

A DECISION PROCESS MODEL FOR ANALYZING
CONSUMER PURCHASES OF ALTERNATIVE-FUELED VEHICLES:
THE CASE OF CNG VEHICLE CONVERSIONS IN BRITISH COLUMBIA

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I. Introduction

Government and industry are actively considering major initiatives to introduce non-petroleum alternative fuels. These initiatives ultimately require the cooperation of fuel users. Yet little is known or understood about how consumers would respond to the option of purchasing vehicles powered by non-petroleum fuels (e.g. Greene, 1989).

This paper proposes a model to explain and predict consumer purchases of alternative fuels and vehicles. The model is adapted from a decision process model used in market research (Engel et al 1978). It incorporates the concepts of risk and uncertainty, attitude and elimination by aspect (Tversky 1971). The model addresses decisions made by individuals in the context of a social process.

The specific consumer choice analyzed was the decision to retrofit a conventional gasoline vehicle to operate on both CNG and gasoline (manufactured dual-fuel CNG/gasoline and single fueled CNG vehicles are not yet available).

The strength of the proposed model is explaining the steps through which a gasoline auto owner becomes a routine user of CNG fuel. At each step, the model examines the attitudes of consumers and the attributes of fueling systems as perceived by consumers (Fennel 1980) in the context of their social environment.

This model allows us to explore the following hypotheses about the CNG market in British Columbia.

1. Most users of natural gas systems are still evaluating their purchase. Therefore, the purchase of a conversion kit does not indicate the buyer is a confirmed CNG user.

2. The percentage of confirmed CNG users could be increased dramatically by more government and industry commitment to CNG and continued expansion of the refueling system.

3. The lack of information and organized institutional support for the conversion of vehicles to CNG blocks consumers with low levels of technical knowledge from switching fuels even though the savings may be substantial.

4. Technical knowledge is used by consumers to reduce risk, but this knowledge does not explain who is attracted to this option. CNG users are primarily motivated by fuel cost savings, not by other attributes of the alternative fuel technology.

II. Background to the Study

Canada has large natural gas resources, making the switch to natural gas fueled vehicles a project of interest to the government and Canadian industry. In British Columbia, the public utility, BC Hydro (recently changed to BC Gas)* has developed a refueling and conversion program which has led to the conversion of over 8000 gasoline fueled vehicles to dual fueled, natural gas-gasoline in the Vancouver area. These vehicles are serviced by 57 refueling stations. About half these vehicles are owned and operated by households, not businesses or government agencies.

To have their car converted from gasoline use to dual-fueled, CNG-gasoline capability, these car owners purchased conversion kits and contracted with private conversion shops. As an incentive, many converters have received government grants to

* The discussants in this group all refer to the gas utility as B.C. Hydro. In fact, the gas utility activities of BC Hydro have been bought by Inland Gas Co., forming a new gas utility which covers all of British Columbia. This new utility is called BC Gas. However, the discussants were not unaware of this change.

Another note on the new utility; during the merger of these companies, the marketing program for CNG was on the back burner, affecting the perceptions of the discussants. Now that the reorganization is complete, BC Gas has plans to expand its

marketing, including the sale of a home refueling device. Discussants were questioned about this product. offset the costs of conversion. In addition, the government has not charged taxes on compressed natural gas (for cars) and has maintained a low, stable price for compressed natural gas.

The conversion to natural gas involves changes in vehicle performance, maintenance, refueling routines and interior luggage space. Understanding consumer experiences with CNG in Canada provides insights into obstacles and opportunities for introducing alternative fuels in Canada as well as other nations.

III. Developing the Model

We developed our decision process model from a cross-disciplinary review of theory and then modified its design through preliminary testing in focus groups and interviewing. The model was designed to incorporate behavioral realism (for a more detailed review of the literature see Turrentine, Harvey and Sperling 1989). A. Economic Choice Models

← Transportation researchers have depended primarily upon economic theory to model vehicle and fuel choice. These models have focused upon household resources and preference rankings for aspects or attributes of products (Mannering and Train 1985). These models have predicted household choices for the narrow range of attributes typically associated with conventional vehicles. However, they are inadequate in dealing with alternative fueled vehicles for the following reasons.

1. Economic theory assumes consumers have good knowledge of the options they are considering (Becker 1976). In the case of alternative-fueled vehicles, consumers may have inadequate knowledge of the new product to make a comparison.

2. The models assume that a purchase represents a completed decision (Finn 1985). In the case of alternatively fueled vehicles, a purchase may only be one step towards becoming a confirmed user of a new fueling system.

3. Economic models depict human behavior as occurring in a single time frame. All options, resources and influences are modeled as though they present themselves at one time. However, consumer decisions about relatively complex choices may involve considerable time and sequential decisions in distinct contexts (Turrentine et al 1989).

4. Economic models portray consumer decisions in an isolated context (Douglas and Isherwood 1979). In the case of alternative fuels markets, consumers may look for signs that large portions of the population are switching fuels and look for symbols of institutional commitment to the new fueling system.

Nevertheless, household economics will be a primary motivation for consumers of alternative fuel systems. Therefore, the concept of goal-oriented, economic behavior, influenced by some attribution process was seen as crucial to the model. Both product attributes and consumer resources are considered in the model.

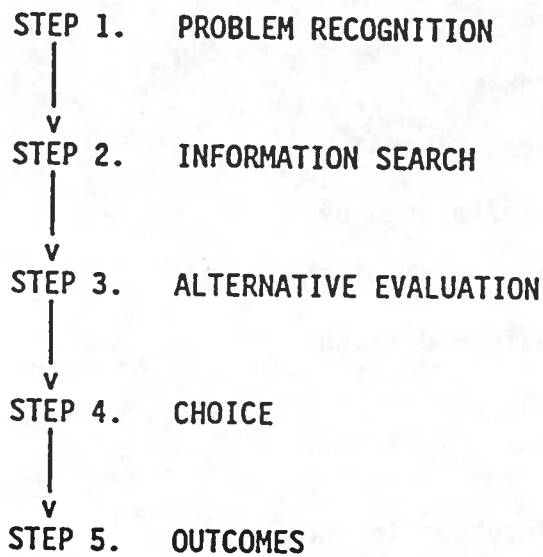
B. Extended Decision Process Models

There is considerable risk and uncertainty involved in the purchase of new products (Bauer 1961). While a model needs to incorporate the concept of resource optimization, it must also capture the extended process of a decision where a consumer collects information and even tests a product before settling their mind (Chafee and McLeod 1974).

Consumer decisions about automobiles are often complex, involving heightened consumer involvement, considerable information search, attention to media, personality, lifestyle and cultural values (Engel, Blackwell and Kollat 1978). Marketing researchers have in recent years developed extended decision

process models to examine consumer behavior in complex contexts (Horsky and Sen 1982). While not elegant by disciplinary theory standards, these models seem to be particularly effective at explaining complex consumer activities.

At the core of decision process models is a time sequence of psychological steps or stages in the decision. Below is a flow chart of this core process presented by Engle, Blackwell and Kollat (1978:32).

