.9
9.0
32.9
6.5
7.5
0
1
10
100
1,000
10,000
100,000
1,000,000
Deaths per
Million per Year

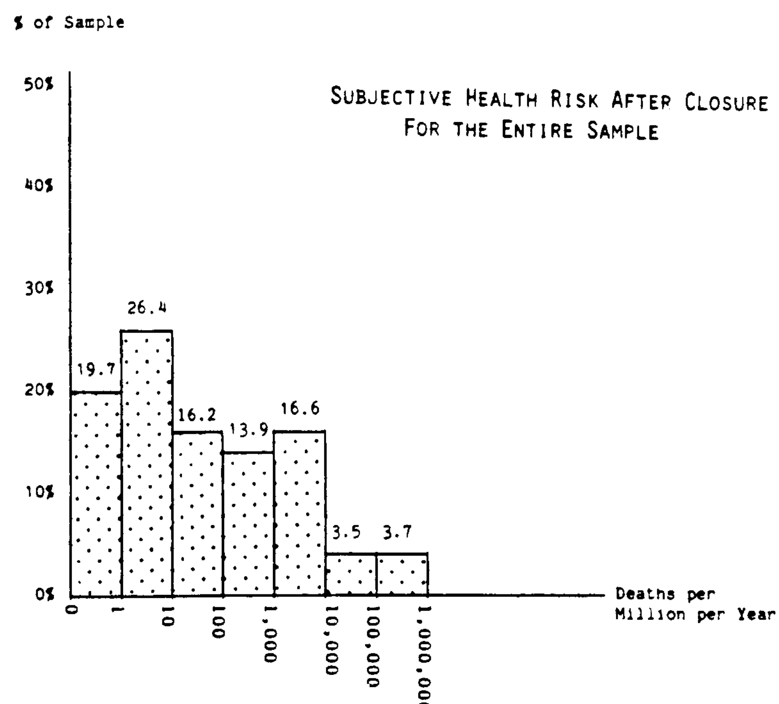
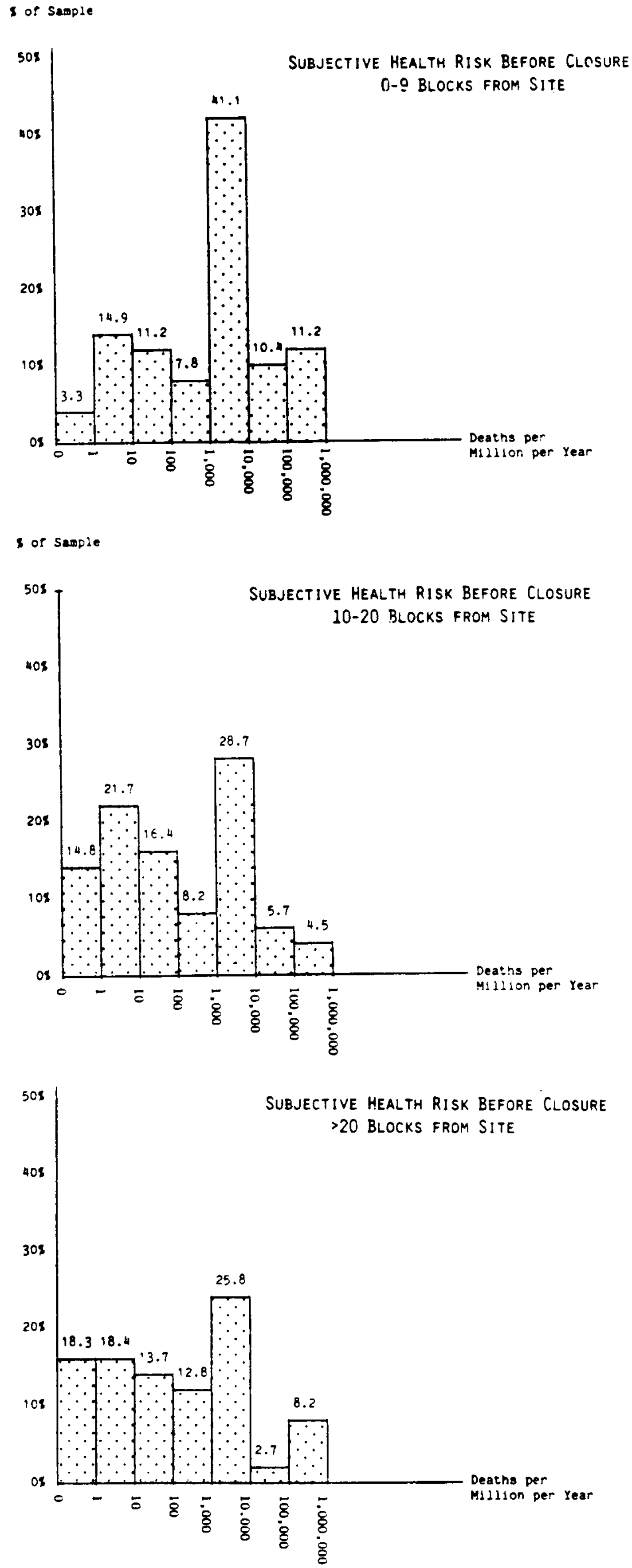

% of Sample
50%
40%
30%
20%
10%
0%
SUBJECTIVE HEALTH RISK AFTER CLOSURE
FOR THE ENTIRE SAMPLE
19.7
26.4
16.2
13.9
16.6
3.5
3.7
0
1
10
100
1,000
10,000
100,000
1,000,000
Deaths per
Million per Year

FIGURE 7-13



% of Sample
50%
40%
30%
20%
10%
0%
SUBJECTIVE HEALTH RISK BEFORE CLOSURE
0-9 BLOCKS FROM SITE
41.1
14.9
11.2
7.8
11.2
3.3
Deaths per
Million per Year
0
1
10
100
1,000
10,000
100,000
1,000,000
% of Sample
50%
40%
30%
20%
10%
0%
SUBJECTIVE HEALTH RISK BEFORE CLOSURE
10-20 BLOCKS FROM SITE
28.7
21.7
16.4
14.8
8.2
5.7
4.5
Deaths per
Million per Year
0
1
10
100
1,000
10,000
100,000
1,000,000
50%
40%
30%
20%
10%
0%
SUBJECTIVE HEALTH RISK BEFORE CLOSURE
>20 BLOCKS FROM SITE
25.8
18.3
18.4
13.7
12.8
8.2
2.7
Deaths per
Million per Year
0
1
10
100
1,000
10,000
100,000
1,000,000

Figure 7-14

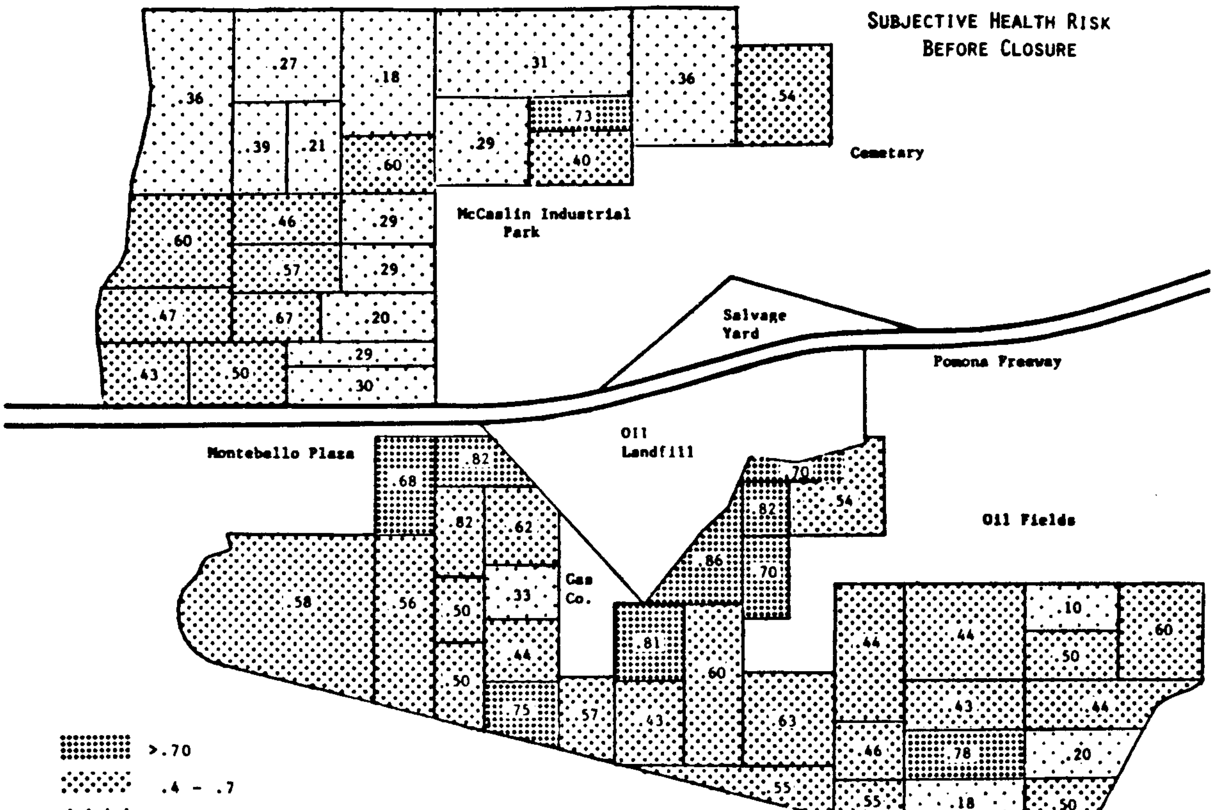
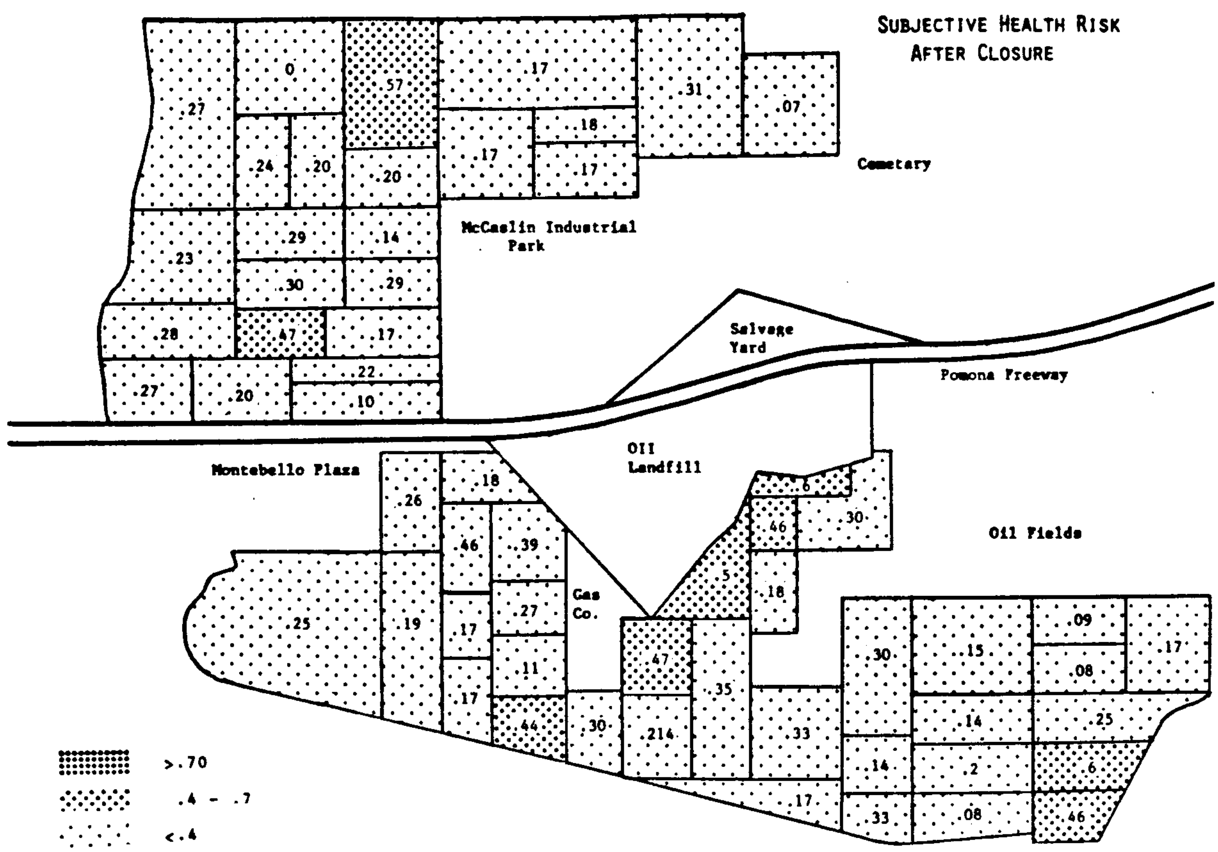


Figure 7-15



to represent subjective health risk is the fraction of residents who fell into the upper mode of the bimodal distribution of risk perception. Therefore, values of the subjective risk measure will fall between O and 1, with neighborhoods having a high number of upper mode residents approaching 1 and neighborhoods with a low number of upper mode residents falling near 0. The Figures generally show that in neighborhoods closer to the landfill, the fraction of residents with a high level of health risk perception is larger. The results also indicate a large shift in risk perception with closure of the landfill. In the section that follows, the effects of perceptions and subjective judgments on property values is explored.

