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ANALYSIS OF FEDERAL STIMULI TO DEVELOPMENT OF NEW TECHNOLOGY BY SUPPLIERS TO AUTOMOBILE MANUFACTURERS

An Exploratory Study of Barriers and Facilitators

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16. Abstract

The role of suppliers to the auto industry in promoting innovation is explored. Thirty-two innovations are investigated, and information on their success/failure, area of impact, and key decision points is generated. Based on this data base, barriers and facilitators of the innovation process are identified. The most frequently mentioned barriers to innovation are: federal regulations, cost, technical reliability, market demand, and vehicle integrity impact. Identified as common facilitators are: federal laws, the incentive of solving a persistent problem, recognition of market potential, direct government R&D, and the technological capability of suppliers.

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PREFACE

In response to the urgent national need to develop socially beneficial auto technology, alternative incentives for inducing innovation are being assessed under the Auto Technology Program. This is a complex task, encompassing regulatory incentives, R&D incentives, economic incentives, and institutional incentives for both buyers and producers of innovative automotive technology. The current study, with its focus on the suppliers to the auto industry, provides an important link in addressing these questions.

This work was carried out as part of the Auto Technology Program of the Transportation Energy Efficiency Project, (TEEP) at the Transportation Systems Center, under the sponsorship of William Devereaux, Office of the Secretary of Transportation. The contract monitors were Robert Ricci and Bruce Rubinger.

Information and data for the study were collected by means of structured interviews with fifteen managers in 13 first-level supplier firms to the automotive industry. A total of 32 innovations were investigated, and for each of these a mini-case or "caselette" was created. These caselettes related to specific projects directed toward the introduction of new or improved products, components, systems, materials, designs, etc., which were engaged in or proposed by the responding firms or others in their sector of the industry. Using a general model of the innovation process, modified to represent the industry of concern, the key decision and leverage points in the new technology application process were established. By analysis of the caselettes, the study identifies general barriers to, and constraints on, the adoption by the auto industry of technical innovations originating from suppliers.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

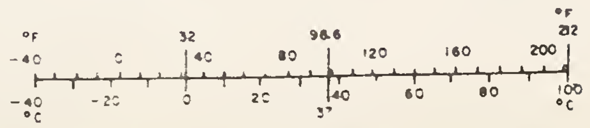

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF TABLES (CONTINUED)

1. INTRODUCTION

1.1 OBJECTIVES OF THE STUDY

This was a brief exploratory study of the barriers and facilitators* that affect technological innovation by suppliers to the automotive industry and the adoption of such innovations by industry. The specific focus in the study was on key decision and action points in the life of specific innovations or potential innovations (ideas for new products) which may affect their successful development and marketing. A longer-term objective of the general program, of which this study was one part, is to identify and assess those key decision and action points in the R&D Innovation process which are potentially amenable to influence by the Federal Government through: changes in regulations, monetary incentives, subsidies, direct R&D, technical assistance, or other means of providing incentives to the R&D/Innovation process. Emphasis in this exploratory study was on interaction between the suppliers and their large number of auto industry customers.

1.2 SCOPE OF WORK AND TASK DESCRIPTION

The following tasks represent the agreed-upon scope of the study:

a. Using a general model, modified to represent the industries of concern, describe the key decision and leverage points in the new technology-application and product-development processes in firms supplying products and materials to automobile manufacturers.

b. Select several target groups of suppliers to the auto industry who supply products, equipment, materials, services, etc., with a high technical content and with a potential for innovation.