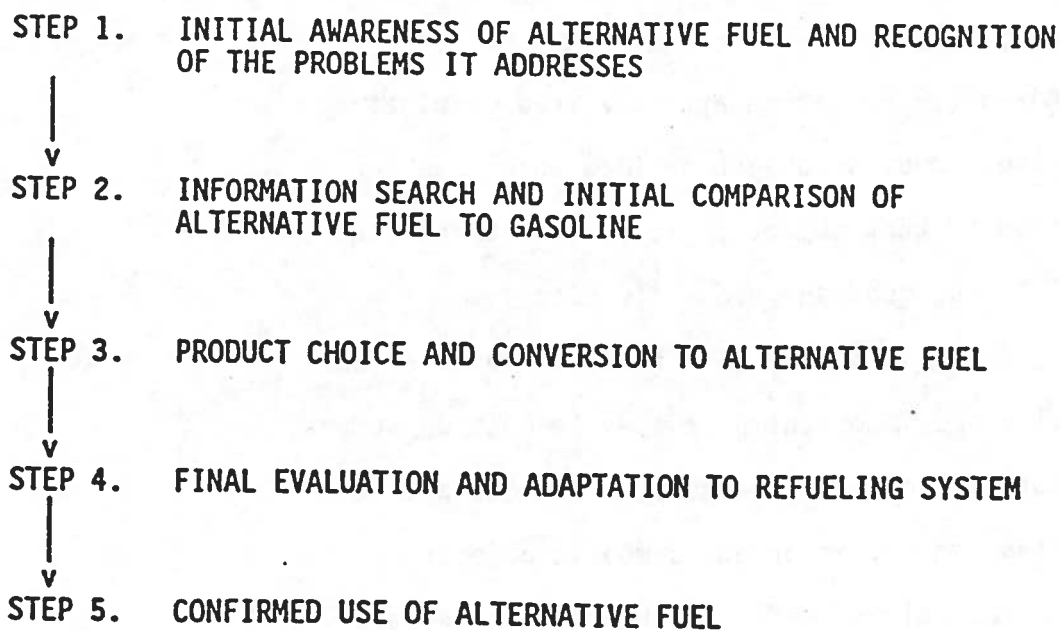


The strength of this model is that it breaks the decision into a sequence of events and contexts, allowing more precise analysis. Engel, Blackwell and Kollat develop a complex model, depicting the influence of mass media, cognition, information, beliefs, attitudes, personality and circumstances upon each step and feedback relations between steps.

While the form of this model is appropriate to the complexity of consumer choices for alternative-fuel systems, it does not fit exactly with the particular circumstances of the CNG

alternative fuels market. At step three, the alternatives in British Columbia are gasoline, CNG dual-fuel systems and propane (LPG). Because consumers have considerable experience with gasoline, and minimal or no experience with alternative fuels, the information search, alternative evaluation, and choice relate only to the alternative fuel. Consumers must purchase the alternative system, have it installed and adapt to the new refueling system to see how it compares with gasoline before they can make a long term commitment.

Therefore, evaluation is in two steps, with a primary evaluation which leads to conversion and a final evaluation which leads to long term commitment. The model we adapt depicts the consumer decision process for conversion to CNG as:



C. Attribution and Elimination by Aspects Model

Attributes (or aspects) refer to the benefits and drawbacks of the alternative fueling system for the consumer (Meyers and

Shockers 1981). Early in our research, it was noted that the product attributes which consumers consider most important, change as consumers go through the stages of the consumer process. This process resembles Tversky's (1971) elimination by aspects (EBA) model in which consumers eliminate choices by sequential consideration of product attributes.

However, in contrast to EBA, the changes were not the result of a cognitive procedure but the result of changing circumstance. For example, as CNG users moved to final evaluation of their new refueling system, they left behind their initial concern for some attributes, such as trunk space (which was a strong initial concern) and became more concerned with the density and expansion of the refueling network.

D. Consumer Attitude Models

Fishbein and Ajzen (1975) define attitude as a combination of beliefs and feelings about an object or idea which cause a consistent orientation to that object or idea. This translates as stable likes and dislikes, good and bad evaluations.

The role of attitudes in alternative fuels markets is important; automobiles are important purchases to most consumers, account for large portions of their budgets, are necessary to their daily activities and are important symbolic objects communicating tastes and values. While alternative fuels have minimal impact on many aspects of automobiles, such as styling, they do impact consumers by shifting the institutional relations from oil companies to gas and electric utilities, and shifting engine technology to different fuels. Consumers may have strong

feelings and beliefs about fuels and gas utilities, and about oil companies and gasoline. In our model, we identify attitudes as positive or negative and examine them at each step in the decision process.

E. Signs and Symbols

At each step, consumers rely upon social information to validate their own decisions and to get a sense of whether they can rely upon this technology in the future. For example, before consumers can go on to step five of the process and become confirmed users, they must get a sense of the permanence of the fueling system infrastructure. They gain this sense by observing the signs of the new fueling system and symbols of the institutional structure.

Signs are anything which communicate the presence of compressed natural gas fueling systems to consumers. Signs can communicate the scale and boundaries of the CNG market to non-users and users alike. For example, the large number of fleet vehicles on the road signifies the scale of CNG use in fleet operations. The lack of signs of private use of CNG indicates small scale private use.

Symbols are anything which communicate shared public messages about compressed natural gas fueling systems. For example, British Columbia government vehicles fueled by CNG may communicate the commitment of the government to a CNG program.

We specify each step according to two sets of descriptors derived from the concepts above: perceptions and social messages.

(see fig. 1). Important perceptions for the consumers are their resource availability, the perceived benefits and drawbacks of the product attributes, and the attitudes regarding the social value of the product. Important social messages transmitted to the consumer are signs indicating market acceptability and symbols of social commitment.