7.3 Property Values Near the OII Landfill

The development of residential property near the Operating Industries, Inc. (OII) Landfill occurred in the mid-1970's. Residents in the vicinity are troubled by a decline in the value of their property that they believe is caused by the location, size and the presence of hazardous wastes at the OII Landfill. The effects on property values are further aggravated by intensive media coverage that has tended to focus on the possible risks and the presence of odor problems, which has appeared to have strongly influenced perceptions and subjective judgments within the area.

The Hedonic Price Method Property Value Model

The Hedonic Price Method (HPM) attempts to value certain environmental amenities (or disamenities) by studying markets in which an environmental attribute may be captured (See Rosen 1974). In this case, the value that people hold for avoiding hazardous waste problems may be proxied by relative declines in the real estate market near the hazardous waste site.

The model postulates that the value of a home is a function of the quantity and quality of certain physical attributes of the home and neighborhood including perceived environmental conditions. By estimating a reduced form property value equation, relative role of each of the factors can be determined, including the relative importance of perceived environmental conditions in determining the value of homes.

Data

Although property value data was collected in the survey, insufficient responses from recent home buyers made it impossible to analyze recent market conditions. A majority of our responses came from residents who bought their homes in the mid-1970's when the homesites were developed but before current perceptions and judgments about the OII Landfill were formed. In order to follow through with the analysis of property values in the area, current secondary property value data was obtained through a real estate information network (see Chapter 4 on secondary data studies). This data included home sales information and characteristics from August 1983 through November 1985 (including the closing of the OII Landfill late in 1984).

Through visual inspection of the site it was determined that neighborhood characteristics were fairly homogeneous throughout the sample area and thus an index for physical quality of neighborhoods was not needed. Although the property data from the survey was insufficient to allow estimation of a property value equation, the perception and subjective judgment data, however, did provide information on current odor perceptions and subjective risk judgments. Combining current property sales data from secondary sources with current perception and subjective judgment data from the survey has made it possible to construct a hedonic model to explore how perceptions and subjective judgments affect property values. As developed earlier in this Chapter, subjective risk and perceived odor data were grouped into neighborhood variables. The use of neighborhood variables in explaining property values better reflects the dynamics of a real estate market where prices are set in response to the interactions of many people and not simply on individual perceptions and subjective judgments.

Since neighborhood subjective risk and perceived odor data is present for both before and after closure of the OII Landfill, there arises a question arises about the timing of the shift from before to after closure risk judgments and perceptions. It was hypothesized, that a lagged effect would be present and that before closure perceptions would persist (at least in terms of buyers moving to the area) past the date that the OII Landfill actually closed. A six month lag was used, evenly splitting the period between the two points in time for which subjective risk and odor perception information was obtained. The OII Landfill officially ceased accepting additional wastes on the last day of October 1984, but home sales during the first 6 months following the closure were assigned the neighborhood subjective risk and perceived odor values that were present before closure. A linear functional form was used in specifying the equations because of the ease in interpreting the coefficients and because results obtained from alternative log forms were not significantly different.

Results

In the secondary data set, 179 home sales were identified within the area near the OII Landfill during the 28 month period. The data was pooled in order that information on both before and after closure could be included in the analysis. Table 7-1 shows the results of four model specifications corresponding to the inclusion of subjective health risk, subjective risk from explosion, perceived odor and all three, respectively. The results suggest that subjective health risk may be the primary factor causing a decline in property values. With a coefficient of $-13,719 and a t-value of -1.80, it appears that the effect of subjective health risk is both significant and non-trivial. Neither subjective explosion risk nor perceived odor appears to be significantly contributing to the fall of property values. Considering the change in the size of the coefficient on subjective health risk from the first specification to the fourth, it appears that the multicollinearity between subjective health risk, subjective explosion risk and perceived odor is sufficient enough to cause sign changes in the coefficient on subjective explosion risk and to significantly alter the coefficients on odor and subjective health risk. However, it is clear from the individual specifications that odor and risk from explosion are much less significant in explaining the observed property value decline. Other significant variables in the model include the date of home sale, the area of the home, the year the home was built, presence of a swimming pool, and the proximity of the house to the highway.

Assessment of Total Subjective Damages Around the Site

The coefficient on the effect of subjective health risk on property values, as identified in the econometric model, is $-13,719. To arrive at a total assessment of property value damage for the area, the total number of homes in each neighborhood cell was identified from an aerial photo and multiplied by the fraction of homes in the upper mode of subjective health risk judgment. This number identified the fraction of homes with a high subjective risk judgment in each neighborhood, which was then multiplied by the coefficient on subjective health risk ($-13,719) and then summed over the sixty neighborhoods. This same procedure was followed using the after closure fraction of residents in the upper mode of subjective risk judgment to arrive at an after closure assessment of damages. The subjective benefits of closing the landfill amount to the difference between the before and after subjective damage assessments (see Table 7.2). The before closure estimate of subjective damages amounted to over $27 million for the 4100 homes near the site. After closure subjective damages amounted to $13 million resulting in a subjective benefit of closing amounting to $14 million.

These figures represent the magnitude of the real economic damages that residents in the area must bear because of property devaluation in the area of the 011 Landfill. These figures also indicate the effect that closing the site may have had on property values and also suggest the magnitude of the potential benefits of better risk communication if, in fact health risks are actually small (see, Chapter 8 for further discussion).

TABLE 7-1

HEDONIC PROPERTY VALUE REGRESSION
For Homes Near the Operating Industries Inc. Landfill in Monterey Park, California

Variable Name	Mean	Std. Dev.	Estimated Coefficients (t in parentheses) 1	2	3	4
Dependent Var.						
Sale Price ($)	135,863	35,253				
Independent Var.						
constant			96,231.1 (8.26)	90,674.9 (7.72)	95,711.9 (7.65)	95,560.0 (7.70)
Subjective Health Risk[1]	0.41	0.20	-13719.8 (-1.80)	-	-	-22051.7 (-2.07)
Subjective Risk From[2] Explosion	8.43	3.26	-	-5.66 (-0.014)	-	865.8 (1.53)
Perceived Odor[3]	17.43	7.20	-	-	-184.1 (-0.95)	-88.9 (-0.35)
Date of Home Sale by month (08/83 = 1;08/85 = 25)	15.1	7.7	491.8 (2.70)	647.2 (3.83)	581.0 (3.29)	464.7 (2.52)
Area of Home (ft^2) ($\bar{X}$ - SqFt)	-0.041	475.5	50.63 (9.04)	49.61 (8.81)	50.61 (8.87)	51.09 (9.00)
" " " $(ft^2)^2$	224,807.3	262,400.7	0.021 (3.83)	0.0194 (3.61)	0.0191 (3.56)	0.019 (3.68)
Number of bathrooms	2.0	0.64	488.0 (0.12)	1,653.6 (0.41)	1,062.7 (0.27)	538.5 (0.13)
Year Home Built (i.e., 77, 84, 56)	58.8	9.8	523.4 (2.82)	454.0 (2.44)	457.7 (2.51)	499.3 (2.66)
Swimming Pool (0 if no pool; 1 if pool)	0.17	0.38	13,354.0 (4.00)	12,564.4 (3.76)	12,614.2 (3.79)	13,153.0 (4.19)
Scenic View From Home (0 if no view; 1 if view)	0.07	0.26	1,554.3 (0.31)	1,636.8 (0.33)	1,633.6 (0.33)	1,145.4 (0.23)
Fireplace in Home (0 if no fireplace; 1 if fireplace)	0.45	0.50	-603.4 (-0.21)	-1,219.5 (-0.42)	-883.9 (-0.30)	-502.2 (-0.17)
Proximity to Highway (1 if within 2 blocks; 0 otherwise)	0.06	0.24	-12,173.8 (-2.35)	-10,831.3 (-2.09)	-10,776.1 (-2.09)	-12,331.5 (-2.36)
R^2			0.802	0.798	0.799	0.805
sample size	179					

[1]This variable represents the fraction of respondents within a neighborhood who responded to survey Question 12 with a subjective health risk greater than 5 deaths in 10,000 (step L). Homes sold prior to May 1985 were assigned a value corresponding to before closure subjective risk, and home sold after May 1985 were assigned the corresponding risk value for after closure subjective risk.

[2]This variable represents a logrithmic scale from 1 (no risk) to 26 (certain risk) taken from responses to question 13 of the survey. Each neighborhood was assigned the mean value of responses within that neighborhood with home sold prior to May 1985 receiving the mean before closure value and home sold after May 1985 receiving the mean of the after closure value.

[3]This variable represents the product of frequency and intensity of perceived odor problems from responses to Question 11 in the survey. The resulting scale goes from 1 (very small problem) to 50 (very great problem) with homes sold prior to May 1985 receiving the mean neighborhood value before closure and homes sold later receiving the mean neighborhood value after closure.

TABLE 7-2
SUBJECTIVE DAMAGES AND BENEFITS AROUND THE 011 LANDFILL

Property Value Effects on 4100 Nearby Homes

Before closure loss in Property Values (2,016 Homes with High Subjective Risk)	$27,659,000
After closure Loss in Property Values (973 Homes with High Subjective Risk)	$13,342,000
Subjective Benefits of Closure	$14,317,000

7.4 A Model of Subjective Health Risks

The results of the property value analysis indicate that subjective health risk is the primary factor causing real estate values to fall in the area of the 011 Landfill. In this section, a model for subjective health risk is explored. The large variation in estimates of subjective health risk suggests that those judgments must be due in part to psychological and sociological factors other than a perception of the true health risk. It is therefore interesting to try to model subjective health risk judgments in terms of various psychological and sociodemographic variables assessed in the survey. Potential variables for inclusion in the model are described below in conceptual groups.

Experiential Variables. Obviously, the more that one has been made aware of the potential health problems from the landfill, the higher one's estimate of the health risk is likely to be. Thus, the model includes variables which assess awareness of the potential problem through several sources. In particular, the model includes respondent awareness of media attention to the problem and perception of odor from the site as experiential variables. Also included is geographic distance to the site as a proxy variable for experiential effects. Presumably, those respondents who live near the landfill will have had more reminders of the potential health hazards.

Sociodemographic Variables. Judgments of health risk may vary as a function of various sociodemographic variables. For example, older respondents will have necessarily survived a number of hazards and may therefore place the present landfill risk in a different context than a younger respondent who is raising children. Although we do have specific hypotheses about the risk effects of these variables, we examine income, education, age, gender, number of children living at home, occupation, and ethnicity as possible components in a model of health risk judgments. It is possible to examine ethnicity because of the high proportion of Asian-Americans in this sample.

Site Closure Variable. As already noted, the mean judgment of the health risk was much lower after closure of the site to further dumping than before. We therefore include a dummy variable to indicate whether the estimated health risk is for before of after closure of the site.

The Health Risk Dependent Variable. The strong bimodality in the distribution of health risk judgments suggests that the errors from any model of those judgments would be unlikely to meet the usual distributional assumptions necessary for statistical tests. Also, we are more interested in the determinants of which mode a respondent is in rather than minor variation within each mode, so the subjective health risk variable was recoded to reflect mode. Those in the upper mode received a score of 1 while those in the lower mode received a score of O. Approximately 41.5 percent of the observations were in the upper mode. This recoding does not solve all the problems with the error structure because ordinary least square (OLS) analyses of binary data can be problematic. We therefore perform both OLS and PROBIT analyses. Because of computer limitations on the number of variables which could be used in the probit analysis with a data set of this size, we used OLS to screen variables for inclusion in the probit analysis.

Model for Health Risk Judgments. Table 7-3 gives the partial regression coefficients and their associated t statistics for both the OLS

Table 7-3

Regressions. Explaining Subjective Health Risk
Before Closure of the Operating Industries Inc. Landfill

Variable Name	Mean	Std. Dev.	Estimated Coefficients (t in parentheses) OLS	Probit
DEPENDENT VAR.				
Subjective Health Risk (1 if in upper mode 0 if in lower mode)	0.415	0.49		
INDEPENDENT VAR.				
Constant			0.57 (1.78)	-0.67 (-2.26)
Closure Dummy Var. (1 before closure) (0 after closure)	0.52	0.50	0.094 (2.77)	0.29 (2.68)
Experiential Var.				
Frequency of hearing or reading about 011 problems.	4.11	0.96	0.037 (2.16)	0.14 (2.61)
Perceived odor problems	16.45	14.35	0.013) (9.83)	0.040 (9.44)
Distance from site (blocks)	11.50	7.07	-0.0083 (-3.53)	-0.028 (-3.78)
Socio-Economic Var.				
Number of people under 18 living in house	0.91	1.05	0.047 (2.64)	0.12 (2.27)
Age of respondent	48.48	12.63	-0.0035	-0.0097
Income	47,631	22,038	0.354E-6 (0.45)	-
Sex of respondent (0 female) (1 male)	0.79	0.41	-0.12 (-2.91)	-0.31 (-2.52)
level of education (l-9)	6.34	1.91	0.0019 (0.18)	-
Occupation Var.				
(Sales or Managerial - 1; Service, Repair, Labor, or Farm/Fishery = -1 ; Retired = 0)	0.39	0.84	-0.00078 (-0.038)	-
Ethnic Var.				
#1 (Caucasian = 2; Asian or Hisp. = -1)	-0.17	1.28	0.00076 (0.056)	-
#2 (Caucasian = 0; Hispanic = -1 ; Asian = 1)	0.22	0.79	0.030 (1.45)	-
Sample Size			762	
R^2			0.282	
Likelihood Ratio Test				238.87

and PROBIT analyses. Both analyzes produced exactly the same conclusions. We therefore discuss the results in terms of the OLS regression because it is generally easier to understand. It should be remembered that the statistical tests are for partial regression coefficients. That is, the test asks whether the given variable reliably explains a portion of the variation in health risk after controlling for all the other variables included in the model. With covariation among the predictor variables this can produce conservative conclusions about the importance of a variable.