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* Due to inconsistent usage in the literature, we will use both the term "barriers and facilitators" and the term "barriers/facilitators/incentives" interchangeably. In addition, our terms "R&D/Innovation," "technological innovation," and "innovation" will be used interchangeably in this report.

c. Identify and contact a sample of firms in each group which have a record (based on reputation) for technical innovation or which have high potential for innovation. One of the criteria for selection will be the existence of a "significant" R&D activity. A target sample size will be eight major suppliers, each in a different field (e.g., batteries, carburetors, air conditioners, axles, lubricants).

d. Examine the interface between first-level suppliers and the automakers themselves, where consideration of innovations takes place. This would include the real and perceived barriers and other factors which affect the motivations and ability of suppliers to introduce or sell innovative items and concepts to the automakers.

e. Collect mini-cases from these firms (to be presented in anonymous and disguised form to protect proprietary interests) on specific innovations they or others in their industry sector have tried to introduce to the auto industry.

f. Collect data on general barriers to, and constraints on, producing and applying technical innovations in the auto industry from these same firms.

g. Describe, in the final report, specific decision and action points which are critical in getting technical innovations into automotive products and specific instances or mini-cases to illustrate these points, highlighting the barriers encountered.

h. Categorize the barriers identified in the sample firms and cases.

i. Where feasible, identify those specific barriers which might be amenable to federal initiatives (incentives, regulations, etc.).

1.3 GENERAL PROCEDURE

The major source of data for this study was in the form of mini-cases or "caselettes" from suppliers to the automotive industry. These caselettes related to specific projects engaged in or ideas proposed by the responding firms, or others in their sector of the industry, which were aimed at the introduction of new or improved products, components, systems, materials, designs, etc., to the automotive industry. Some of the caselettes were extracted from our previous studies in this field; the rest came from telephone interviews and direct contact with supplier firms in the industry (see Section 2.4). The methods of selection of the responding firms and individuals, as well as the guidelines for selecting caselettes, are discussed in Section 2 of this report. Original data for the caselettes was collected by means of an interview instrument (see Appendix A) which contained a series of directed questions about the specific cases and the respondent's general experience with the R&D/Innovation process in the auto industry. The interview format permitted open-ended, as well as categorized responses to specific kinds of barriers and facilitators which might have affected the progress of the particular innovation project.

1.4 CONCEPTUAL BACKGROUND AND INITIAL MODEL

There are many points in time and situations in the operations of supplier companies that involve commitment of resources (time, money, energy, management attention, scarce skills) to the innovation process. In some instances, innovation is forced upon them or dictated by their major customers--the auto companies and second-tier suppliers whom the firm may be supplying in turn. (For example, builders of original equipment for the tire industry are subject to the innovation programs, barriers, and expectations of the tire manufacturers who are, in turn, subject to the inputs and constraints of the automakers.) In other cases, the suppliers themselves innovate or introduce a new concept, material, product, system, or piece of equipment. They often do this through the after-market or the replacement market for a number of reasons: resistance or lack of interest (perceived or actual) from the automakers, chances for higher margin, protection of their proprietary interests, maintenance of independence from their major customers, etc. The impulse for innovation can come from any of the two or more levels of suppliers/customers involved in a particular product or equipment line. The decision process and the cost/benefit considerations that govern the response by all of these firms have some degree of similarity.

In analyzing the decision process as it related to specific projects, we identified specific opportunities for such decisions that arise in the supplier firms. As an illustration of the feasibility of doing this, we presented in the proposal a series of general decision points and actions that we identified from our previous studies in this field. These are decisions and actions which have the potential of significantly affecting the R&D/Innovation process and which are influenced by a number of economic and other considerations in the environment of the firm. Although the language, in some cases, is that of the federal procurement process, many of the decision points and actions are quite relevant to the process involved in supplying the auto industry or any other large or dominant customer (for many suppliers one or more auto companies make up all or a dominant share of their markets). The original list is in Table 5-1.