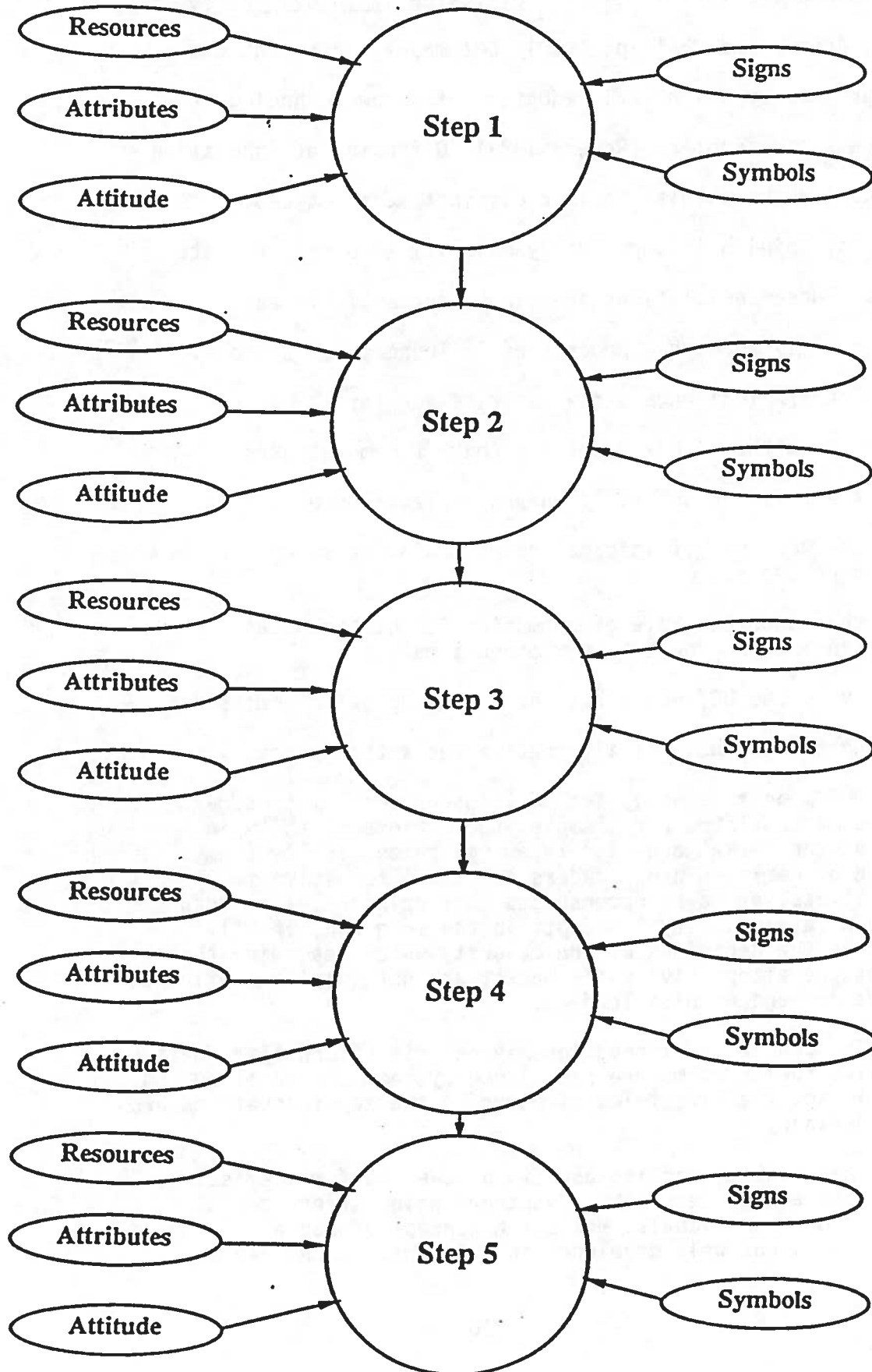
Resources, the first descriptor are needed by the consumer to continue to the next step. Resources can include income, special knowledge and reliably knowledgeable friends. The second descriptor, perceived attributes, measures benefits and drawbacks of the product. The third descriptor, attitudes, refers to negative and positive feelings and beliefs about the technology or other material aspects of CNG. The fourth and fifth descriptors, social messages, introduce the concept of social process into the model.

(Insert fig 1 here)

F. Social Process and Market Development

What is lacking in decision process models is a sense of the social processes involved in the development of markets: that is, the impact of culture, communication and group activities. Economic models ignore social process, viewing market growth as purely aggregate. In the extended decision process model, process is viewed as socio-psychological, in which society is an external influence of decision makers. In the case of alternative fuels, the roles of institutions, social values and communication of technical knowledge demands a more developed sense of social process.

Figure 1. Flowchart of Steps and Descriptors in Alternative Fuel Decision Process Model



A common social process model which has already been used to study alternative fuel systems is diffusion of innovation (DOI) (Harris, Arnoux and Phillips 1980). DOI models represent the social process by which early adopters of a new technology influence later adopters (Rogers 1983). Diffusion of innovation models divide the population into distinct social types: innovators, opinion leaders, early majority adopters and late adopters. These social types are linked sequentially and chronologically through a process of influence; for example, opinion leaders influence early majority adopters.

The strengths of DOI model are that it demonstrate:

1. the influence of early buyers on later buyers.
2. the key role of informal networks in the success of new ideas and products.
3. the important role of communication of technical information in the growth of new product markets.

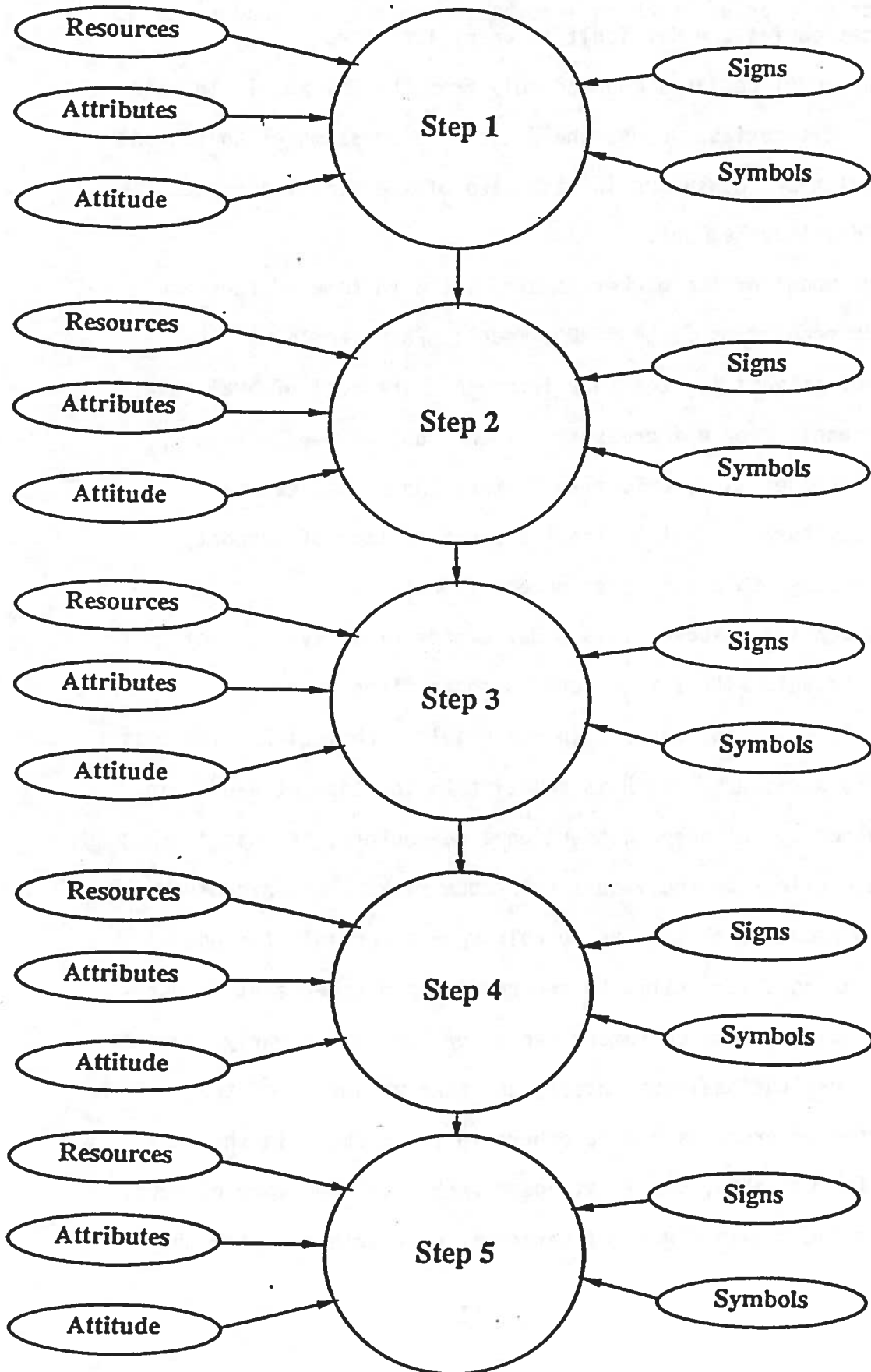
However, the DOI model has the following deficiencies in explaining the purchase of alternative fuels technology.