As expected, the site closure variable is a statistically significant component of the model even after controlling for all the other variables. All three experiential variables had significant coefficients. Odor in particular stands out as an important predictor of subjective health risk. Distance from the site was also a significant predictor after controlling for odor perceptions. Thus, there must be other perceptions or concerns associated with distance, besides the perception of odor, which affect judgments of health risk. Frequency of exposure to media attention about the site also predicted increased health risk judgments.

It is important to recognize that a cross-sectional survey such as this must necessarily suffer from causal ambiguity. For example, we have included frequency of exposure to media attention as a predictor of health risk judgments. However, it might be the case that someone who becomes concerned about the health risks will pay more attention to and seek out media reports about the problem. Similarly, someone who is concerned about the health risk may be more alert for the odor problem and hence report having experienced it a greater number of times.

It is interesting to ask whether sociodemographic variables can explain variation in health judgments over and beyond the variation attributable to the more direct experiential and perceptual variables. Having controlled for the experiential variables, any effects of sociodemographic variables represent largely attitudinal effects. The two socioeconomic status variables of income and education had inconsequential effects. Thus, it is not true that those who had more to lose economically were more concerned about the risk. However, the number of children living at home was a significant predictor so in that sense those who had more to lose were more concerned about the risk. Age of respondent is obviously correlated with having children living at home but age predicted variation over and above that variable. The direction of the effect is that younger people thought the hazards of the site were more risky. Gender also made a significant difference with females believing the site is more risky than did males. A coded variable contrasting managers and sales people against service, labor, and repair people (those in the latter group are presumably exposed to more on-the-job risks) indicated no differences in risk judgments. Similarly, two variables coding ethnic group (one contrasting Caucasians with Asian-Americans and Hispanics and one contrasting Asian-Americans with Hispanics) yielded no significant differences. There are, therefore, no suggestions of any occupational or cultural differences in the evaluation of risk.

A reasonable model of judgments of the health risks associated with the OII Landfill site includes the following components: site closure, media exposure, odor, distance to site, number of children living at home, age and gender. This model accounts for approximately 28 percent of the of the variation in the coded health risk variable. This is substantial for a model of this type, especially given that the dependent variable is binary. What does the model mean? First, the importance of the perceptual odor variable above and beyond the other variables is striking. It is easy to speculate that without vivid, perceptual cues from the site, risk judgments would be greatly reduced. More important than the specific pattern of significant coefficients, however, are the following conclusions: (a) there is great variability and bimodality in judgments of health risk; (b) many respondents have inaccurate beliefs about the extent of the health risk; and (c) the variation in health risk judgments is not random but can be related to systematic differences between respondents.

7.5 Survey Values

The contingent valuation bidding method (CVBM) has been used in a number of studies attempting to value changes in a resource quantity or quality. A study by Smith (1985) suggests that unless adjustments are made to remove invalid bids, estimates can be significantly biased. Because of the hypothetical nature of the CVBM questions and their context within a mail survey, there will be a number of bids which do not accurately or reasonably reflect the true preferences of the individual respondent. Either because of strategic misrepresentation, rejection of the hypothetical scenario or a lack of serious intention, invalid or false bids are likely to be associated with this particular methodology. The existence, however, of these misrepresented bids need not invalidate the analysis of a number of valid bids. In addressing this inherit CVBM problem, it is necessary to identify a reasonable and systematic approach for removing misrepresented bids from analysis. The identification of outlier bids should if possible revolve around a notion of reasonableness and internal consistency. For example, it is not reasonable to expect that an individual would be willing to pay an amount of money that exceeds the costs of relocation or income. Likewise, it is not internally consistent for an individual to bid $0 while suggesting in other responses that landfill closure or cleanup provides a gain in the individual's well being. Evidence for the treatment of outliers also arises from laboratory experiments that suggest that under uncertain conditions a certain percentage of responses change under demand revealing competitive pressure.

In the survey of residents around the OII Landfill two CVBM questions were asked with SO percent of the sample receiving a compensating variation willingness to accept (WTA) version and 50 percent receiving an equivalent variation willingness to pay (WTP) version. The two versions of questions were asked in order to explore whether variations in question framing would influence the resulting disparity between WTA and WTP measures of value. Economic theory suggests that no differences should be expected between the two measures, but work in the psychology of preferences by Kahnemann and Tversky (1982) suggests that many individuals show loss aversion. In other words, observed behavior indicates that people value a loss (income or non-income) greater than an equivalent gain (income or non-income). Based upon this evidence it was hypothesized that the CVBM questions could be framed in such a way as to cancel the differential effect. WTP questions were framed in such a way that the individual was faced with the choice of paying some amount of money (loss) or having the landfill reopen (Question 14) or locate in their neighborhood (Question 23), both of which would be perceived as losses. The tradeoff in this case was between facing two losses (an income loss versus a non-income loss), as opposed to the traditional framing that would trade a loss in income for a gain in utility (closing the landfill). In the WTA version, the framing of the questions was intended to induce a choice between a gain in income and a gain in closing or moving from the landfill. The traditional WTA approach would have asked the willingness of the individual to accept payment in compensation for a loss.

From responses to the subjective health risk questions reject $0 bids could be identified from the WTP respondents. Individuals who answered in the lower risk mode when asked about the level of risk before the landfill closed and then responded in the upper risk mode after closure were considered logically inconsistent and removed from further analysis (5 such individuals out of 250 were identified). Individuals who responded with a $0 WPT bid and responded that their subjective risk level had changed from the upper mode to the lower mode were also removed from analysis because they apparently rejected the scenario by saying they were not willing to pay although their subjective utility had increased (8 responses out of 250 fell into this category). The combined adjustments to the lower tail of the WTP suggested by this approach amounted to 13 out of 250 responses or approximately 5 percent. This was the only reasonable approach suggested by responses to questions in the survey and so it was decided to treat both the WTA and WTP distributions symmetrically by removing 5 percent from each tail or 10 percent from the entire distribution. Laboratory results indicate that, on average, a 15 percent adjustment is necessary so this adjustment level is also presented. The results presented in Table 7-4 show the three levels of treatment (O, 10, 15 Percent). Notice in valuing the closure of the OII Landfill that the WTP mean falls much more rapidly than the WTA mean bid. This is largely due to the presence of fewer extremely high bids in response to the WTP version than in response to the WTA version. It is apparent from the disparity between the two measures that framing of the value question is not the only mechanism inducing differences between the valuing methods. It is quite plausible that strategic misrepresentation induces a stronger upward pressure on WTA bids than its corresponding downward pressure on the WTP bids. In other words, individuals are more likely to overstate the amount of compensation they would require on the chance that they may receive a windfall, whereas, when asked about their willingness to pay, the response may be understated because of the nature of a public good and the “free rider” problem inducing individuals to underreport their true values.

Comparing Contingent Valuation and Hedonic Property Value Results

The first step necessary to compare the results from both methodologies is to annualize and adjust the property value damages into an average monthly figure that would correspond to the monthly bids given in response to the CVBM questions. The annualized monthly property value damages before closure are estimated to be $56 per month per home, and after closure the damages are estimated to be $27 per month per home.# Therefore, the benefits of landfill closure are estimated to be the difference between before and after monthly damages or $29 per month per home. This figure of $29 per month per home corresponds roughly with the CVBM bid for landfill closure of $25.73 after 15% of the outliers have been removed. This result provides useful information on how the two methodologies compare on generating benefit estimates and provides evidence for calibrating the two methodologies.

#$27,659,000 / 4100 homes = $6,746 Per home
$ 6,747 per home x 10% annual interest rate = $674 per year per home
$ 674 per year per home / 12 months = $56 per month per home.
Benefit calculation for site closure:
$ 56 per month per home (before closure)-$27 per month per home (after closure) = $29 per month per home.

TABLE 7-4

Valuing the Closure and the Presence of the OII Landfill: Contingent Valuation

	Mean Bids[1]			
	Level of Outlier Treatment			Median Bid
	0%	10%	15%	
Valuing the Closure of the OII Landfill				
WTP[2]	$88.02	38.36	25.73	$10.00
(NOBS)	(250)	(226)	(212)	
WTA[3]	835.20	649.07	558.83	300.0
(NOBS)	(179)	(161)	(153)	
Valuing the Presence of the OII Landfill				
WTP[4]	221.73	189.79	165.56	25.00
(NOBS)	(272)	(246)	(232)	
WTA[5]	751.38	618.88	598.39	500.00
(NOBS)	(218)	(196)	(186)	

[1] A1l Bids are monthly figures

[2] The landfill is now closed. IMAGINE for a moment that OII was planning to reopen the landfill, (this IS NOT the case, however). How much at the most would you be willing to pay each month to prevent the reopening of the landfill, which would expose you to the levels of odors and risks which existed prior to October 1984?

[3] IMAGINE yourself back before October of 1984, before the OII landfill was closed with the odor problems and risks that existed at that time. You are given a choice between closing the landfill or being paid some amount of money per month. What is the least amount of money per month you would have accepted rather than closing the OII landfill?

[4] IMAGINE you live in an identical house in an identical neighborhood with the same monthly house/rent payments you now pay but without the OII landfill in the community. What is the largest amount of money per month that you would be willing to pay to prevent the OII landfill from locating at the same distance it is now from your home?

[s] IMAGINE that you were given the opportunity to live in an identical house in an identical neighborhood with the same monthly house/rent payments you now pay but without the OII landfill in the community. What is the smallest amount of money per month You would have to be paid to turn down that opportunity?

CHAPTER 8

CONCLUDING DISCUSSION

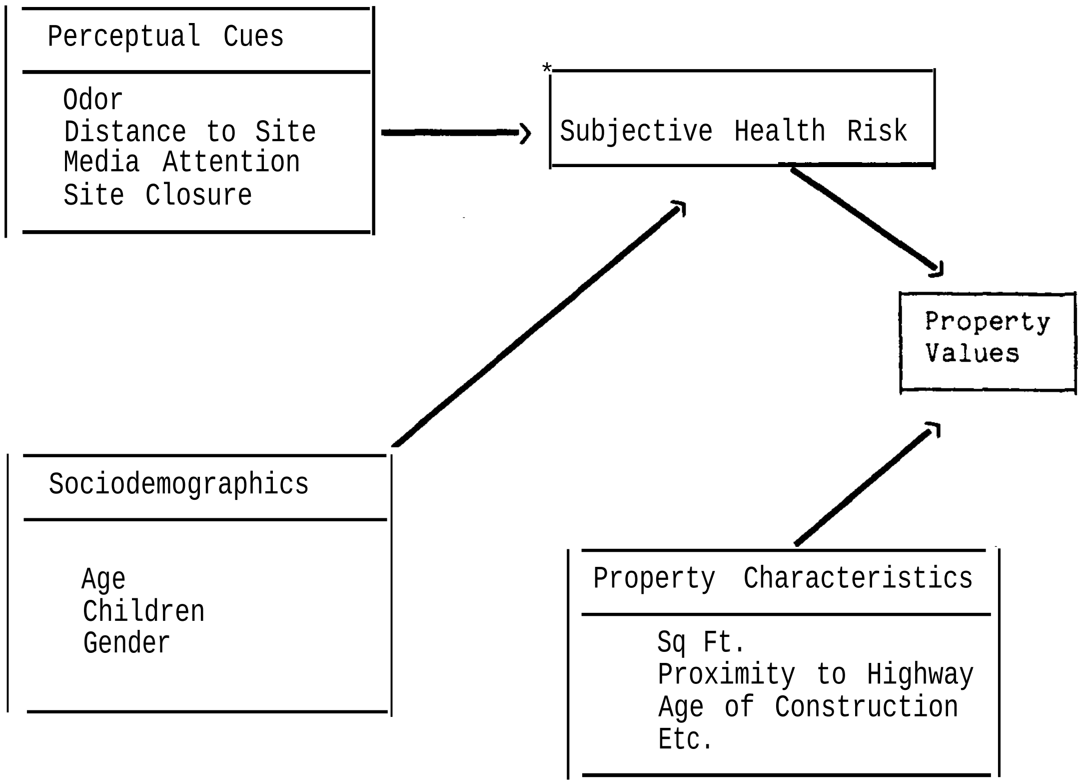
The previous two Chapters have provided basic descriptions of the impact of the 011 Landfill on property values and of the survey results on subjective risk. The goal of this Chapter is to integrate those results into a coherent framework and to consider the policy implications of those results. Figure 8-1 illustrates a schematic framework that integrates the model of subjective health risk with the model of property values. The left side of the figure represents a model for subjective health risks. Note that this is a model of the subjective risk estimates of individual survey respondents. The right side of the figure represents a model for property values. As explained in the previous chapter, the property value modeling is necessarily an aggregate analysis because property value changes could be linked with subjective health risk variables only at the neighborhood level. We consider each portion of the schematic framework of Figure 8-I in turn.