Once the key decision and action points have been identified in the supplier firms, it will then be necessary for DOT to match them with the various possible interventions or incentives which are within its power to initiate or influence. That is, certain decision points and the associated barriers that could filter out a possible innovation might be impactable by one or more federal interventions, as indicated in Figure 5-1. This figure is serving as a rough guide to the design of a number of potential "natural" experiments involving incentives and barriers in the R&D/Innovation process. We are currently applying this approach to identifying barriers and potentially effective incentives related to the programs of NASA, ERDA, EPA, and other federal agencies. It should be quite useful in the next step, beyond the current study: identifying feasible and cost/effective interventions by the Federal Government. This flow diagram (Figure 5-1) is an abbreviated version of a much more elaborate one which we have used to examine, in some detail, the micro-dynamic behaviors involved in the situation. We have used it as a guide, for example, to a comparative study of the perceptions and reactions of industrial managers to federal incentives to innovation in four countries and are using it currently to formulate similar studies in several other countries.

2. METHODOLOGY

2.1 GUIDELINES

The methodology for this study was developed by considering two basic guidelines. First, the conceptual model (Figure 5-1) served as a means of establishing objectives for the content of the data that would be required to identify barriers/facilitators/incentives that suppliers to the automotive industry encounter in all stages of the technological innovation process. Specific attention was given to those barriers and facilitators that involved actual or potential governmental intervention. Secondly, the study was designed to explore and compare the experiences of several suppliers to the automotive industry within the constraints of time and budget.

As a means of focusing the actual data collection, short case histories ("caselettes") of suppliers' attempts to conceive, develop, and market innovations became the most practical approach to satisfy the two methodological guidelines. The case data were developed with respondents in sufficient detail to identify the important barriers and facilitators that acted during the innovation process but without extensive technical detail and early historical events. The relative importance of these factors, including governmental intervention, was then obtained by summarizing and comparing the data obtained in these cases.

2.2 SELECTION OF TARGET GROUP OF SUPPLIERS

The target population of the study was identified as OEM suppliers of the automotive industry. The automotive industry was specified first. <u>The Standard Industrial Classification Manual</u> (1972) lists the <u>user</u> or <u>automotive industry</u> under major group 37: "Transportation Equipment; more specifically, industry no. 3711, Motor Vehicles and Passenger Car Bodies; establishments primarily engaged in manufacturing or assembling complete passenger automobiles, trucks, commercial cars and buses, except trackless trolleys -- Industry 3743; and special purpose motor vehicles," (SIC Manual, 1972, p. 196). This category does not include farm machinery and equipment (3523) nor construction machinery and equipment (e.g., bulldozers, 3531), which are "off-road" vehicles. The specification of the target population, OEMs which are potential sources of innovations and major suppliers of the automobile industry, was somewhat more difficult because several SIC codes are involved. The SIC codes involved are Industry No. 3714 (Motor Vehicle Parts and Accessories), 3011 (tires and tubes), some industry numbers in major group 32 for automobile glass (e.g., windshields made from purchased glass are in industry no. 3231); automobile stampings (e.g., body parts, hubs and trim) are in industry no. 3465; 3647 (vehicular lighting equipment); 3694 (ignition systems); 3691 (batteries) and 3592 (carburetors, pistons, rings, and valves). In summary, eight industry numbers (3714, 3011, 3231, 3465, 3647, 3694, 3691, and 3592) included most of the OEM suppliers of the automobile industry (3711). The SIC codification, of course, is not the only classification system that could be used to identify the target population of suppliers. For example, materials and services were not included. The target population was actually broader than indicated by the SIC codes listed above.

2.3 IDENTIFICATION AND SELECTION OF SAMPLE OF SUPPLIERS

Within the target population a sample of firms was identified which had a reputation or a record for technical innovation or potential for innovation and that have supplied the automotive industry on a relatively continuous basis over the years. The existence of R&D activity within the supplier was one way of identifying these firms; personal contacts also supplied a list of the "major" suppliers of the automotive industry. Once the data collection had begun, this list was expanded by the additional information obtained from respondents.