1. DOI models downplay the decision process of consumers who enter the market late. For example, the actions of the main portion of the market are seen to emerge automatically from the influence of early opinion leaders. In the alternative fuels market, it has yet to be demonstrated that opinion leaders can convince a late majority to adopt. In the long run, it will probably be the decisions of the majority which determine the growth of the alternative fuels market and not just the influence of innovators and opinion leaders.

2. The concept of innovation may not fit alternative fuels. Alternative fuel systems are substitute systems for gasoline and may not impact the lifestyles of users in the way innovations are usually defined.

3. The most attractive aspects of CNG are fewer emissions and national energy security, advantages which affect social groups and not individuals. While the concept of social innovations is not well developed in DOI, this is an area of

Figure 1. Flowchart of Steps and Descriptors in Alternative Fuel Decision Process Model



considerable importance for alternative fuels marketing.

4. DOI models segment the market according to a set of distinct categories, such as innovators and opinion leaders. These categories are difficult to operationalize.

Our model deviates considerably from the DOI model. In place of ideal categories, we use the decision process model to segment the population; consumers in each step of the decision process form a distinct segment.

Our model of the market is dynamic, with some of the same feedback mechanisms found in DOI models. For example, as the number of drivers in step four increases, the pool of available, knowledgeable people increases, pulling more drivers into step two. The model is dynamic also in that the market can be influenced through institutional support or lack of support, making passage to a next step more difficult.

As mentioned above, this model avoids rigid typecast of market segments with fixed labels such as "innovators", "techies", or "risk takers". In our model, technical knowledge is viewed as a resource which is relative to the task at hand. In the absence of reliable institutional guarantees, technical knowledge allows an individual to reduce risk. There are other means to reduce risk such as to rely upon a mechanic friend.

By using their skills to reduce risk and uncertainty about new technology, some consumers can enter the market early, depend less on institutional guarantees, and take advantage of the attributes of products before others in the market. In the case of British Columbia, those with good technical knowledge of cars, for whom fuel savings were of interest, were able to enter the

market before other drivers.

TESTING THE MODEL ON BRITISH COLUMBIA DRIVERS

A set of in-depth group interviews (focus groups) were used to investigate the fit of the process model. The focus group data are not representative, but were invaluable in testing the structure and explanatory power of the model. Using the focus group data, we were able to design our model and to identify hypotheses for more quantitative investigations.

Focus group discussants were recruited through Canadian Facts, a marketing agency in Canada. Discussants were contacted by phone and paid \$ 30 Canadian for their participation (\$1.2 Canadian dollars = \$1 U.S. dollar).

Four groups were recruited. Two groups were composed of experienced CNG owners drawn from Department of Motor Vehicle lists of converted cars and had the following characteristics:

- a. three car owners who use their vehicle for their own business
- b. three owners of small or mid-sized vehicles
- c. three people who own 2 cars, one operating on CNG, the other on gasoline only.
- d. three persons who converted their car in the last year

The other two groups were composed of gasoline fueled car owners drawn from the phone book with the following characteristics.

- a. three car owners who use their car for their own business
- b. three car owners with at least two cars in their household
- c. three owners of mid-sized or compact cars
- d. three people who investigated conversion but have either decided against or have not yet decided.

The focus group discussion was moderated by one of the authors (Turrentine) and was based upon the process model

described here. In the following section, our model is described qualitatively in detail, based on the focus group interviews and on previous insights. In addition, we examine several hypotheses related to each step.

THE MODEL

Step 1: Initial Awareness of the Alternative Fuel and Recognition of the Problems it Addresses

The resources needed to move into this step are minimal. People need to be drivers and in contact with media messages about CNG or with friends who have converted to CNG. Those in step one do not need special technical knowledge or financial resources to gain initial awareness of CNG and to grasp the problems it addresses.

The attributes which affect the decision process at step one are those which can be easily communicated via media and informal networks. To attain step one, the consumers need a positive attitude toward the type of fuel and the public utility or a negative attitude toward the competing industries. To attain step one, there needs to be adequate public messages which communicate the attributes of the fueling system and the commitment of the industry.

Fuel savings has been the most attractive attribute of CNG in British Columbia. The price of CNG has been controlled to encourage the growth of CNG use in Canada. Conversion grants have been offered by both the federal and provincial governments to help consumers recover conversion costs and gain the fuel

savings. The public utility advertised these grants and the possible fuel savings.

Previous market studies in British Columbia have identified the main market for CNG as drivers with high gasoline consumption who can quickly recover the costs of conversion. Our model would identify a more complex market, progressively segmented according to the decision process. We see a larger group as entering step one than the one identified in previous studies. However, at each step that group is reduced by new constraints until a relatively small group attains step five.

Our model says individuals will attain step one---awareness of CNG technology and social problems it addresses---if they perceive themselves to have resources and a positive attitude toward the attributes presented in the social messages about CNG being received via media and informal channels.

In British Columbia, the social messages about CNG related primarily to fuel savings. Consumers in B.C. for whom fuel costs are significant have been attentive to the social messages about CNG. This is a somewhat larger group than those with high fuel costs. This group could include retired persons with large sedans for whom fuel costs are significant are multi-vehicle owners who are sensitive to fuel costs.

Fuel cost is only one possible incentive to segment the market. Lower emissions could be another incentive; it is a market which is not yet developed in B.C.. Those consumers who are attentive to ways of reducing pollution will pay attention to messages about cleaner fuels. In this way the numbers of persons

entering step one could be increased.

Specific Behavior and Remarks of Step One Discussants in the Focus Group Interviews

Most of the members of the second two focus groups---non-owners of CNG vehicles---were in step one of the decision process; they had become attentive to the advertisements and informal messages about the possible fuel savings for CNG, were aware of the government's interest in CNG, and were aware of CNG vehicles on the road. A few focus group participants of were not interested in fuel savings; they had not paid attention to messages about CNG related to fuel savings. However, when other topics arose in focus group discussions, such as lower emissions, safety or home refueling, these discussants became interested.

For example, the most commonly held attribute of CNG was the fuel's low cost. Fuel cost savings of fifty percent was referred to many times by discussants throughout the focus group interviews. This figure originates primarily in advertising, although in some case it was based upon an observation of pump price (even though CNG sales were measured in kilograms while gasoline is measured in gallons), in some cases as hearsay and in the case of a few users on their own calculation.