Subjective Health risks

The descriptive analysis of the subjective health risk variable is striking because it provides strong evidence that at least many respondents have inaccurate beliefs about the true health risks associated with the landfill. There are three reasons for claiming that the health beliefs of many respondents are inaccurate. First, the mean and median subjective risk judgments are inconsistent with completed health studies reviewed in Chapter 7; these studies have not been able to detect any health consequences as indexed by such variables as school absences. Also, using extreme estimates in the calculation of the risks due to a pollutant such

FIGURE 8-1

A MODEL OF SUBJECTIVE HEALTH RISK AND PROPERTY VALUES



as vinyl chloride produced a risk estimate which, although it was necessarily a gross overestimate, was still below the median subjective health risk estimate. Second, the distribution of subjective health risk judgments is definitely bimodal: some respondents give a very low risk estimate and others give a very high estimate. Obviously, both modes cannot be correct. So, even if we do not know which mode is closer to the true health risk, we can conclude that all the respondents in one of the two modes must necessarily have inaccurate beliefs about the health risks. Either those in the high mode are greatly overestimating the true risk or those in the low mode are greatly underestimating the true risk. Third, closing the landfill site to further dumping is unlikely to have had any immediate effects on the true health risks. The potential problems such as seeping chemicals and methane gas accumulations associated with this and other landfills are due to materials deposited in the landfill many years before: closing the site is unlikely to abate those problems but may prevent future problems many years hence. However, many respondents reported a major decrease in their judgment of the health risk when the OII Site was closed to further dumping. Such a decrease is almost surely not representative of the actual change in health risk. It is therefore reasonable to conclude that for many people living near the OII Landfill their subjective health risk is a very inaccurate estimate of the objective health risk.

If subjective health risks are inaccurate, then variations in those judgments must be due to psychological and sociological factors other than a perception of the true health risk. It is therefore interesting to model subjective health risk judgments in terms of various psychological and sociodemographic variables. Such a model was developed in Chapter 7 (see especially Table 7-3 for details). The important components in that model can be divided into two broad classes: (a) Cues and reminders about the potential hazard and (b) sociodemographic variables. It is certainly consistent with psychological models that the more one is reminded by cues about the presence of the landfill and its potential hazards, the greater one judges the health risk of the site. Of particular importance in the model is odor. Odor provides a definite perceptual cue to the existence of the landfill and its hazards and it is a cue which is difficult to ignore. Thus, it is not surprising that those who reported high intensities of this cue frequently tended to rate the risk higher. However, there is again no objective evidence that the actual health risks are directly related to odor. The importance of such variables in the model of health risk suggests that management of perceptual cues (e.g., reduction of odor, reducing or eliminating the number of trucks dumping at the site) might produce appreciable reductions in and, hence, in this case more accurate judgments of health risks. Cross-sectional survey data cannot verify such a claim, however.

The presence of sociodemographic variables in the model of heath risk is both interesting and disturbing. Sociodemographic variables in the model included number of children living at home, age, and gender. The number of children living at home may be a proxy for an experiential variable. Families with children may be more likely to have a parent at home during the day. More time at home would result in greater exposure to perceptual cues (such an odor). Also, an increased estimate of risk is probably consistent with the greater exposure to the risk. Attempted explanations of the age and gender effects would probably be gratuitous. It is not so important what sociodemographic variables are included.

Rather, it is more important that any such variables are included. The usefulness of any sociodemographic variables implies attitudinal effects on judgments of health risks, effects which cannot be easily related to experiences with the site. Such attitudinal effects are notoriously difficult to reverse.

As noted in Chapter 7, the particular pattern of coefficients is not so important as the following conclusions: (a) there is great variability and bimodality in judgments of health risk: (b) many respondents have inaccurate beliefs about the extent of the health risk: and (c) the variation in health risk judgments is not random but can be related to systematic differences between respondents.

Subjective Health Risk and Property Values

There are unfortunately all too many examples where variation in some decision-relevant judgment, especially a judgment such as health risk which have a significant attitudinal component, is not related to any interesting behavioral consequences. We therefore turn to the right portion of Figure 8-1 to ask whether the variation in health risk judgments, a variation which is rather extreme in this sample, is related to behavior. In particular, the modeling of property values in Chapter 7 asked whether subjective health risk is a predictor of property values after controlling for differences in property characteristics. Even though having to aggregate the subjective health risk variable to the neighborhood level probably worked against finding a relationship with behavior, a reliable reduction in property values due to subjective health risk was identified. Aggregating the estimated loss per house across all houses in the study area by neighborhood produced an estimated loss before closure of more than $27 million and a benefit due to closing the site of more than $14 million. Thus, the subjective judgments of health risk by people living in the study area are translated into objective monetary costs. In other words,attitudes are costing people a significant amount of real money in that their homes are worth less.

Although the aggregate effect of the subjective health risk on property values is large, it is important to put that effect into perspective. The highest aggregate neighborhood health risk index (the proportion of respondents in a neighborhood) in the high mode was .86, this yields an expected loss of .86 * $-13,719 or $-11,799. This is somewhat smaller than the estimated loss of $-12,173 due to the disamenity of being within two blocks of the freeway. In other words, in terms of property devaluation it would be better to be near the landfill than the freeway (note in the maps of Chapter 7 that some unfortunate neighborhoods are adjacent to <u>both</u> the landfill and the freeway). Also, the average value of the subjective health risk index was .41 so the average loss due the health risk was ,41 * $-13,719 or $-5,625. However, the estimated monthly appreciation in house prices during the study period was almost $500 per month so the loss due to subjective health risk was, on average, less than the yearly appreciation. Nevertheless, the losses are real and substantial.

<u>Changing Subjective Health Risk</u>. Two main conclusions emerge from the study results: (a) subjective health risks are likely to be overestimates of the objective risks and (b) the overestimated subjective health risks are associated with significant property value losses. In many respects it is similar to the situation with earthquake predictions. In several instances the overreaction to such predictions has resulted in economic losses due to property devaluations that far exceeded the economic losses

property damage were the predicted earthquake to occur. When, as in the case of the OII Landfill, total damages from the overestimates of risk are on the order of $27 million, a program designed to change subjective estimates of health risks can easily be cost effective.

The modeling reported above, points to two components for possible intervention: perceptual cues and attitudes associated with sociodemographic variables for designing a program to reduce subjective health risks until they are closer to the objective risks. Of the two, psychological research shows that perceptual cues are much easier to change than attitudes. Managing the perceptual cues which serve to remind people about the risk can be very effective in reducing risk estimates to appropriate levels. The management of perceptual cues would involve such things as reducing odor, reducing visibility of the site using plantings or screening, reducing activity at the site (e.g., reducing number of trucks entering and leaving), and reducing media attention devoted to the site. These are not necessarily easy to implement. Some of these strategies such as reduced media attention can only be recommended, not mandated. Others such as reducing odor and reducing activity are difficult or impossible to implement short of closing the site. However, if such reductions can be obtained, the management of perceptual cues can have dramatic effects. In this case, closing the site reduced odor and reduced activity. These reductions were associated with a large reduction in the proportion of people in the high mode who were greatly overestimating the risk. Finally, this reduction in the proportion of people overestimating the risk translates through the property value equation to a savings in property value losses of about $14 million--more than half the original loss--in the area around the landfill site. The policy implications are clear. If subjective health risks for a hazardous site are overestimates of the objective risk, then the perceptual cues about the risk should be managed as extensively as possible. The economic savings obtained by correcting and/or avoiding inappropriate property devaluations are likely to be large.

After major changes in the perceptual cues, many people maintained high risk estimates. These high risk estimates translate via the property value equation into an estimated loss of about $13 million. This residual loss is due partly to perceptual cues that cannot be easily modified (visibility of the site and the methane plant) and to risk attitudes. Given that further modifications of perceptual cues are probably impossible, further reductions in subjective health risks and their associated effects on property values could only be achieved by credible, effective communications about the objective risk. In other words, risk attitudes and beliefs must be changed. Changing attitudes is notoriously difficult and there are several factors which compound the problem in this context. First, many psychological studies (see Tversky and Kahneman 1974; Slovic, Fischoff, and Liechtenstein, 1977) have shown that most people have trouble understanding probabilistic information in general and expert assessments of risk in particular. Second, to be effective, risk communications must come from credible sources. In the present survey, respondents made it very clear that EPA was not a particularly credible source. Third, even though it has not been especially effective, much more is known about <u>increasing</u> subjective risk judgments (e.g., risks of smoking, risks of not using seat belts) than about <u>decreasing</u> risk judgments. Fourth, communications about issues with a high affective component (e.g., the emotionality surrounding a landfill hazard issue) are often misinterpreted and misunderstood. For these and other reasons a quick fix via risk communications for the attitudinal inflation of risk estimates is improbable. The potential elimination of approximately $13 million in property value losses would, however, justify considerable efforts to change subjective risk estimates to more appropriate levels.

While changing risk attitudes will not be easy, there are several studies which suggest some optimism. Hammond and his colleagues at the University of Colorado (see, e.g., Hammond and Adelman, 1974; Hammond et al. 1984) have been successful in reducing disagreements about a risk among experts and then communicating the resulting judgment about the risk to the public. Examples include public concern about a new police handgun bullet and about possible plutonium pollution from a nearby plant. Characteristics of these successful efforts to reduce concern about risks which were overestimated shared the following characteristics. First, a citizen panel (such as the HELP group) selects a group of independent scientists to evaluate the risk. The danger is that all too often, the citizen's panel will want to become technical experts themselves in order to make their own risk judgments. Their proper role is representing community values and the procedure generally works best if they stick to that. Second, the group of scientists uses standard scientific and scholarly procedures (e.g., references to referred journal articles, development and defense of mathematical equations producing the risk estimate) to resolve their differences. Also of use in this stage are psychological techniques for studying judgments, techniques which help identify issues of disagreement which need resolution. Contrary to the danger in the first stage, the danger here is that the scientific experts will make action recommendations for the community. Such recommendations necessarily are based on both risk judgments, which the technical experts should make, and assumptions about community values, which the technical experts should not make. Third, once agreement on the magnitude of the risk is obtained (and surprisingly such agreement is almost always obtained), the results are communicated to the public via the local media. What is communicated to the public is the experts' conclusion that the risk is either low or high and a comparison of the risk to known, widely-accepted risks. For example, comparing the danger of plutonium emissions to smoking or hospital X-rays.

Although the above approach is not a panacea, it does offer a reasonably inexpensive means for attempting to reduce subjective health judgments which due to attitudes overestimate the true risk. Given the magnitude of potential benefits, the past success and relatively small cost of such procedures justifies their use in an attempt to change subjective health risks.

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APPENDIX

VALUING RISK: A COMPARISON OF EXPECTED UTILITY WITH MODELS FROM COGNITIVE PSYCHOLOGY*

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1. Introduction

Psychologists have documented many systematic deviations in behavior from that predicted by the expected utility model. Much of this evidence has been generated in experiments where subjects have been asked what their behavior would be in response to hypothetical situations (see, for example, Liechtenstein and Slovic, 1971; Slovic et al. 1977; Kahneman and Tversky, 1979; Tversky and Kahneman, 1974, 1981; Abelson and Levi, 1985). Based upon these experiments, cognitive psychologists have argued that errors in decisionmaking under uncertainty arise from the improper application of intuition or simplifying rules of thumb (heuristics), from the improper consideration of factors irrelevant to the decision (framing), and from errors in reasoning about probabilities.

Economists have also conducted laboratory experiments exploring behavior under uncertainty. Results of these experiments, while in part confirming deviations from rationality (e.g., Grether and Plott, 1979), suggest that in a repeated market environment the expected utility model is "not universally misleading," (Plott and Sunder, 1982, P. 692). Economic experiments generally use actual cash payments, induce values (control the value to the subject of the commodity used in the experiment so it is known with certainty to the experimenter (Smith, 1976)), and employ many repeated trials to allow individuals to practice and become familiar with the market institution (Coppinger, Smith and Titus, 1980; Smith, Williams, Bratton and Vannoni, 1982; and Coursey, Hovis and Schulze, 1986).

One principle focus of experimental economics has been the testing and development of market institutions which perform well, that is lead to

Pareto optimality. Since Pareto optimality by definition is an idealized <u>rational</u> outcome, experimental economists have in fact tested and developed institutions which tend to <u>produce</u> rational behavior. This focus contrasts substantially with the objective of many experiments conducted by cognitive psychologists which have as their objective the detection of <u>deviations from</u> rational behavior.

This paper presents results which attempt to integrate the separate lives of research conducted by economists and psychologists. Since some evidence exists that behavior under uncertainty becomes more rational with repeated trials in a market environment, the first objective of the research reported in this paper is to examine what deviations from rationality will persist in a market environment under conditions of uncertainty. To this end, an attempt has been made in developing an experimental design and in analyzing results to follow procedures and employ concepts drawn from both cognitive psychology and experimental economics.