2.4 PROCEDURE FOR CONTACTING SAMPLE OF SUPPLIERS

The list of supplier firms to be contacted was generated "opportunistically" from the total list of major suppliers of the automotive industry. That is, personal contacts in these firms were both sent a letter describing the study and then telephoned to arrange interviews with individuals who had dealt with the automotive industry and were aware of the innovation history of their firm. As a result of contacting the initial list of suppliers, other firms were recommended as possible participants in the study, and these firms were then contacted by letter and telephone.

2.5 DEVELOPMENT OF DATA GATHERING INSTRUMENT

In order to standardize and focus the format of data collection for the caselettes, an instrument was developed (included as Appendix A). This instrument was an interview guide that could be used both for telephone interviews as well as for interviews conducted in the supplier organizations, where feasible. This instrument was developed as a result of the first pilot telephone interviews conducted for the study and is divided into three parts. In the first part, the list of specific innovations to be discussed is developed. Relevant dates, including when the innovation was developed, tested and marketed were often noted at this point. The innovation was also labeled as a technical "success" or "failure" and a commercial "success" or "failure" in the first part of the instrument. The second part of the interview schedule asked for the description of the development and marketing of the innovation with special attention to barriers and facilitators. Data collected in this second section became the body of the caselette. The third section of the instrument was a checklist of actual or potential barriers or facilitators that were specific examples of government intervention drawn from the model (see Figure 5-1). These factors included direct R&D/Innovation in house, influence through grants and contracts for R&D innovation projects, regulation, and others. The second and third sections of the instrument were repeated for each innovation discussed by the respondent in order to develop each caselette individually.

3. CASELETTES

3.1 OVERVIEW

The information and data for this study were collected by means of personal interviews with 15 managers and 13 first-level supplier firms to the automotive industry. A total of 32 innovations was investigated, and a corresponding number of 32 caselettes and additional information on barriers and facilitators were generated for these 32 innovations. Of these 32 innovations, 23 (71.9%) were investigated by means of phone interviews; data on 7 (21.9%) innovations was collected by means of field-site interviews and 2 (6.25%) caselettes were generated by both phone and site interviews. The average amount of time that had elapsed since the innovation was developed and adopted or discontinued was 3.9 years; the oldest was 18.5 years, and the newest innovation was currently pending. But a total of 30 (93.75%) of the innovations was developed within the last 10 years.

A summary of these 32 innovations is presented in Table 3-1. The 13 firms are lettered A-M, and the names of the innovations are disguised in order to insure that the confidentiality of firms and respondents is protected. The disguised name of the innovation, however, does reflect whether it was a new product, component (new part in existing product) or a new process, and the part of the vehicle affected. (cf. Lindgren and Fitzgibbons, 1975)* On the average, about 2 innovations (32 innovations from 13 firms) were investigated for each firm.

Most of the innovations in this sample did achieve technical success. A total of 30 of these innovations was reported by respondents as being sufficiently developed to be classified as technological successes, and the remaining two were pending.

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* One set of categories used to classify the part of the vehicle affected is given in Lindgren, L.H., and Fitzgibbons, R.B., "Automotive Data Base for Manufacturing Assessment System for the Department of Transportation", Transportation Systems Center, DOT/TSC No. 803, Rath and Strong, Inc., Management Consultants, corrected copy dated June 6, 1975.