A true calculation of possible cost savings is difficult; for a person contemplating conversion it requires a good understanding of particular cars and the capital costs required for conversion. The one-half figure is easily grasped and drew attention to the economy of the fuel (but ignores the conversion cost).

Other attributes, which were not advertised by the utility, such as the safety features of CNG (CNG fuel tanks are less vulnerable to impact than gasoline tanks) were not common knowledge among step one discussants. Instead, when pressed on this point, those in step one, as well as discussants in other steps came up with a number of horror stories of the dangers of propane. There had recently been some bad propane accidents in Vancouver: therefore, danger had become a public attribute of propane, an attribute which several persons in step one transferred to CNG. For example, several discussants observed that the propane tanks attached to the rear underbody of propane converted sedans have exposed valves; few of the discussants in step one understood these were propane and not CNG tanks. Another sign of CNG is the distinct smell of alternative fuels. Non-users are not aware of the distinction in smell between propane and natural gas, but are aware of the distinction between alternative fuels and gasoline.

In addition, the more technical aspects of CNG were not well understood, such as range, refueling issues, and maintenance attributes. A few step one discussants were aware of the space problems with tanks; however, few had ever seen a conversion. Most were not aware of the dual-fuel aspect of CNG conversions.

The reduced emissions of CNG vehicles were also not understood by step one discussants. The air pollution issue has not been prominent in British Columbia, although a few days prior to the focus groups, the major daily newspaper had run an article on the air pollution problem in Vancouver, catching the attention

of several discussants.

Among step one discussants, attitudes toward CNG as a fuel seemed to be quite positive. There were some negative reactions to the concept of gas under high compression. The natural gas utility (BC Hydro) is positively regarded. There was a negative attitude towards government; several step one discussants were suspicious that the government would probably tax CNG when it became popular.

When asked how they knew about CNG, the most common reply was having seen fleet operators with CNG bumper stickers which said "Powered by natural gas". Most discussants were aware of CNG powered BC Hydro trucks and taxis. Other fleets, such as "Venice" bakery trucks were also mentioned. While fleet vehicles are conspicuous, private vehicles are not.

The second most familiar sign of CNG is the small red window stickers put in all CNG and propane operated vehicles. However, non-users and users alike find it difficult to distinguish propane and CNG on this basis because the stickers for each are quite similar.

The yearly booth of the gas utility at the Pacific National Exposition (PNE) was a familiar site to nearly all the discussants. Several had glimpsed the CNG display. In addition, television, radio, BC Hydro bills and newspaper ads were mentioned.

There were only a few mentions of having seen CNG pumps. In contrast, most step one discussants had seen propane tanks at stations, which are prominent and brightly painted. The

distribution system of natural gas for domestic use is not automatically associated with natural gas for vehicles. When asked to project themselves into using CNG, discussants expressed fears of being stranded in out of the way places while traveling. In general, these people did not imagine the potential network of supply nor the dual-fuel capabilities.

Several step one discussants mentioned that none of the new car dealers which they had recently visited had made mention of CNG. One or two wondered about what would happen to the attractive, extended warranties available. When asked to project how they would promote CNG, one woman insisted that she could only see success if the manufacturer-supplied dealers would offer CNG cars as standard.

For several of the step one discussants, the focus group introduced them to more information about CNG, not via the moderator but primarily through three persons in each group who had attained step two. These persons had been purposefully put together with step one discussants to observe the social interaction of the two groups. The amount and type of information these step two discussants controlled was both interesting to the step one discussants but also intimidating. The reasons for this intimidation are related to the constraints of step two, the need for technical understanding of automobile engines.

Step 2: Information Search and Initial Alternative Evaluation

Step two imposes the greatest constraint upon the market. The reason for this constraint is that to attain step two, a

consumer needs technical knowledge of automobile engines or friendship with someone who has direct knowledge of CNG. While fuel savings are the primary motivating factors for step one decision makers, most do not have the technical knowledge necessary to attain step two.

To conduct an information search and compare the alternative fueling system with gasoline fuel, the step two decision maker must feel confident they have made an adequate comparison or that a competent friend has made that comparison on their behalf. Most auto users have been using gasoline engines for many years without need for technical knowledge because gasoline was the only fuel choice. The addition of alternative fuels to the market creates a new complexity to vehicle choice. This need for technical knowledge is more acute with retrofit systems because the consumer must make a comparison without benefit of testing the equipment beforehand on their vehicle and because retrofits are not covered by the same warranty systems as gasoline-fueled vehicles.

The important attributes at step two are those which relate directly to the searcher's own vehicle and not the general attributes of CNG vehicles. These attributes are technical details supplied by friends, mechanics and utility salespersons. In addition, the step two evaluator is confronted with the visual aspects of the engine conversion kit: the tanks, the refilling equipment and engine adaptors. Finally, the step two evaluator is supplied with some estimates of costs, benefits and government grants.

To attain step two, the consumer also needs a positive attitude toward the sources of information used in the search; if the public utility or government lacks credibility, the messages will not be accepted. Finally, public messages need to identify and support the sources of information and expertise used in the search and evaluation; there should not be any contradictions between the technical knowledge circulating in informal networks and public messages.

The step two decision maker is impacted by the development of the market in a different way than the step one decision maker. Because they are evaluating the impact of the conversion on their own vehicle and use patterns, they pay attention to a smaller segment of the market; they look for converted vehicles like their own and talk to CNG users who appear to be using the CNG vehicles for similar purposes.

Specific Remarks and Behavior by Step Two Decision Makers in The Focus Group Interviews

There were six discussants recruited on the basis of having started the conversion, going as far as a credit check, but that had not completed the process. To complement observations of step 2 discussants, step one discussants were asked to imagine what they would do if they wanted to find out more about CNG, and step 3,4 and 5 discussants were asked to remember what they had done when they went in search of information.

The primary motivation for initiating a search was the promise of fuel cost savings. Most imagined fuel savings of 50%. In addition, several said that the government grant was a highly

motivating factor. In addition, several step two discussants had been attracted by the promise of fuel coupons.

While step one discussants were evenly divided between women and men, among the step two, three, four and five discussants, there was only one woman. While we did not attempt a random sample, this gender split was confirmed by CNG sales personnel and previous market studies. The gender split relates partly to the need for technical knowledge. In the focus groups, the women were uncomfortable with discussing the technical details of the vehicles. One step one woman articulated this discomfort; her response to the technical information being shared by a step two discussant was mixed: she appreciated the information but said it was difficult for her to make a decision on the basis of that information. She believed that single mothers like herself relied upon the car dealer and warranties, but never on such technical information.

In order to conduct their search, step two discussants came into direct contact with a range of expert opinions about CNG, from BC Hydro personnel, conversion shops, experienced CNG owners, taxi drivers and refueling station workers. One location where several discussants had begun their information search was the BC Hydro exhibit of CNG at the Pacific National Exposition, a yearly fair. The second most frequently cited location for a search was to phone BC Hydro. In response to calls, BC Hydro sent CNG salespersons to houses or businesses to provide cost estimates.