A second objective of the experiment reported here is to provide evidence to help interpret a number of empirical studies of natural and man-made hazards. These studies suggest that for low probability, high loss events, large deviations from rational behavior are likely to occur. For example, studies of flood and earthquake insurance (Kunreuther, et al., 1978) and of the value of avoiding exposure to hazardous substances (Burness et al., 1978 and Smith and Desvouges, 1966) all suggest deviations from rationality. Such studies document a difficult and as yet unresolved policy dilemma. In some cases (such as hazardous wastes) many individuals seem to place inexplicably large values on avoiding risks. Yet in other cases (such as floods or earthquakes) many individuals refuse to insure against objectively similar risks. While it is difficult or impossible to replicate the high loss nature of such events in the laboratory, it is possible to explore a range of risk to see if behavior at low probabilities is in some way different from behavior at relatively higher probabilities.

Finally, considerable controversy has surrounded the use of hypothetical as opposed to actual responses from individuals. Thus, the experiment was also designed to collect both hypothetical and actual data involving cash purchases of insurance. Hypothetical values were obtained both before and after individuals had actual market-like experience so that the effect of experience on the accuracy of hypothetical responses could be assessed.

The experiment itself involved the sale of insurance to subjects who were given an initial stake of $10; the insurance protected them from a four dollar loss which would occur if a red poker chip was drawn from a bag containing both red and white chips. If a white chip were drawn, the subjects received one dollar. Subjects submitted bids for and obtained insurance in a Vickrey sealed-bid auction. Vickrey auctions have been well documented as having both strong theoretical as well as strong demand revealing properties in an induced value laboratory context. (Vickrey, 1961; Coppinger, Smith and Titus, 1980). In our experiment, subjects participated in ten independent auction trials (where each trial involved the sale of insurance for that trial alone and a chip was drawn in each trial) for each of four probabilities of loss (0.4, 0.2, 0,1, and .01). Thus, each subject participated in forty actual auctions, ten at each probability.

Results of the experiment can be briefly summarized as follows: At the higher probabilities (.4 and .2) auction results are broadly consistent with a risk neutral version of the expected utility model in that average bids across trials correspond reasonably well with expected values. These bids are roughly normally distributed, but the variance is substantial. At the lower probabilities of loss, 0.1 and .01, the expected utility model progressively fails. Average bids across trials exceed expected values for insurance at an increasing rate as the probability decreases. Variance at these probability levels also increases. This result is largely consistent with prior results in experimental psychology. As the probability decreases, bids for insurance in the later trials become increasingly bimodally distributed. We interpret this bimodality to result from the increasing influence at low probabilities of two psychological processes: <u>framing effects</u> and changes in subjective probabilities due to the <u>gambler's fallacy</u>. Framing effects can occur when individuals, as they attempt to derive bids by intuitively <u>adjusting</u> the $4 loss downward to take into account that the loss will only occur some of the time, choose bids for insurance which are anchored at approximate round values such as $2.00, $1.00 and $.00. At low probabilities this intuitive method of deriving bids apparently becomes very imprecise and subjects, unsure of what they should bid, split on an upper and lower anchoring point. This bimodality is not present until later trials and develops as the median bid increases (weakly at p = .1 and sharply at p = .01) across trials. We interpret the source of this increase to be gambler's fallacy (Kahneman and Tversky, 1972; McClelland and Hackenberg, 1978). At the lower probabilities, where few or no red chips are drawn, each successive white draw falsely convinces some (but not all) subjects that the subjective probability of drawing a red chip in the next round has increased. Apparently at higher probabilities a sufficient number of red chips are drawn so that gambler's fallacy is, for the most part, self-cancelling (that is, the effect of drawing reds causes the reverse of the effect of drawing whites as noted above), and mean bids remain constant across trials.

If it is generally true that behavior at low probabilities is strongly subject to framing effects and gambler's fallacy and that the distribution of values tends towards bimodality, then deriving policy implications in uncertain environments would be difficult. For example, these results imply that the continuing absence of a major nuclear power accident involving public deaths may increase fear that such an event will occur in the future.

On the issue of hypothetical versus actual behavior, results again differ for higher as opposed to lower probabilities. At the higher probabilities, hypothetical values tend to be adequate predictors of actual auction behavior. At the lower probabilities, hypothetical bids increasingly diverge from and overestimate actual bids measured either as mean bids across subjects and trials. Hypothetical bids obtained after some auction experience were better predictors of actual behavior than completely inexperienced hypothetical bids. Thus, based on our results, hypothetical experiments may not be entirely misleading. However, hypothetical responses should be regarded with caution when small probabilities are involved.

2.0 Experimental Design

2.1 Theoretical Issues

This section develops the theoretical basis for the detailed experimental design presented below. In contrasting expected utility theory (EUT) with models from cognitive psychology, we draw strongly on the formalized theoretical structure developed by Kahnernan and Tversky (1979) which they term prospect theory (PT). PT has been evolving rapidly over the last decade and we apply the label broadly to include several extensions of the model including the effect of framing on decisions.

In general, our experiments were conducted as follows: each subject is given the opportunity to make a bid of B dollars for insurance against a possible loss of L dollars which occurs if a red chip is drawn. The probability of drawing a red chip is given as p. If a white chip with a stated probability of l-p is drawn, each subject is rewarded with a gain of G dollars. The gain is included in part to finance successive trials. If a subject has an initial wealth of Y^o dollars and utility is a function U(Y) of wealth Y, then, according to EUT the expected utility of the situation described above without purchase of insurance is

$$pU(y^o-L)+ (l-p)U(Y^o+G) \tag{2.1}$$

and the expected utility with purchase of insurance is

$$pU(Y^o-B)+ (l-p)U(Y^o+G-B) \;. \tag{2.2}$$

The most that an individual should pay for insurance can be obtained by setting (2.2) equal to (2.1) and solving for the bid, B. The notion here is that individuals will only be willing to increase the bid to the point that the expected utility with insurance falls to the level of expected utility without insurance. Since the loss and gain ($4 and $1 respectively) are small relative to wealth, EUT would imply that it is reasonable to suppose that changes in wealth are constrained to an approximately linear segment of the utility function. Thus, a linear approximate utility function

(2.3) $U(Y)=U(Y^0)+U'(Y^0)\bullet \Delta Y$ where $\Delta Y=Y-Y^0$

may be substituted into (2.1) and (2.2) without loss of generality. If (2.1) and (2.2) are then set equal, the bid for insurance solves as

(2.4) $B=p\bullet L.$

Thus, the bid is equal to the expected value of the loss (EV). Since, as noted above, Vickrey auctions have been shown to be strongly demand revealing, we would expect bids to be equal to EV or at least normally distributed around EV for a large range of probabilities p if EUT is a good predictor of behavior.

While maintaining the linear weighting of EUT, prospect theory makes use of two modifications. First, the utility function is replaced with a rather different value function. Second, the probabilities are replaced by a weighting function which depends on the probabilities.

PT postulates that individuals are assumed to care only about relative changes from their current wealth position and to dislike a loss in wealth much more than they enjoy an equivalent gain. Thus, according to PT the value function is not an argument of wealth, but rather of changes in wealth, ΔY. Further, the value function $v(\Delta Y)$ has the properties that $v(0)=0$, the left hand derivative $v'(0)^-$ exceeds the right hand derivative $v'(0)^+$ at the origin, and that both derivatives are positive, so $v'(0)^- > v'(0)^+ > 0$. As we show below, the value function likely plays no role in the structure of our experiment, but it has been introduced by cognitive psychologists because many individuals seem to make errors in judgment because they reason in relative rather than absolute terms and show intense aversion to perceived losses.

The weighting function $\pi(p)$ of PT overweights small probabilities $(\pi(p)>p)$, underweights large probabilities $(\pi(p)<p)$ and shows subcertainty $(\pi(p)+\pi(1-P)<1)$. The subcertainty feature implies that when a certain outcome is compared to an uncertain prospect, the prospect will be underweighted relative to the certain outcome. This modification in the model adjusts for the observation drawn from psychology experiments that individuals seem to be biased towards certainty.

Given PT as described above, the value of the prospect posed by the experimental situation without insurance would be given by

(2.5) $\pi(p)\nu(-L)+\pi(1-p)\nu(G)$

and the value of the situation with insurance would be given by

(2.6) $\nu(-B)+\pi(p)\nu(o)+\pi(1-p)\nu(G)$.

Note that (2.6) is not written as $\pi(p)\nu(-B)+\pi(1-p)\nu(G-B)$. This is because subjects must first pay for insurance, a <u>certain</u> loss which is valued as $\nu(-B)$ and implicitly weighted with unity. After this adjustment, subjects face a modified prospect of $\pi(p)\nu(o)+\pi(1-p)\nu(G)$ which is underweighted since $\pi(p)+\pi(1-p)<1$ reflecting a bias against uncertainty central to PT.

To obtain the bid for insurance, the two expressions (2.5) and (2.6) are set equal. This algebraic manipulation is specifically legitimized by cognitive psychology in the following way. The model presented here can be interpreted as a mental representation which individuals use in deciding how much to bid for insurance. Thus, subjects in the experiment will note that the gain of G dollars will occur with or without purchase of insurance. This implies that $\pi(1-p)\nu(G)$ may be cancelled from (2.5) and (2.6), that is, the gain can be ignored in the decision process. If an individual has insurance, a red draw causes no loss, so the term

$\pi(p)v(o)$ may be dropped from (2.6) since $v(o)=0$. This leaves a comparison of the certain loss associated with purchasing insurance which is valued as $v(-B)$) with the uncertain loss associated with drawing a red chip which is valued as $\pi(p)v(-L)$. Thus, we arrive at

(2.7) $v(-B)=\pi(p)v(-L)$.

Since the value functions on both sides of (2.7) evaluates small decreases in income, -B and -L, respectively, a linear approximation of the value function is appropriate so, for decreases in income $(\Delta Y<0)$ we have

(2.8) $v(\Delta Y)\approx v(o)+v'(o)^{-}\cdot\Delta Y=v'(o)^{-}\cdot\Delta Y$

since $v(o)=0$, Substituting (2.8) into (2.7) yields

(2.9) $B = \pi(p)L$

and therefore the bid is equal to the weighting function times the loss. Thus, bids for insurance against a small loss will, according to PT, involve the weighting function but not the value function. Individuals can be thought of as recognizing that they must choose between two small <u>dollar</u> losses: a sure one of B dollars and an unsure one of L dollars. We will discuss a possible mental process for arriving at this bid shortly.

First note that we can evaluate the predictions of PT relative to those of EUT by dividing the actual bids obtained in the experiment by EV which is a known constant, PL, for any stated probability, p, and loss, L. If PT is taken as the basis of analysis, dividing (2.9) by EV yields

(2.10) $B/EV=\pi(p)/p$.

Given the assumptions on the weighting function (relative overweighting of low probabilities) B/EV should be greater than unity for small probabilities, and B/EV should be less than unity for larger probabilities. Thus, our experimental design focuses on the values of B/EV over alternative probability levels. If the frequency distribution of individual values of B/EV at all probability levels is normally distributed around unity, then bids should closely correspond to EV and EUT would be supported by the data. Alternatively, if the frequency distribution of individual values of B/EV is not normally distributed around unity, some version of PT is likely to be the more appropriate theoretical structure.

Before concluding this discussion, two further issues must be introduced. First, even in the case where subjects are shown the number of red and white chips to be used in the lottery, the subjective probability of an individual may differ from the objective probability provided to subjects. Thus, a subjective probability, s, may be substituted into either the EUT or PT formulation for the bid for insurance (equations 2.4 or 2.9, respectively) replacing the objective probability, p. It is important to note in this context that the weighting function itself used in PT is not a subjective probability. Rather, if individuals make a logical error in probability perception (such as gambler's fallacy) the false subjective probability must be substituted into the weighting function. The notion of subjective probabilities is, of course, not inconsistent with EUT and such a substitution may be made there as well.

Second, PT also incorporates the notion of framing. One possible type of framing is the result of anchoring and adjustment. To understand this process, we must ask how individuals actually arrive at bids in a way consistent with the formula, $B=\pi L$, derived from PT. Since the potential loss, L, is four dollars, cognitive psychologists argue that subjects will, in deriving a bid, intuitively attempt to adjust this loss downward to take into account that the loss will only occur some of the time. The weighting function, π, is just a mathematical representation of this adjustment process. The bias in π as opposed to p can be viewed as reflecting typical errors in this adjustment process. Subjects faced with the problem of coming up with a bid for insurance against a four dollar loss with a probability of .1 may be viewed as going through the following mental process:

<u>Example</u>

> "Should I bid $4.00? No, the loss will not occur all the time so insurance is not worth that much. Should I bid $2.00? No, this still seems to be too high a proportion of $4.00. Should I bid $1.00? Maybe. Should I bid $.50? Maybe. Should I bid $.00? No, insurance is probably worth something more. I think $.50 is probably closer than $1.00 to the proportion of $4.00 which represents the likelihood of the loss so I guess that will be my bid.

Note that EV is $.40 in this case and, in the example above, the adjustment process has generated a bid which is quite appropriate. However, many subjects are likely to "guess" $1 .00 since the intuitive process used in the example above is not highly accurate. That is, individuals may not engage in formal mathematical calculations in arriving at their bids. Values such as $4.00, $2.00, $1.00, $.50 and $.00 or other "round" numbers are termed <u>anchors</u>. Anchors may be viewed as discrete alternatives used in the decision process. Unfortunately, it has been well documented that individuals tend to pick up inappropriate information for use as anchors. For example, If subjects in our experiment had been told that a previous subject had bid $5 for insurance, many subjects might have included this amount for evaluation as a possible bid. Then, $5 may have been used as an anchor even though the possible loss was only $4. We attempted to avoid the presentation of any extraneous information which might have resulted in such anchoring of bids. However, the data presented below strongly suggests that individuals constructed their own anchors possibly along the lines suggested in the example given above.