TABLE 3-1. SUMMARY OF 32 AUTOMOTIVE INNOVATIONS

FIRM	INNOVATION # AND NAME (DISGUISED)	TECHNICAL Succ.	TECHNICAL Fail	COMMERCIAL Succ.	COMMERCIAL Fail	AREA OF IMPACT Safety	AREA OF IMPACT Energy	AREA OF IMPACT Environ.
A	A1 Body-interior Component	X		X		X		
	A2 Air-fuel system Component	X			X		X	X
	A3 Transmission Component	X		X			X	
B	B1 Electrical System Component	X		X			X	
	B2 New Material (Electrical system)	X		X			X	
	B3 Emission System Component	pending		pending			X	X
	B4 Electrical System Component	X			X	X		
C	C1 New Material (Body-interior)	X			X	X		
D	D1 New Material (Body-interior)	X		X		X		
	D2 New Material (Body-interior)	X		X		X		
E	E1 Brake System Component	X		X		X		
	E2 Brake System Component	X		X		X		
F	F1 Emission System Component	X		X		X		
	F2 Emission System Process	X		X			X	X
G	G1 Body Manufacturing Process	X		X			X	
H*	H1 Fuel System Component	X		X		X	X	X
	H2 Engine Component	X		X		X	X	X
	H3 Body Component	X		X		X	X	X
	H4 Fuel System Component	X			X	X	X	X
	H5 Fuel System Component	X		X			X	
	H6 Body Component	pending		pending			X	X
I	I1 Body-Interior Component	X		X		X		
	I2 Body Component	X			X	X		
J	J1 Body Manufacturing Process	X		X		X	X	
	J2 Air-fuel System Component	X			X		X	
K	K1 Body Component	X (partial)			X		X	X
	K2 Body Component	X			X		X	X
	K3 Body Component	X			X		X	X
	K4 Body Component	X			X		X	X
L	L1 Body Component	X		X			X	X
M	M1 Emission System Manufacturing Process	X		X		X		X
	M2 New Material	X		X			X	
TOTALS 13	32	30	0	21	9	16	21	15
%		93.75% (2 pending)	0%	65.6% (2 pending)	28.1%	50%	65.6%	46.9%

$\bar{X}$ = 2.46 innovations per firm

*H is a major automotive manufacturer

A lower rate of commercial or market success was reported for these 32 innovations than the rate reported for technical success. A total of 21 (65.6%) innovations was classified by respondents as a commercial success while 9 (28.1%) innovations were commercial failures requiring development to be discontinued. Two of the innovations were classified as pending, which was also their status for technical success or failure.

The remainder of the information summarized in Table 3-1 pertains to the area of impact of these 32 innovations. One of the purposes of this study was to focus on new technologies that would influence the quality of the environment, the safety of vehicles and energy usage. All of these 32 innovations had a purported impact on at least one of these areas. A total of 16, or one half of these innovations, had an impact of increased safety of the vehicle; 21 (65.6%) of the innovations were aimed primarily at reducing energy consumption (both fuel and electrical); and 15 (46.9%) of these innovations were primarily aimed at reducing the negative impact the vehicle has on the environment.* In addition, 16, or one half of these innovations, had an impact on two or more areas - either safety and/or energy and/or the environment.

Although this sample of firms and innovations was not random, it covers a wide range and diversity of industry groupings of suppliers to the automotive industry. The disguised names of the innovations are an indication of this diversity.

3.2 CASELETTES: DESCRIPTIONS, BARRIERS, AND FACILITATORS

On the second page of the interview schedule, space was provided to develop a short description of the history of the development of the innovation. These caselettes were reduced in

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* The frequency of impact on these 3 categories was <u>not</u> found to be statistically significant (x^2 = 1.192,2 degrees of freedom). That is, this sample of innovations can be thought of as having an equal impact on safety, energy, and environmental considerations.

size to produce 32 short disguised descriptions of the innovations which are included here, using the same identification and disguised name that appeared in Table 3-1. Barriers and facilitators are listed after each description.

A1: Body Interior Component. This innovation was both a technical and market success until another innovation was substituted for it. It was a component designed to increase the safety of the vehicle and was installed in the interior. It was first developed for and sold to the after-market distributors before it was sold directly to the automotive manufacturer. The task was to develop a reliable and inexpensive product. Once the supplier began to deal directly with the automotive industry it was difficult to retain the design function and difficult to retain the added value of the product.

A1: Barriers

1. Technical reliability of the component was a problem, although overcome.
2. Cost: this component had to be an inexpensive addition to the car.