The level of technical knowledge among participants affected

the length of search. One participant had watched a local conversion shop begin business and after stopping to talk to a mechanic, purchased a conversion immediately. This participant had considerable technical knowledge of autos and was able to explain to other CNG owners, the effects of CNG on their vehicle.

Step two discussants learned new attributes of CNG not advertised. Searchers discovered the clean burning aspects of CNG, and possible lower maintenance costs. Two searchers had heard about the new home refueling system.

Step two discussants were confronted with whether the conversion kits would work in their car. Two searchers said they were surprised at the size of the tanks. One searcher ended his search when he saw how much space was used by the tanks in the trunk; he needed the trunk space for his real estate signs.

However, step two discussants were relatively ignorant of refueling procedures, availability, range; their primary considerations were cost, performance and fit of the system. While frequency of fillup was mentioned as a drawback by a couple of searchers, it was not stressed. They were uncertain of the frequency of refueling.

There was a strong, positive attitude toward NG as a fuel and toward the utility, which was viewed as helpful. The most negative attitudes were expressed toward the CNG tanks, which loomed as both costly and bulky. Two users asked if there could be a greater range of tank sizes available in the future.

The public messages about CNG which influenced the search and evaluation were the signs of other consumers making the same

decision and the symbolic importance of the grants, coupons and vitality of the utility. For example, although one step two discussant declined to convert because of the loss of trunk space, this same discussant was impressed by the development of the home refueling system.

The development of the market, through its visible signs has an important impact upon the step two discussants. All six step two discussants had not yet chosen to convert. While they expressed positive attitudes to the technology, most had not gone on because they did not believe the attributes fit their situation. However, they were also not convinced that the market was meant for them. They saw bakery trucks and other utility type vehicles on the road, but did not see others like themselves using the CNG. Non-commercial use of CNG is not as visible and the informal networks of information for non-commercial use are not as active. Several of the discussants in step four used their vehicle for their business. They had been influenced by other business persons. Two step four discussants, for instance, used their CNG vehicle for delivery and had discussed the conversion with friends in the delivery business.

Step 3: Product Choice and Conversion

Step three decision makers are those who chose a product and conversion shop. The decision to purchase a conversion kit and have it installed is the most committing action of a CNG user. Conversion costs are high. These costs varied for participants from 1000 to 5000 dollars, depending on the use of grants and number of tanks installed. To attain step three, step two

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decision makers need to perceive that they have adequate financial resources and the ability to deal with conversion shops.

Calculating the returns on investment are difficult. Converters must have financial and technical knowledge related to the conversion of their car so they can evaluate the quality and prices of conversion shops, or they must have friends whose advice can be trusted.

Conversion shops do not have the same institutional reliability as does the gas utility. To carry out the conversion, step two decision makers would have to find a shop which they trusted. The conversion shop presents the decision maker with new information, generally of higher technical content than received elsewhere, that is very specific to their car. The converting car owner must rely upon a mechanic for much of the information about how the conversion will be done; information, therefore, is not as publicly available as in the other steps.

Specific Remarks and Behavior by Step Three Discussants in the Focus Groups

There were no discussants in step three. Data for this step are primarily from experienced CNG users recalling their own conversions. A few statements of non-users were included as imagined decisions to convert.

The discussion of the conversion process enlivened the conversation to the point that the facilitator was unable to guide the discussion. Each user was interested in the cost and nature of others' conversions. While the conversion process

reportedly had gone relatively smoothly for many of the participants, for several it had been troublesome; time costs and unexpected setbacks had often been beyond their expectations. In addition, post-conversion adjustments were necessary for many of those who converted.

Several said they felt victimized by the shop. One discussant said, with agreement from several others, that the shops seem to do anything to get you to convert. One attitude about the shops was that they were seen as small actors, unable to absorb the costs of problems with the conversions. Therefore even an honest mechanic was seen as somewhat incapable of dealing with conversions if there were problems. One discussant asked why BC Hydro would take a chance with such shops doing the conversions. In response to his question, several users noted that many of the shops have gone out of business.

As counterpoint, several converters mentioned that their mechanic gave very specific attention to their vehicle. One man who had a troublesome conversion mentioned how his mechanic took the time to order the correct part from Italy. Others noted that their mechanic took responsibility for replacing malfunctioning equipment.

Problems with conversions were leaks around the filling equipment, incorrect tuning, and difficulties switching between gasoline and CNG.

The decision of many to go ahead with the conversion was based upon the belief that the refueling network would expand. In a later interview, a conversion shop owner expressed some

amusement with the lack of concern among converters over range. He found that many initially were unwilling to put in two tanks because of cost and lost space; these converters ususally returned at a later time to add a tank.

When step one discussants were asked to imagine themselves in the situation of conversion, they expressed some discomfort with the idea. They wished that either a trusted friend or the car dealer would make the decisions for them. Important information and signs and symbols of good work (e.g. honesty and reliability) were beyond their grasp.

Step 4: Final Evaluation of the Refueling System

Once the conversion is complete, the alternative fuel (CNG) owner can go on to see if the savings, performance, maintenance and refueling system for their conversion is reliable. While a few conversions fail for technical reasons and can be a source of concern, in this step users tend to shift their attention to attributes of the refueling system, simply because the consumer had had no chance to evaluate this system before conversion. Step four users interact with a new set of institutions, the refueling stations. The stations represent the institutional structure of CNG at this step.

Although the alternative fuel user has made the decision to convert, they have not yet decided once and for all that their fuel is the best fuel in town. They hope they have made the right decision, and test their choice until it seems as good or better than just having a gasoline-powered car. Even after a

number of years of using alternative fuels, step four decision makers may have doubts about their systems. Because gasoline is the standard fuel, if a car hesitates or stalls, the alternative fuel is suspected. If an alternative refueling station is closed down, the future of the alternative fuel industry may be questioned.

As a user, they join a club-like group. At the pumps, at the shops, in consumer focus groups or by chance meeting, they encounter other users in the population. Users are quite aware of other users, recognizing them through their red window stickers, bumper stickers and at the pumps. Users often ask each other questions about maintenance, how to use pumps, how to get the best economy, the reliability of others' equipment, and the effect of natural gas on their engine.

Specific Remarks and Behavior by Step Four Discusants in the Focus Groups

The data for this section come from the responses of experienced users on maintenance, operation and refueling.

All the users were satisfied with the economy of the fuel. Using a variety of means to calculate that economy, most stated a 50% savings. To calculate economy, users relied on one of two techniques: they compared costs for a standard trip -- for example, one retired man measured the fuel cost for a trip to his son's house -- or, more commonly figured their fuel costs at the end of a fixed time period, such as the monthly charge on their credit cards, or daily and weekly costs.

One man said his maintenance cost had been cut in half. He

noted that whenever he switched to gasoline, the oil got dirty. However, one man had his truck engine wear out completely and complained it was because of the CNG. There were some users who claimed occasional use of gasoline was good for the engine, that it lubricates the valves, moistens the gaskets.