2.2 The Structure of the Experiment

Each experimental session employed eight student volunteers recruited from undergraduate economics classes at the University of Colorado. Five experimental sessions (total of 40 participants) provide the primary data reported in this paper. No student participated in more than one session. Subjects received a $5 guaranteed payment for participating. In addition, they were given a $10 stake at the beginning of the experiment; they were allowed to keep any of the stake remaining and any gains at the end of the experiment. Subjects were assured that even if they lost all their stake, they would still receive the $5 payment.

Overview. In the course of an experimental session, each participant made a total of 51 bids to purchase insurance in the following risky situation which was fully described to the participants. A chip is to be drawn from a bag containing R red chips and W = 100-R white chips. If a white chip is drawn, each participant receives $1. If a red chip is drawn, those having insurance lose nothing but those without insurance lose $4. Before being placed in the bag, the stacks of chips were displayed on a table in front of the participants so they would have a more concrete representation of the specific probability levels. The four values of R used in each session were 1, 10, 20, and 40 corresponding, to p = .01, .1, .2, and .4 respectively. The particular value of R being used was always made explicit before each bid. The total of 51 bids consisted of two basic types: hypothetical bids (7) and Vickrey auction bids (44). The method used for obtaining each bid type is described separately below and then the sequence of the bid types is described.

Hypothetical Bids. Two types of hypothetical bids were collected: inexperienced and experienced. For the inexperienced hypothetical bids, the risky situation was described to subjects as hypothetical and they were asked how much they would hypothetically pay for an "insurance policy" which would offer full protection against the $4 loss associated with the draw of a red chip. Subjects wrote their bids on paper. These inexperienced hypothetical bids were meant to be comparable to the types of responses obtained in many psychology experiments (for example, Slovic et. al., 1977).

To obtain the experienced hypothetical bids, subjects were asked the same hypothetical question after they had had experience with the Vickrey auction and with the drawing of chips for other probability levels. Subjects entered their bids on computer terminals in the same manner as described below for the Vickrey auction.

Vickrey Auction Bids. A Vickrey auction determined who received insurance on each round. Subjects read written instructions, heard an oral explanation of the auction procedure, and were given an opportunity to ask questions. After the appropriate number of chips were displayed and placed in the bag, subjects entered bids for insurance on a computer terminal. This terminal also displayed the current composition of the chip bag. The computer accepted bids between, inclusively, O and the subject's current balance in units of one cent. After everyone had entered a bid, the computer rank ordered the bids from highest to lowest and displayed the "reigning price"--the fifth highest bid for insurance--on each subject's terminal screen. Only the four subjects with bids above the reigning price received insurance. In the case of ties for the fourth highest bid, remaining insurance policies were randomly allocated among those with tied bids. Those receiving insurance were only required to pay the reigning price. This, of course, represents the key feature of the Vickrey auction which eliminates incentives for strategic behavior which are present in auctions in which individuals must pay exactly what they bid. After each auction, the computer displayed the original balance, the reigning price, whether or not insurance had been received, adjustments to the balance, if any, and the new balance. Other than the reigning price, subjects received no information about the bids of other subjects. Terminals were arranged so that no subject could see the terminal of any other subject and subjects were not allowed to talk with each other. At the beginning of the experiment subjects participated in four practice bidding rounds which did not affect their balances in order to familiarize them with the procedures used in the Vickrey auction.

Great care was taken to avoid the use of any judgmental words in the written and oral instructions. This is in contrast to some previous experiments using the Vickrey auction which have used "winners" to designate those who have received insurance. The use of such words might artificially increase the value of holding insurance above its value as protection against the loss associated with the draw of a red chip.

Risky Event. After the auction and distribution of insurance, the experimenter reached into the bag of chips, stirred the chips noisily to reinforce beliefs of randomness, and drew a chip from the bag so that all subjects could see its color. Another experimenter entered the color of this chip at a control terminal so that the appropriate adjustments--$l to all if a white chip was drawn and $4 loss to those without insurance if red chip was drawn--could be made to the subjects’ balances and displayed on their terminals. To allow pooling of data across sessions and to ensure that all subjects received the same probabilistic experience, the drawing was controlled (the different colors of the chips were distinguishable by texture as in Phillips and Edwards, 1966, and many similar psychology experiments) according to the following sequences:

Probability Level	Sequence
p = .01	W W W W W W W W W W
p = .10	W W R W W W W W W W
p = .20	W W R W W W R W W W
p = .40	W R R W W W R W W W

Sequence. The different components of the experiment were presented and data were obtained in the following fixed order:

Inexperienced Hypothetical Bids at p = .2, .1, .01, and .4

Vickrey Auction Practice Bids, 4 rounds at p = .2

Vickrey Auction Binding Bids, 10 rounds at p = .2

Experienced Hypothetical Bids at p = .1

Vickrey Auction Binding Bids, 10 rounds at p = .1

Experienced Hypothetical Bids at p = .01

Vickrey Auction Binding Bids, 10 rounds at p = .01

Experienced Hypothetical Bids at p = .4.

Vickrey Auction Binding Bids, 10 rounds at p = .4

The fixed order of probabilities makes it impossible to have experienced hypothetical bids for p = .2 because that was always the first probability level presented in the actual auctions.

3.0 Results

Summary statistics describing results of the experiment are presented in Figures 1-3. These figures depict means, medians and, variances of bids divided by expected value, B/EV, respectively. As noted in Section 2.1, we normalize bids for insurance by dividing by expected values so we can directly compare results at different probability levels with each other and with the predictions of EUT. According to EUT we would, of course, expect mean and median measures of B/EV to equal unity.

The left hand panel of Figure 1 shows grand means of B/EV plotted against probability of loss. The curve labelled "Auc" is the grand mean value for all ten trials from the actual auctions. Note that at the two higher probabilities of loss, .2 and .4, mean B/EV is close to unity suggesting that behavior corresponds quite well to the predictions of EUT. However, at the lower probabilities of .1 and .01, EUT fails to predict observed values. Mean bids rise to about two and one-half times EV at a probability of loss of .01. Thus, on average individuals overbid for insurance at low probabilities. This result at low probabilities is entirely consistent with the predictions of PT and can be interpreted as a direct consequence of the weighting function. From equation (2.10), PT predicts B/EV = $\pi(p)/p$, which should exceed unity for small p; since it is assumed that $\pi(p)>p$ in this case. Mean auction values do not necessarily support PT at the higher probabilities (.2 and .4) since PT argues that $\pi(p)< p$ for large p which implies $B/EV<1$. However, it should be noted that PT only predicts small underbidding at higher probabilities for the