A1: Facilitators

1. The market was ready.
2. State regulation on safety stimulated development and adoption.

A2: Air-Fuel System Component. This innovation was a technical success but a market failure. It was designed to increase the performance and economy of the vehicle. Precise distribution of fuel is a persistent problem for any internal combustion engine, especially for an automobile which operates under a wide range of acceleration conditions. Solving this problem provided the incentive, but the new component could not compete economically with existing systems.

A2: Barriers

1. Technical reliability had to be high.

A2: Facilitators

1. The incentive of solving a persistent problem.

2. Cost: the barrier which prevented adoption and further development.

2. Technological capability of the firm.

A3: Transmission Component. Both a technical and commercial success, this innovation was designed for a select market of high performance cars. The automotive industry came to this supplier to request development of the product for its medium-to high-priced lines. Consequently, the innovation was viewed initially as satisfying a smaller, higher-priced, special market. In addition, the basic design eventually had the advantage of allowing the product to be easily convertible in production to two other options with different performance characteristics. The increased performance potential of the product has a favorable impact on fuel consumption.

A3: Barriers

1. Technical problems: reliability, ease of use and low noise.
2. Changes in manufacturing engineering were the key to reducing and maintaining low cost.

A3: Facilitators

1. Market potential.
2. Technological capability of the firm.

B1: Electrical System Component. The need to improve the performance of the electrical system of the vehicle led to the development of an improved design for an existing component. The use of computer-aided design (CAD) greatly facilitated the development of this product, replacing the old trial-and-error development methods formerly in use by this supplier. The innovation was both a technical and market success.

B1: Barriers

1. Lack of top management support, project was viewed as "ivory tower".

B1: Facilitators

1. The need to improve performance of the system was recognized.

2. Resistance from manufacturing. It was thought the old design was easier to make.
3. NSF internship program structure changed.
4. ERDA not interested in the firm's "approach" to the problem. It is "too restrictive and narrow".

2. Computer-aided design facilitated development.
3. Availability of consultant.
4. Idea originated from an "applied" project.
5. Price of raw material increasing.
6. NSF (National Science Foundation) internship program provided individual who did initial work.

B2: New Material for Electrical System Component. Although the automotive customer was eager to have this new material incorporated into the component, the research manager concerned insisted on a careful, thorough approach to development, which increased the time required for development. The idea for the innovation was carried by a former technician "in his pocket" to another department, after he had returned to this supplier firm with an advanced degree and was transferred from his former department. As a result, the idea was more readily adopted by top management. In addition, the raw-material supplier hired a competent engineer in the area, and he aided development. The material resulted in energy savings as well as fewer manufacturing problems than a competitor's alternative innovation in this area.

B2: Barriers

1. Research manager insists on slow, thorough development.
2. Had to "bootleg" idea in order to gain acceptance.

B2: Facilitators

1. Top management supported idea after introduction in another department.
2. Raw material supplier aids in development.
3. Major customer adopts.

3. One customer not interested because of higher manufacturing cost.

4. Relatively easier to manufacture than a competitor's alternative innovation.
5. New raw material in plentiful supply.

B3: Emission System Component. This innovation is currently being developed and its status concerning technical and market success has yet to be determined. The component has a direct automotive application, and the supplier has the technological and manufacturing capability in this area. The innovation will respond to the need to reduce fuel consumption and pollution. An automotive customer did not respond favorably to a proposal to develop this component four years ago, but the more recent proposal was more favorably received. The proposal includes a three-way development effort: a university lab, the supplier and the automotive customer. A competitor's product has been evaluated and appears to be inferior.

B3: Barriers

1. Lack of top management support for the project.
2. Early lack of favorable response from automotive customer.

B3: Facilitators

1. Technical and manufacturing capability (both in-house and locally).
2. Application of the innovation to automotive industry (potential market); customer acceptance of idea is increasing.
3. Competitor's product is inferior.