Most converters said the weight of the tanks was more than they had expected. Several had expected at first to only need a single tank. Several had been forced to add extra springs to their vehicles. One man thought that the poor driving range was due to the weight of the tanks and thought a stainless tank would be lighter. Another man said the weight was actually a bonus in snow; it saved putting a bag of sand in the car.

There were several mentions of problems in switching between the two fuels, including stalls, starting problems, and residual gasoline in the system. Most users said they experienced some power loss: many use the figure ten percent. Others say they switch to gasoline on steep hills or when pulling a trailer.

Some users said their car starts more easily, and doesn't need to be warmed, even during the coldest spell. However, others had experienced starting problems associated with switching between fuels. Some said that the engine runs smoothly on CNG. One man said it had no engine knock.

Some had experienced unexplained stalls. A few users recalled stalling and needing to be towed. There is an element of public embarrassment in these accounts. Stories were told of getting stuck on bridges, in intersections or on the highway in vacation clothes. One woman gets nervous about being low on fuel

because she does not want to stall or have the car hesitate in traffic. It is difficult for drivers to estimate just how much fuel is in the tank when one goes in for a refill.

While the technical bugs were seen as solvable, more concern was directed towards the refueling system: primarily, that the number of refueling stations did not expand at the rate they had expected. In fact, the small network of stations was, in the minds of a few users, a shrinking network. The limited and perceived lack of expansion was a symbol of the lack of institutional reliability, casting doubt on the future of CNG for these users. The limited availability of fuel was a sore subject for many of the step four discussants. They were fully satisfied only if there was a station along their routine route, but even then many users complained of stations closing temporarily or permanently.

In addition, most users experienced maintenance problems with many of the stations. One common problem was the loss of an o-ring on the station's refueling equipment. One woman learned from another user to get a new o-ring from the attendant. She and another user said that some station attendants will simply close the pumps when all that is wrong is the missing o-ring.

Some compressors have broken down at stations. (In addition, compressors must be shut down for routine maintenance each year). The explosion of a compressor at a Husky station just before the focus group interviews brought a curious response. The danger of the explosion was not mentioned (even during the discussion of propane explosions); instead, the primary concern was the closing

of the Husky station. Several users said that to arrive at a station when it was out of service was frustrating. The small network of stations requires a substantial search for another station.

Although refueling times are greater for CNG than gasoline, the issue among discussants was the variability of refueling. One man fills his car late at night to avoid lines and to take advantage of high compression levels. Several users complained of the lower pressures and lines at stations. An interesting topic of discussion was the storage pressures and costs of refilling a tank. Users say they want to get the best refill possible. Therefore they complain if for some reason the compression is low at the station or, if for some other reason (e.g. high ambient temperatures), they are unable to get a maximum fill. One man was able to convince the others that if one got a fill at maximum station pressure, one could get more in the tank and a better price as well (this latter claim is not accurate because natural gas is metered by weight at refill stations; a station manager reported to us that his cash accounts and supply balance within pennies each month).

The problem with refueling stations was viewed as a symptom of a failing market for CNG. One man said the utility had broken its promise on this accord; other users in his focus group echoed his sentiments. One man questioned why the utility wasn't providing stations in particularly important locations, for example on the route to Hope. There was concern that the stations will never extend into the United States.

Despite these problems, the attitude of the step four discussants towards the fuel and technology was positive. Most had achieved some savings with the fuel and several felt the CNG system started easier, ran cleaner and caused less wear on their engines.

Step 5: Confirmed Use of CNG

Confirmed use of the alternative fuel is the final step in the decision process model. A confirmed user has completed a final evaluation of the fuel and finds it satisfactory. Confirmed users have achieved the goals originally motivating their conversion and overcome the barriers to routine use of the fuel. The final attribute encountered in step four which encourages confirmed use is that the refueling network is convenient for the alternative fuel user. The alternative fuel users either adapt themselves to the new refueling network or may have been preadapted to the system because their transport and travel patterns match the new refueling network.

Specific Behavior and Remarks of Step Five Discussants

A few of the focus group discussants were confirmed users of the CNG fuel as indicated by their willingness to convert their next car to CNG. and to consider seriously the purchase of a home refueling system.

These individuals had stable use patterns which fit the refueling network, had achieved considerable savings, and were not inconvenienced by the technology. In addition, these step five discussants were convinced of the long term marketability of

the fueling system.

CONCLUSIONS

CNG conversion is a multi-step process for consumers, taking time and resources. Automobiles are a major investment for most consumers and alteration of their auto for CNG use constitutes considerable risk. In addition, the conversion process is not easy. At each step in the process, some consumers are unable or unwilling to continue their investigation because of the requirements of that step.

Consumers first learn of CNG through the media or through informal networks. Those consumers for whom fuel costs are a problem recognized that CNG could be a solution. They go on to make a search for more information about CNG, contacting the gas utility, a mechanic and CNG users to see if they could take advantage of those savings. To make an initial evaluation of the potential benefits of the CNG system for their own car, these potential users of the fuel need technical knowledge of automobiles in order to make a comparison with gasoline fueling. Some consumers are able to rely upon friends or family who have the needed technical knowledge.

Those consumers who are able to make an initial comparison of CNG with gasoline and who have a vehicle and resources to make the conversion go on to contract with a conversion shop. The conversion shop is a formidable barrier to conversion because of the lack of institutional support for consumers. Because the conversion shops are small businesses, consumers must be self-

reliant. As a result, the warranties and guarantees for CNG fueling systems are not as substantial as those for gasoline fueling systems provided by manufacturers. The government supplies conversion grants to help consumers overcome the initial costs of the conversion.

Those consumers who are able to convert go on to make a final post-hoc evaluation of their CNG conversion. Because their car is dual fuel, and because gasoline is the standard fuel, CNG users continue to compare fuels. While some technical problems arise for CNG users, the primary issue emerging for long term commitment to CNG is the convenience of the refueling network. While CNG refueling range is small for most vehicles, CNG users express their discontent in terms of fuel availability and not range.

CNG users in British Columbia entered the market before the refueling network was adequate for all of their uses. These early converters suspended their evaluation of the refueling system believing that the refueling network would expand rapidly. However, their expectations were not met on this account leading to an attitude change towards the gas utility. A few CNG users have travel and transport patterns which match the existing network. These users are confirmed CNG users.

The duration and multi-step nature of this decision process in British Columbia has led to a complex, market development process. The market has become segmented, with consumers at various steps in the decision process. At each step, consumers are receiving information from consumers at other steps.

Consumers at step one look for general signs of CNG use and symbols of institutional commitment. Consumers making initial evaluations (Step 2) about the viability of CNG for their own vehicle look for more specific signs from CNG consumers with similar vehicle and use patterns. Consumers at step 4 look for symbols of institutional commitment and signs of growth before going on to step five.

The market in British Columbia could be developed further with attention to the market model above. The primary segment of the population attracted to CNG has been those interested in saving money on fuel. Other individuals, attentive to messages about air pollution, safety or convenience have not been targeted. Public messages about the potential benefits of CNG in these areas could increase the number of step one decision makers. Government commitment to the CNG program must be consistent. While grants demonstrate government interest, the failure of government to convert its own vehicles to CNG puts a question in the minds of step one decision makers.