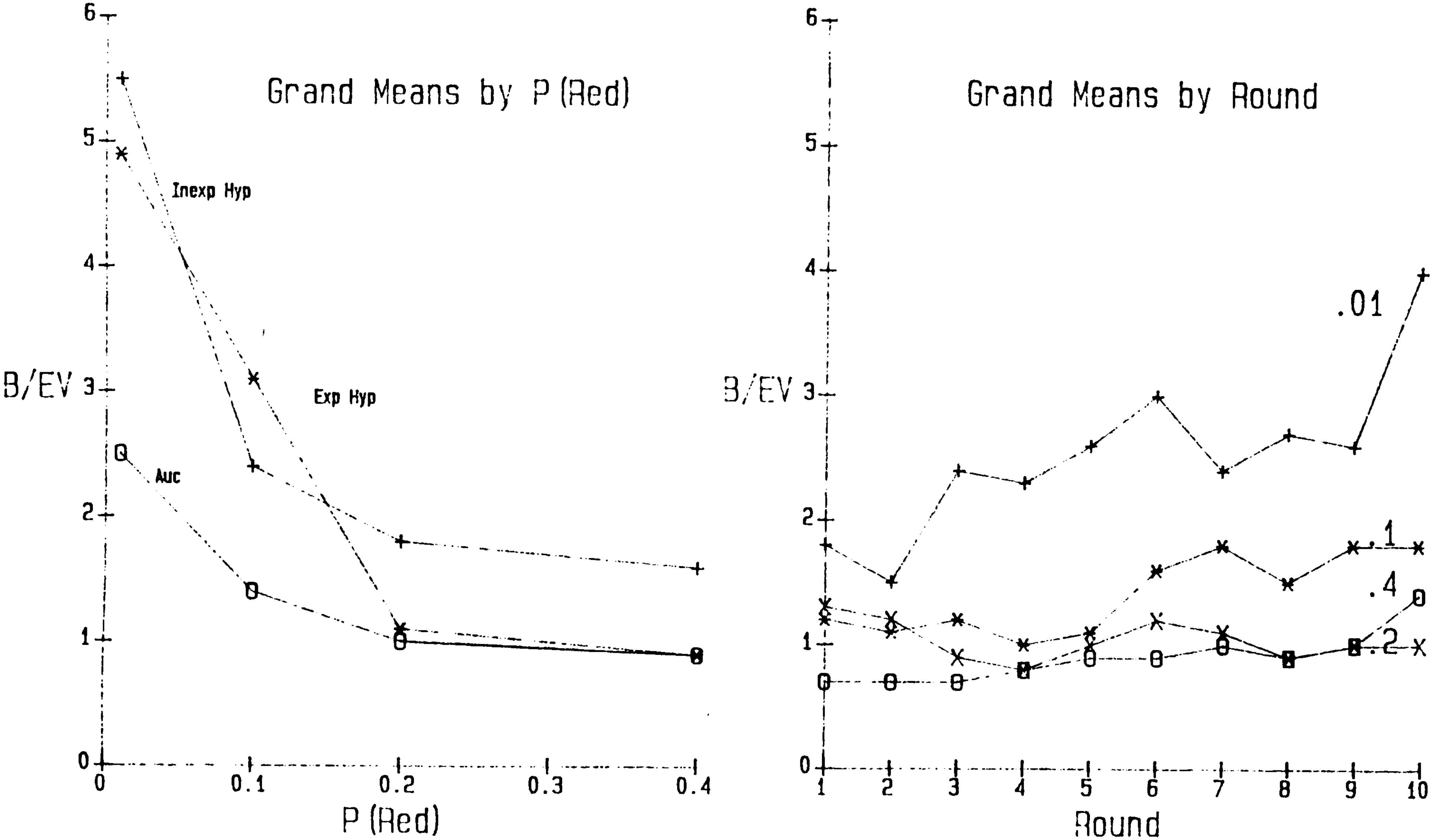

Figure 1: Mean Bids by Probability and Round

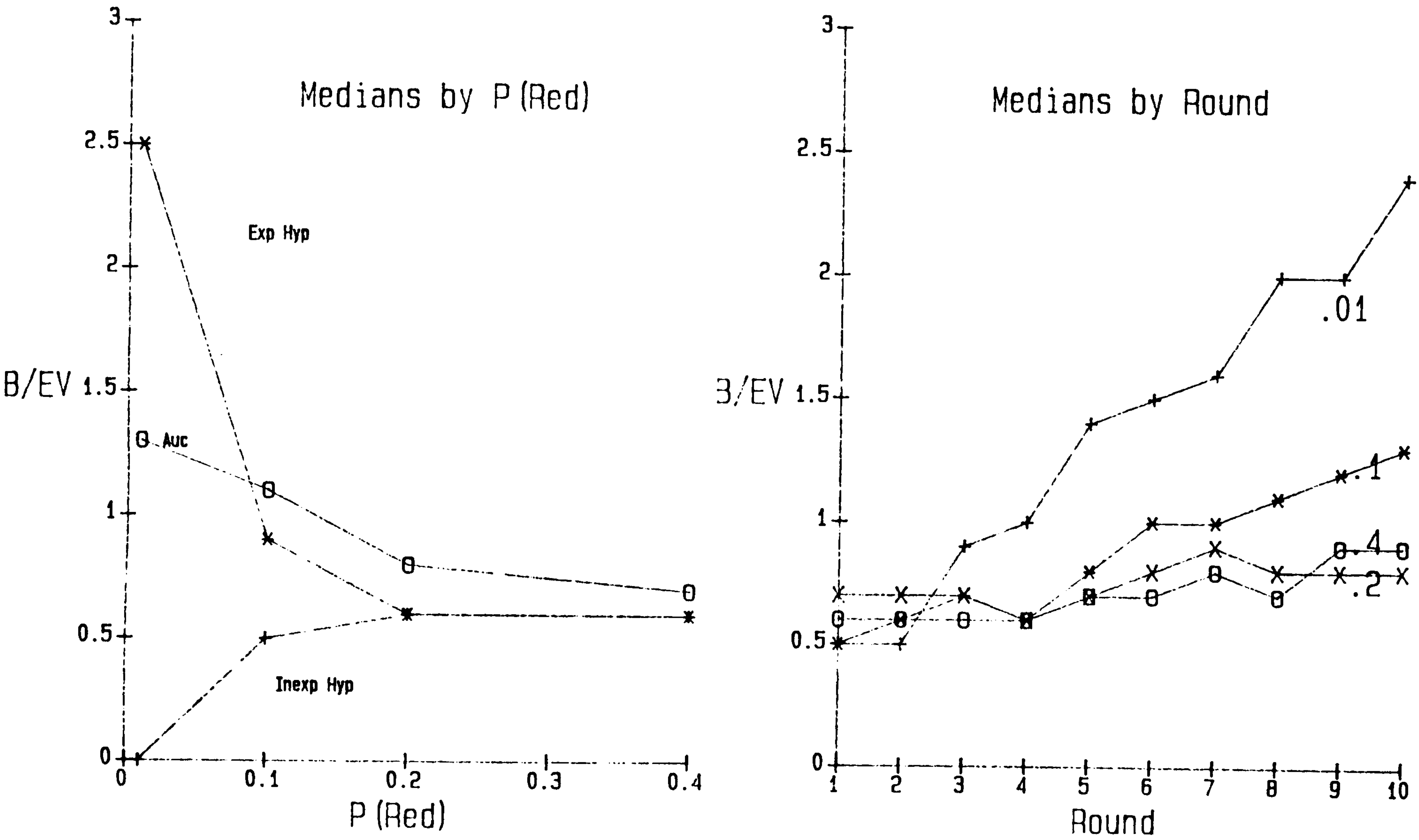

Figure 2: Median Bids by Probability and Round

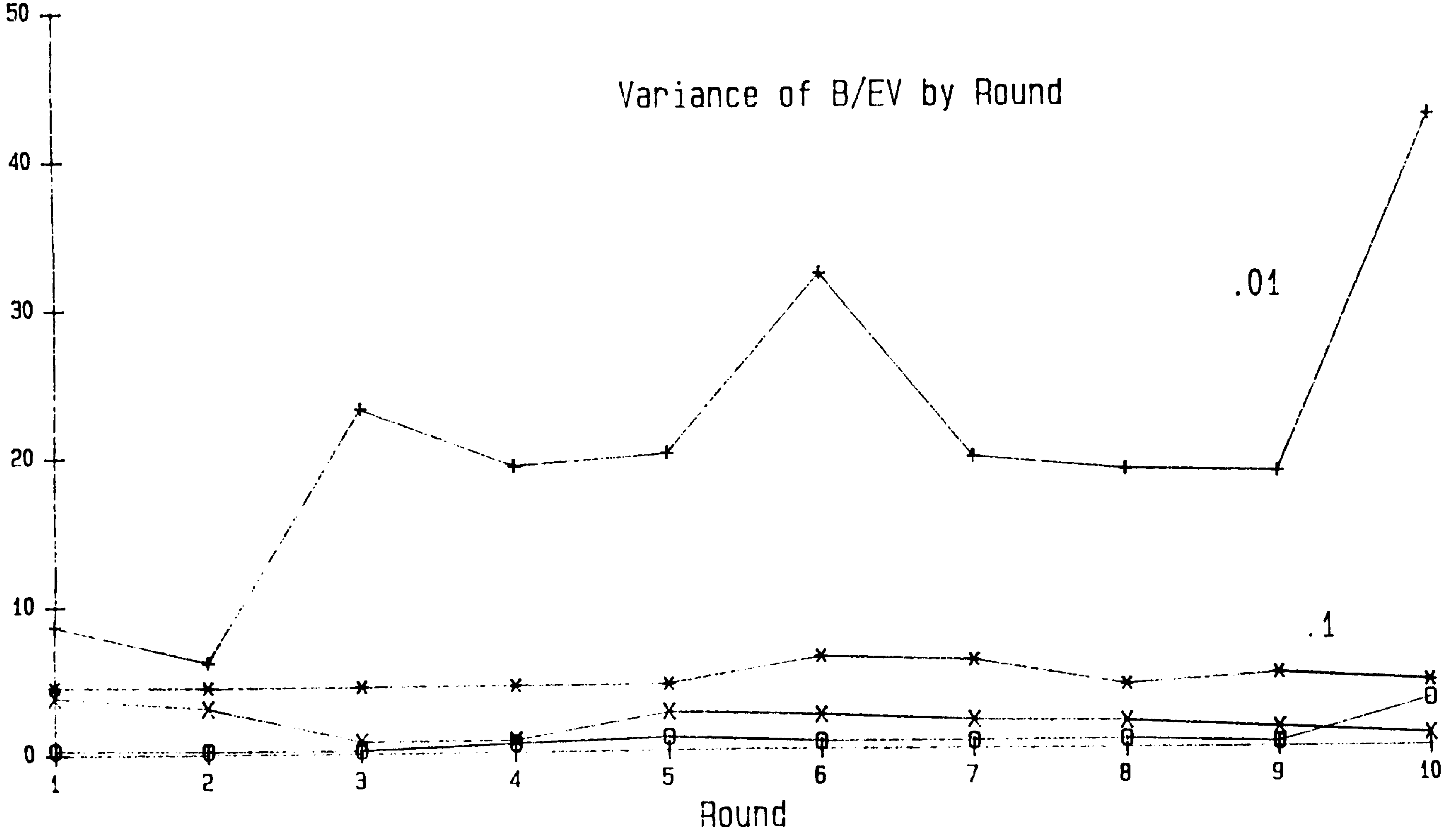

Figure 3: Variances of Bids by Round

specific weighting functions typically proposed, so we doubt that these data support a rejection of PT at higher probabilities. Rather, EUT and PT are similar in their predictions at higher probabilities for the case of insurance against loss.

Turning to the left hand panel of Figure 2, which is similar to the left hand panel of Figure 1, but presents medians, the curve labeled "Auc" moves downward substantially in comparison to Figure 1. This curve still shows overbidding at low probabilities, but now shows underbidding at high probabilities, consistent with PT. But, the median auction curve of B/EV remains within plus or minus thirty percent of unity, suggesting that median behavior is not grossly different from what EUT would predict. However, this result combined with mean behavior suggests that some or all individuals, some or all of the time (note we are taking grand means and medians over rounds) must deviate substantially from EUT since mean values of B/EV deviate substantially from unity at the lower probabilities. This divergence between mean and median auction bids at low probabilities implies that the individual values of B/EV cannot be normally distributed, an issue we will return to later. Note also, that the variance of auction B/EV is much higher for p = .01 as shown Figure 3.

Hypothetical values of B/EV for both inexperienced and experienced responses labeled "Inexp Hyp" and "Exp Hyp," respectively in Figures 1 and 2, mirror the results for the actual auction. At the higher probabilities, hypothetical values are similar to the values EUT would predict, but deviate substantially from EUT at lower probabilities. For mean values shown in the left hand panel of Figure 1 , experienced hypothetical are quite accurate and outperform inexperienced hypothetical in predicting actual auction bids at high probabilities. Both measures perform equally poorly in predicting mean auction B/EV at low probabilities.

Inexperienced and experienced median hypothetical differ widely both from each other and from actual auction values of B/EV at low probabilities, as shown in the left hand panel of Figure 2. All measures converge at the higher probabilities. Variance increases at low probabilities for hypothetical measures as depicted in Figure 3. Clearly, hypothetical values are reasonable predictors of auction values at higher probabilities, especially if subjects have experience with the auction environment. However, hypothetical measures may be very misleading as compared to actual auction measures at low probabilities.

The right hand panels of Figures 1 and 2 and the variances reported in Figure 3 present information on auction values of B/EV across rounds or trials. The means in Figure 1 remain constant and near unity across rounds for the higher probabilities of .2 and .4, show a slight upward drift for .1, and show a large upward movement at .01 across rounds. This pattern is even more evident for median values as shown in Figure 2. Variances reported in Figure 3 remain relatively constant across rounds at probabilities of .4, .2 and .1, but the variance for B/EV rises sharply across rounds for probability level .01.

We interpret the upward drift over rounds of B/EV at the lower probabilities as the result of gambler’s fallacy. That is, if a run of successive white chips is drawn, subjects become falsely convinced that the subjective probability of drawing a red chip has increased. This effect is not apparent at higher probabilities because when a red chip is drawn, subjects either "reset" their subjective probability close to the objective probability or assume that the odds of drawing another red chip have gone down. Thus, gambler’s fallacy appears to be self canceling when subjects experience fairly frequent draws of a red chip. Of course at low probabilities, long runs of successive draws of white chips are likely and the cumulative effect of gambler's fallacy will be apparent. When examining the right hand panels in Figures 1 and 2, it is important to remember that across the ten rounds at a probability level of .01 no red chips were drawn. Also, at the probability level of .1 only one red was drawn (on the third round). We postpone for the moment a more detailed analysis of gambler's fallacy.

4.0 Evidence on Anchoring and Adjustment

Given the likelihood that B/EV is not normally distributed at low probabilities and that mean values, median values, and the variance of B/EV all increase over rounds, we turn to a detailed analysis of the frequency distributions of B/EV both at differing probabilities and for an early and a late round. These frequency distributions strongly suggest an important role for anchoring and adjustment.

Figure 4 presents frequency distributions for auction values of B/EV at probabilities of loss of .4, .2, .1 and .01 respectively, where the left hand panels depict round 2 results and the right hand panels depict Round 7 results. These particular rounds were chosen to avoid the starting and ending rounds and to avoid an immediately preceding draw of a red chip.

Looking at the round 2 results presented in the left hand panels, the frequency of zero bids increases as the probability of a red chip decreases. In each panel the modal value of B/EV is less than unity. Thus, modal bids in Round 2 are uniformly below EV and seem to be near plausible anchors. The modal values of the bids themselves (not B/EV, just B) are near possible anchors of $1 at a probability of .4 (EV=$l .60), $.50

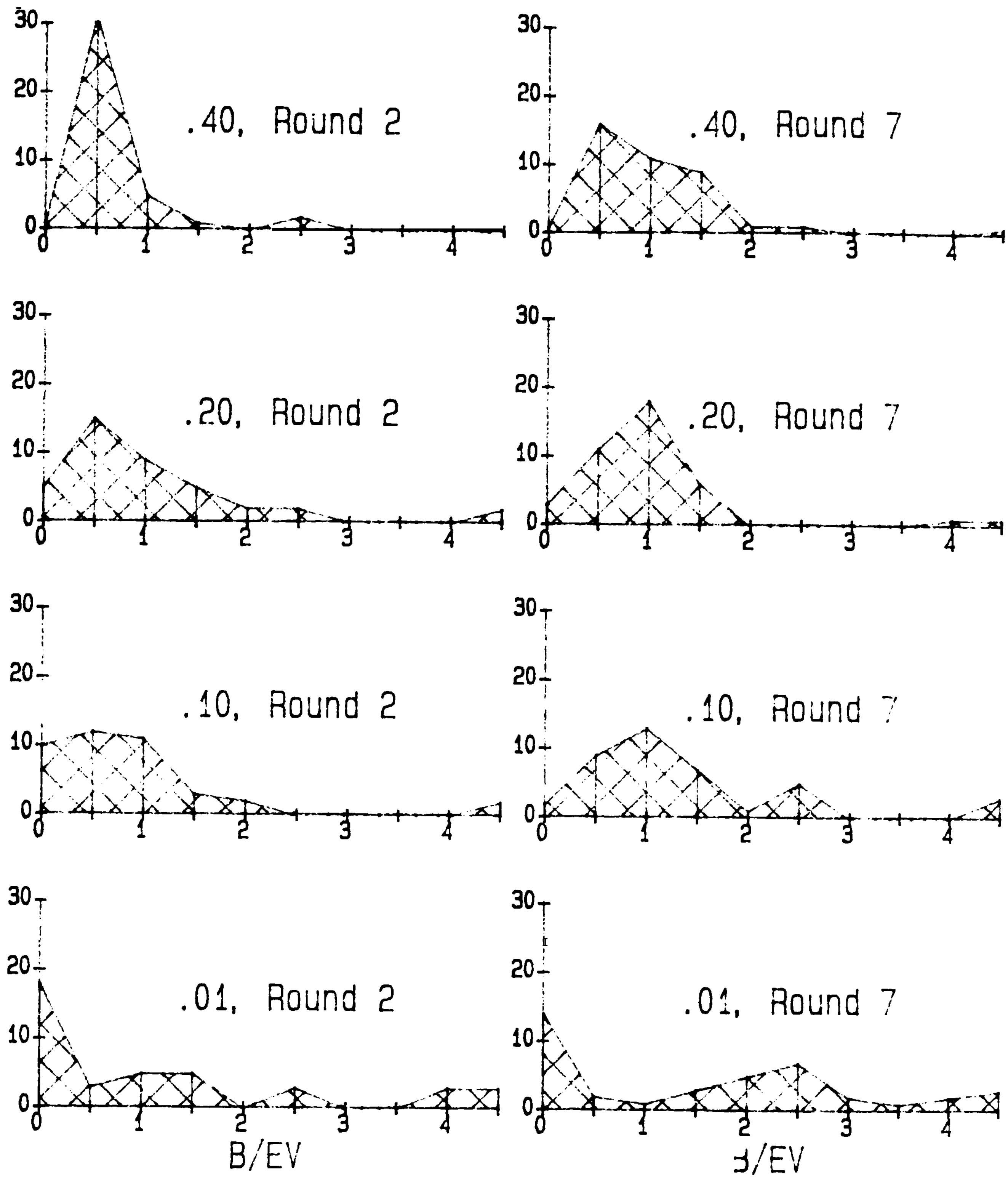

Figure 4 : Frequency Distributions for Auction Bids

at a probability of .2 (EV=$.80), no single strong anchor at a probability of .1 (EV=$.40), and $.00 at a probability of .01 (EV=$.04). Many bids take on these particular "round number" values in the early rounds. Thus, it appears that individuals initially tend to settle on anchors below EV in these data.