B4: Electrical System Component. This is an innovation designed to protect against failure of the electrical system. Although a technical success, it recently was discontinued because of an evaluation of lack of market potential. The automotive application was initially attractive, but the recent relaxation of a government regulation killed interest in the project. Other applications of the innovation are being explored.

B4: Barriers

1. Recent relaxation of government regulation.
2. Top management did not view product as technologically compatible with firm.
3. Firm lost interest in marketing product.
4. Mistake was made in originally selling this innovation in-house as having a limited application. Now it is difficult to look at other applications.

B4: Facilitators

Originally, this innovation had a market potential in the automotive industry.

C1: New Material for Interior Component. This innovation was a new material to be incorporated into an existing product to increase the safety of the vehicle. The existence of the safety problem was generally known in the industry and another supplier announced the development of an innovation to solve this problem. This firm followed with development of its own innovation. However, all the suppliers generally agreed that incorporation of this innovation into the car would raise its cost by about $1.00. One major automotive customer rejected this innovation because of this increased cost, and this decision tended to cool off the innovative spirit industry-wide.

C1: Barriers

1. Cost.

C1: Facilitators

1. Incentive of solving a chronic safety problem.
2. Customer's initial interest in the solution.
3. Technological capability of supplier.

D1: New Material for Interior Component. This innovation was a revival of an earlier development (cf. C1) which had been a technical success but had only limited commercial success in the industry. It was designed to increase the safety of the vehicle and was reintroduced at the request of an automotive customer who, in turn, was responding to a consumer complaint. This particular automotive customer appears to be more sensitive to consumer complaints than others. Cost was negotiated and eventually this innovation became an unqualified market success.

D1: Barriers

1. Time required to negotiate price (cost).
2. Development of adequate testing procedure and equipment.
3. Supplier of raw material is not able to respond quickly to change in order; demand for large quantities required. (In the past the raw-material supplier had to build a new plant to meet specifications change and volume required).
4. The Federal Government is neither interested nor does it have any expertise in this area.
5. The Federal Government's procurement specifications in this area are 15 years out of date.

D1: Facilitators

1. Market (customer) stimulus.

D2: Modification of Interior Material. This innovation was developed in response to a Federal safety regulation. The suppliers in this industry knew the regulation was coming and did some preliminary work for about five years prior to the mandate, but real work did not commence until government action was taken. Although this innovation did improve the safety of this component of a car, the regulation itself has had a greater impact on other (nonautomotive) industries because the automotive component was already closer to conforming to the standard than other products. The general impact of this and other recent (within the last five years) innovations which respond to government safety regulations has been to increase the importance of quality control in both this supplier, suppliers in this industry and the automotive customers. One aspect of this case is that although the safety of the car is potentially improved in one area by this regulation, it can result in a decrease in safety in another aspect of this component.

D2: Barriers

1. Integration of the new material without changing other component characteristics. (The vehicle is a system).
2. Problems of developing nondestructive testing methods.
3. Difficulty in meeting Federal standard for a car which has to be able to operate under a wide variety of temperature and climate conditions.

D2: Facilitators

1. Federal mandate (safety regulation).

E1: Brake System Component. Developed over a five-year period, this innovation replaced a less reliable component and process of the brake system. The market was ready and the cost and size of the initial prototype of the innovation were reduced in order to make it more acceptable to the automotive customer. It was both a technical and market success; it was first installed as an option on premium cars.

E1: Barriers

1. Time required to make a true innovation safe to use.
2. Cost; there is no room for back up systems in a car as in an aircraft.
3. Maintenance of the integrity of the car while still being able to improve it.
4. Design is a compromise between quality and cost.

E1: Facilitators

1. Very easy to obtain patent rights and licenses.
2. Market was there.
3. Marketing and technical expertise of supplier.
4. Ability to work with automotive customer.
5. After innovation was developed, safety regulation stimulated adoption.