Lowering the perceived threshold of technical knowledge needed to make a comparison of CNG with gasoline would facilitate the growth of step two decision makers. Also, the establishment of a public information agency to supply objective, simplified information about alternative fuels could increase the number of consumers making a search. In addition, more types of fleet vehicles on the road with clear signage, other than vans and trucks, for which sufficient signage exists, facilitates the search process of consumers with cars.

Conversions need continued support through government grants to overcome the initial costs of conversions. A better (or complementary) strategy may be to provide grants for tanks to encourage consumers to gain extended range immediately. In addition, conversions need warranties of similar duration to factory gasoline-fueled warranties to encourage new car conversions.

Finally, the refueling network must be expanded rapidly along with the home refueling systems, to encourage a positive attitude toward the utility among step four decision makers, and to make confirmed use more likely.

A Decision Process Model for Alternative Fuels

Automobiles are expensive investments for most consumers; purchases of automobiles are high risk and therefore high involvement purchases. Consumer decisions about high involvement purchases tend to be extended over considerable time periods.

The addition of alternative fuels as an additional automobile choice adds complexity to the purchase decision. Switching fuel systems from gasoline, which has been standard for several generations, necessitates the development of either adequate information about the new fueling system for consumers to make an easy comparison with gasoline systems or institutional guarantees which reduce the risk in making an initial purchase.

The individual process in making a switch to alternative fuels will not be a single decision, but a multiple stepped process consisting of 1) initial awareness and recognition of the problem to which the new fuel is a solution, 2) an information

search and initial evaluation of the fuel system for their own purposes, 3) product choice and conversion to the new fuel, 4) final evaluation and adaptation to the refueling system and 5) confirmed use of the new fuel.

The strength of our model is that it recognizes that, as consumers move through the process the importance of certain attributes change, consumers need new resources to overcome specific obstacles, consumer attitudes towards the fuel or institutions change, and consumers become attentive to different types of public messages. The model draws attention to the shifting context of decisions.

The model also demonstrates that decisions do not end with the purchase of an alternative fuel conversion kit. The number of confirmed users of CNG in British Columbia is not equal to the number of vehicles with CNG kits. Nor does the number of confirmed users of CNG equal those dual-fuel systems users on the road who use CNG most of the time. Many users of CNG may have suspended their judgement of the refueling network in their initial decision to convert, convinced of the eventual expansion of the refueling network. A decision ends when questions about the CNG system are resolved, resulting in confirmed use.

This study also supports the idea of a social process parallel to the individual's decision process. In the social process, the population of automobile drivers is segmented according to the steps in the decision process. Shifts in technology, institutional support or prices affect the growth of individual segments. In each of these segments, a distinct set

of signs and symbols informs decision makers of the scale and meaning of the market development. There is there is also feedback between segments in the form of public information, signs and informal networks. In a sense, the social group is making a decision together, watching other consumers, testing equipment, watching what the government is doing, watching what the utility is doing.

We adapted this model to fit the CNG dual-fuel, retrofit market in British Columbia. If manufactured dual-fuel or dedicated CNG vehicles were available, some of the specifics of the model would change. For example, conversion shops would be eliminated, placing step three decision makers in new car showrooms. However, the model includes many generalities common to the whole field of choices for alternative fuels; extended decision making, complex market development and the importance of social messages.

The transition to alternative fuels has begun in British Columbia. It is a process which includes industry, government, and fuel users. At the start, this process includes risk and uncertainty on the part of all. Consumers are aware of this risk and many are willing to take that risk if they either have the personal skills and resources to do so and if they sense the rest of society is going their way. As one participant voiced, and the entire group nodded, "we knew we were guinea pigs". Yet knowing they were guinea pigs, this group made a relatively informed choice about being guinea pigs. But their long term choice was still contingent upon other actors; therefore they

have bet on a growing market for their choice. The ability to model contingencies is a critical factor in a consumer model. The model presented here provides a framework for better understanding consumer purchases and for devising effective policies to support a transition to alternative fuels.

**** In Canada, CNG vehicles are commonly referred to as NGV (Natural Gas Vehicles).**

BIBLIOGRAPHY

- Bauer, Raymond
1960 "Consumer Behavior as Risk Taking" in RS Hancock (ed.) Dynamic Marketing for a Changing World Chicago Marketing Assoc., 389-398.
- Becker, Gary
1976 The Economic Approach to Human Behavior, Chicago, University of Chicago Press.
- Chafee, Susan and Jack McLeod
1974 "Consumer Decisions and Information Use", in Consumer Behavior: Theoretical Sources, (eds.) Scott Ward and Thomas Robertson, New Jersey; Prentice Hall, pp. 385-415.
- Douglas, Mary and Byron Isherwood
1979 The World of Goods, Basic Books: New York.
- Engel, James, Roger Blackwell and David Kollat
1978 Consumer Behavior, 3rd Ed., Illinois; The Dryden Press.
- Fennel, Geraldine
1980 "Attitude, Motivation, and Marketing or Where Do the Attributes Come From?", in Attitude Research Enters the 80's, (ed.) Richard Olshavsky, Chicago; American Marketing System, pp. 14-33:
- Finn, Adam
1985 "A Theory of the Consumer Evaluation Process for New Product Concepts", in Research in Consumer Behavior, Vol.1, (ed.) Jagdish N. Sheth, London; JAI Press, pp.35-66.
- Fishbein, M. and I. Ajzen
1975 Belief, Attitude, Intention and Behavior, Reading, Mass.; Addison-Wesley.
- Greene, David
1989 "Consumer Choice of Motor Fuel for Dual and Flexible Fuel Vehicles. SAE Paper 892067.
- Harris, Garth, Louis Arnoux and Peter Phillips
1980 CNG in Auckland: Survey and Analysis, Auckland, New Zealand: New Zealand Energy Research Development Committee, Publication P44.
- Horsky, Dan and Subrata Sen
1982 "Models of Choice: Perspectives from Psychology, Social Psychology, Economics and Marketing", in Research in

Marketing, Supplement 1: Choice Models for Behavior,
(ed.) Leigh McAlister, London; JAI Press, pp.335-349.

Mannering, Fred and Kenneth Train

1985 "Recent Directions in automobile demand modeling", in
Transportation Research: Part B: Methodological, ed.
Fred Mannering and Kenneth Train, Vol. 19B, No. 4, Aug.
pgs. 265-274.

Meyers, James and Allan Shocker

1981 "The Nature of Product Related Attributes", in Research
in Marketing Vol. 5, (ed.) Jagdish Sheth, Greenwich,
Connecticut; JAI Press Inc., pp. 211-236.

Rogers, Everett

1983 Diffusion of Innovations 3rd ed. The Free Press.

Turrentine, Thomas, Greig Harvey and Daniel Sperling

1989 Structural, functional and processual approaches to the
study of consumer behavior: Towards an integrative
framework for the study of consumer responses to
alternative fueling systems, Transportation Research
Center, University of California, Davis.(forthcoming)

Tversky, Amos

1972 "Elimination by Aspects: A Theory of Choice",
Psychological Review, Vol. 79, No. 4, pp. 281-299.

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