Turning to the Round 7 results presented in the right hand panels of Figure 4, at the higher probabilities of .4 and .2 values of B/EV are now distributed around unity, consistent with EUT. At p = .4 for a loss, the distribution is distorted to the left by the anchoring effect of bidding at or near $1.00 which falls near .5 of EV. In other late rounds (not shown) the mode for a probability of .4 switches back and forth between .5 times EV and 1.5 times EV (where 1.5 times EV is consistent with another anchoring point, $2.00). Thus, in spite of anchoring effects, bids remain convincingly near EV=$l .60.

At a probability of .2 the single mode is at EV, in part because the anchoring value of $1 is close to the EV of $.80, again giving a frequency distribution consistent with EUT. Thus, in spite of the apparent presence of anchoring effects, at higher probabilities and in the later rounds where subjects have had experience both with the auction and with losses, bids are essentially consistent with EUT.

This is not the case at the lower probabilities. Here, anchoring appears to seriously affect the results. At p = .1 (shown in the right hand panel in the third row of Figure 4) the frequency distribution of B/EV is clearly bimodal, with the dominant mode at EV, i.e., B/EV=l, and another mode at two and one half times EV. These modes are consistent with two anchors, $.50 and $1.00, where EV is $.40. Since these two anchors both lie above EV, mean B/EV is biased upwards as shown in Figure 1, especially in later rounds. Bidding can be thought of as starting off at a lower anchor below EV in the earliest rounds, quickly moving to an anchor near EV in middle rounds, but then moving to an anchor above EV in the later rounds. This last movement by some individuals is likely due to the effect of gambler's fallacy as discussed above.

Results diverge even further from EUT at a loss probability of .01 in Round 7 (see right hand panel in last row of Figure). The bimodality now surrounds but does not include EV, which is now a minimum point in the distribution. The two modes occur at zero and two and one-half times EV, consistent with anchors of $.00 and $.10 where EV is $.04. The evolution over rounds begins with a single mode at B/EV=O followed directly by development of a second mode at B/EV=2.5. Apparently, gambler's fallacy causes some subjects to switch progressively from the lower mode to the upper mode as the number of successive draws of a white chip increases with each round.

A formal model of anchoring and adjustment can be developed for our experimental structure as follows: Let A_0, A_1, ...A_n be a vector of anchors applied to the selection of bids for insurance ranked in ascending order from lowest to highest. For our experimental situation A_0=$O and A_n =$ L=$4. In other words, anchors plausibly range from no bid to a bid equal to the loss. Some individuals may then use the following rule for selecting a bid given their intuition or belief about pL:

$$B=A_i \quad \text{if } \left(\frac{A_{i+1}+A_i}{2}\right) > p\cdot L > \left(\frac{A_i+A_{i-1}}{2}\right).$$

Such individuals will bid the anchor A_i closest to their assessment of the proportion of the loss, pL, used to estimate the appropriate bid. This line of argument suggests that the frequency distribution of B/EV may well not be normally distributed but show a number of modes, one at each of several possible anchors.

The model developed above for anchoring is consistent with the tendency of individuals to consider only discrete alternatives when making decisions. This phenomenon may be sufficient to generate the weighting function $\pi(p)$ as follows: For low probabilities, most anchors will be above EV, causing average bids to exceed EV because most errors in bidding will result from choices of anchors which lie above EV. For high probabilities, most anchors will be below EV, causing the average bids to be below EV because most errors in bidding will result from choices of anchors below EV. In some sense, the weighting function is an artifact caused by the anchoring process and the typical location of anchors relative to EV. This conjecture could be tested by careful choices of values of L which would change the distribution of anchors relative to EV for low and high probabilities.

In summary, as the probability of loss decreases, the data show that the effects of anchoring become increasingly important and result in bimodality in the distribution of bids. Similarly, as the probability decreases, the effect of gambler's fallacy on bids increases since long runs of successive draws of white chips are likely to occur. We now return to a more detailed analysis of gambler's fallacy.

5.0 Evidence on Gambler's Fallacy

An examination of Figures 1,2, and 4 reveals considerable changes in B/EV across rounds for some probability levels. Such changes are inconsistent with either EUT or PT as those models are formulated because neither Equation 2.4 nor Equation 2.9 , which express the insurance bid B as a function of probability and loss, depend upon round in any way. That is, both models predict that B/EV ought to be constant across rounds: the appropriate bid for Round 1 is the same as the appropriate bid for Round 10.

One possible explanation for the changes in B/EV across rounds is the gambler's fallacy: a belief that the probability of a particular outcome increases the longer that outcome has not occurred. In the context of this experiment, gambler's fallacy is equivalent to the belief that the probability of drawing a red chip increases with each consecutive draw of a white chip. The gambler's fallacy has been demonstrated in psychological studies of subjective probability by Kahneman and Tversky (1972), McClelland and Hackenberg (1978), and others. Although gambler's fallacy is not formally a part of PT, it is certainly consistent with the cognitive heuristics and biases which are presumed to underlie PT.

To incorporate the gambler's fallacy into either EUT or PT we need only replace p, the objective probability, with s, the subjective probability, in the theoretical development of both models in Section 2. The subjective probability, s, may be a function of both the objective probability, p, and the past history of red and white draws across rounds. The predicted bids according to EUT and PT are then given respectively, by

(4.1) $B=s*L$ and

(4.2) $B=\pi(s)\cdot L$.

In either case, as s increases then B ought to increase. According to the gambler's fallacy, s increases after drawing a white chip and decreases after drawing a red chip. Thus, according to both models, systematic changes in B as a function of the color of the previous chip drawn would indicate systematic changes in s.

The top panel of Figure 5 shows the probability that B increased given any change in B after a white chip and after a red chip for each probability level. For all probability levels, the probability that B

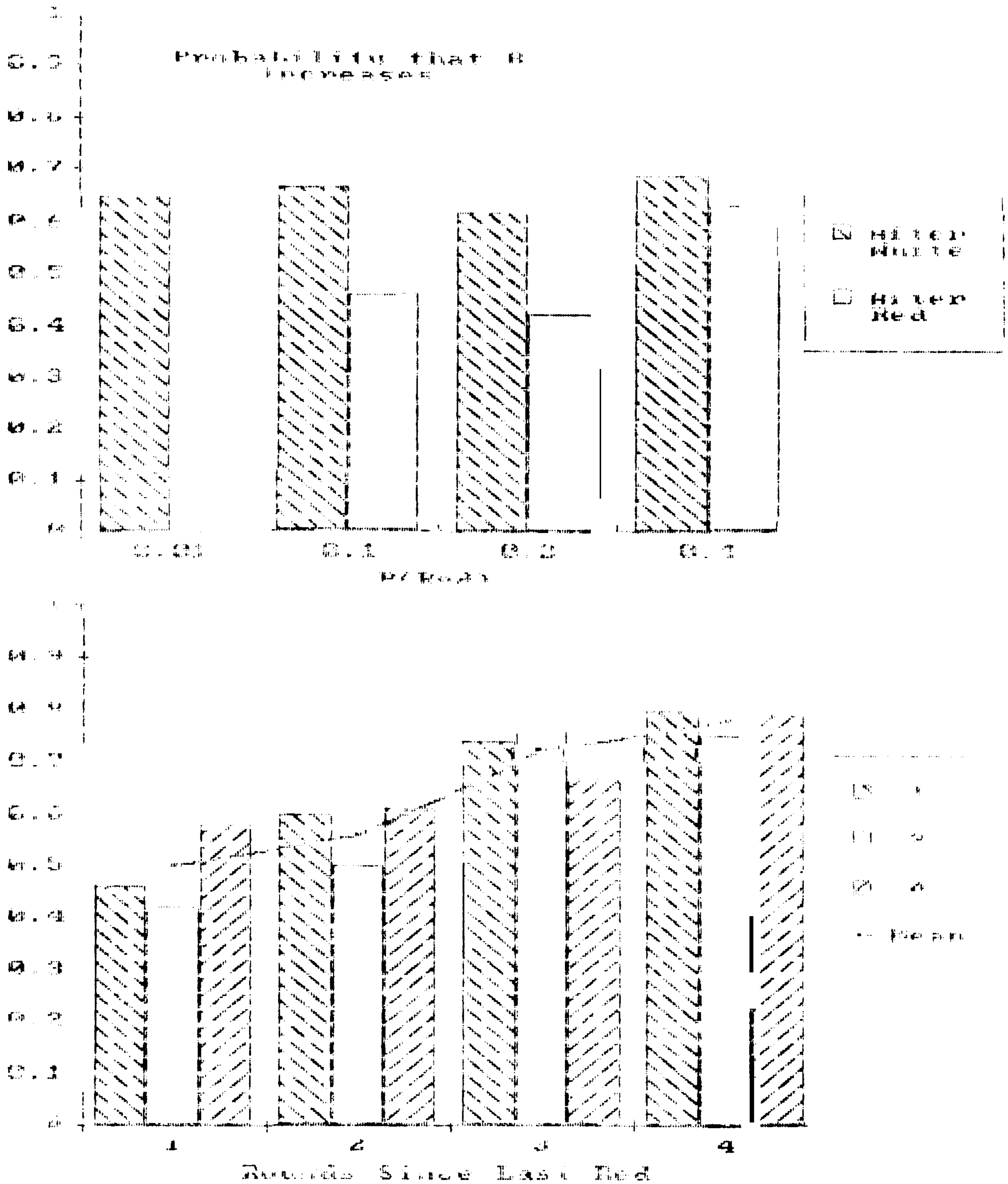

Figure 5: The Gambler's Fallacy

increases given any change in B after a white chip is about .65. Of course, if round-by-round changes in s and consequently B were not systematic then the expected probability that B increases would equal .5. The fact that the probability that B increases after the draw of white chip is greater than .5 is consistent with the gambler’s fallacy. When the probability of a red chip is .1 or .2 then it is slightly less likely (.45) that B will increase following a red chip than it will increase. However, it is slightly more likely that B will decrease following a red chip. This is not true, on average, when the probability of a red chip is .4. In summary the differential probability that B increases when the probability of a red chip equals .1 or .2 is consistent with the gambler’s fallacy but the lack of a differential for .4 is not.

According to the gambler’s fallacy, the subjective probability that a red chip will be drawn ought to increase the longer the time since a red chip has been drawn. In other words, for each successive white chip s ought to increase. Hence, it ought to be more likely that B will increase after four consecutive draws of white chips than after one draw of a white chip. The bottom panel of Figure 5 displays the probability that B increases given any change in B for each probability level of a red chip as a function of the number of rounds since the last red chip was drawn. The continuous line represents the weighted mean across probabilities of a red chip. In this panel, "Round 1" represents the first round after a red chip has been drawn. Note that p = .01 is not included because a red chip was never drawn in that series of rounds. Consistent with the gambler’s fallacy, the probability that B increases given any change in B increases steadily with the number of rounds since the last red chip was drawn. This is true for the mean as well as for all levels of probability for a red chip. Immediately after the draw of a red chip, the probability that B increases rises to .78. This effect is entirely consistent with the gambler's fallacy. Also note that this effect explains the lack of a differential in the top panel of Figure 5 when p = .4. When p = .4 there are more instances of short runs of white chips and fewer instances of long runs. The bottom panel shows that for short runs of white chips the probability that B changes is not that different from .5. When p = .4 there are more instances of short runs of white chips. These short runs are therefore overweighted in the average for p = .4 in the top panel of Figure 5. When the data for p = .4 are disaggregated by length of run in the bottom panel of Figure 5, then that probability level also shows clear evidence for the gambler’s fallacy.

6.0 Conclusion

The principle objective of the experiment reported in this paper was to explore insurance behavior in a laboratory market-like environment where the probability of loss was varied and the loss itself was held constant. Thus, the predictions of expected utility theory as well as models from cognitive psychology could be compared against actual behavior at both higher and lower probabilities of loss. Additionally, repeated trials were included in the experiments so that the effect of experience on decisionmaking could be determined. The results of the experiment suggest that although expected utility theory is an adequate explanation of behavior at higher probabilities of loss, at lower probabilities a much more complex model is required to explain observed behavior. This complex model has been evolving within cognitive psychology principally under the guise of prospect theory and includes features such as the overweighting of low probabilities and the anchoring and adjustment process documented in our results. Additional results of our experiment include, at low probabilities, a large gambler's fallacy effect and a strong tendency for bimodality. These results are consistent with the direction and spirit of prospect theory. Further, they serve to reinforce our general conclusion that models which arise from cognitive psychology and which consequently focus on the mental processes and possible errors in those processes are central to any explanation of economic behavior motivated by low probability events.

Although it can be argued that markets themselves seem to promote rationality, they do not seem to help very much for low probability, uncertain situations at least within the range of experience observed in our experiments. This implies that decisionmaking at low probabilities is likely to be subject to error even in a market context. That is, behavior will be less than perfectly rational. Individual responses to threats from low probability hazards such as floods, hurricanes, earthquakes, nuclear power, or hazardous wastes are likely to suffer from the entire litany of cognitive difficulties identified above.

This complex of cognitive difficulties poses a real challenge for public policy in that few ways have been yet devised to help individuals overcome such problems. The experimental approach employed in this research may be of use, however, in identifying workable strategies for public policy. For example, future research might attempt to test ways of communicating risks to subjects in an experiment similar to the one described herein.

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