E2: Brake System Component. This innovation was developed from a similar product in use outside the United States through licenses and extensive modification. Both a technical and commercial success, its development was stimulated by an automotive customer's eagerness to install it on his cars because he felt the driver would notice the difference. The major problem to overcome was the cost of the component. This was accomplished through both design development and manufacturing automation.

E2: Barriers

1. Many patents and much information available--the problem was to decide which license to obtain. Legal aspects

E2: Facilitators

1. Market pull and customer eagerness were the key stimuli here.

came first in this case.

2. Cost.
3. Manufacturing changes required to reduce cost. New design and new materials were not sufficient to reduce cost to an acceptable level. Even then, volume and learning curve was necessary for justification.
4. An existing government regulation temporarily stopped the development and adoption of more pervasive version of this innovation, but modifications were made in the system and the regulation was changed. This was only a minor factor in this case.

F1: Emission System Component. This innovation was both a technical and market success. The primary facilitator influencing its development was a governmental environmental regulation, although the safety of the car was also improved with this innovation. Although cost, fuel economy and legal constraints were barriers, technical breakthroughs in the areas of durability and weight reduction were instrumental in facilitating commercial success.

F1: Barriers

1. Cost.
2. Weight addition.

F1: Facilitators

1. Federal law on environment.

3. Corrosive fuel ingredient.
4. Reliability and durability of component.
5. Fuel economy law.

F2: Emission System Treatment Process. This innovation was an example of capitalizing on a technological opportunity which became both a technical, as well as a commercial success. The primary facilitator was a Federal emission standard imposed by law. The history of the development of this innovation demonstrates, among other things, the trade-off between emission standards and fuel economy and how the supplier can foster innovation by attempting to meet these standards.

F2: Barriers

1. Cost.
2. Weight addition.
3. Corrosive fuel ingredient.
4. Reliability and durability of component to be made.
5. Fuel economy law.

F2: Facilitators

1. Federal emission standard.
2. Increased space in the interior of the car.
3. Fuel savings.

G1: Body Manufacturing Process. The innovation is the result of three years of development in two other countries. The process could not be transferred to this country in its original form because of its high cost. However, the cost was eventually reduced, and the need for lighter-weight cars in response to Federal fuel economy laws stimulated development and adoption. Currently, this innovation is a technical and a commercial success.

G1: Barriers

1. Process originally developed in another country.

G1: Facilitators

1. Fuel economy laws.
2. Supplier had ample funds for development.

2. The final part had to meet original collision impact characteristics (standards).
3. A final part failed to meet safety standards.

3. Federal procurement policy is consistent with law on fuel economy.

H1: <u>Fuel System Component</u>. <u>H2: Engine Component</u>. <u>H3: Body Component</u>. <u>H4: Fuel System Component</u>. (All of these innovations have very similar development histories, barriers and facilitators and, therefore, only one caselette and listing of factors is included here.) The first three innovations were both technical and commercial successes. The last (H4) was a technical success but a commercial failure. The potential of these innovations was their increased safety, weight reduction and positive impact on environmental constraints imposed by emission regulations. However, serious technical problems had to be overcome through development. The availability of government information during all phases of development greatly facilitated the eventual technical success obtained for all four of these innovations.

<u>H1: Barriers</u>

1. Safety standards remain in force on new component.
2. Reliability of new component under various operating conditions.

<u>H2, H3, H4: Barriers</u>

1. Same as above.
2. Same as above.

<u>H1: Facilitators</u>

1. Government regulations, and laws on fuel economy and emissions.
2. Availability of government information.
3. Procurement policy consistent with laws and regulations.

<u>H2, H3, H4: Facilitators</u>

1. Same as above.
2. Same as above.
3. Government direct R&D.
4. Government financial incentives for lighter car.

H5: Fuel System Component. This innovation was under development for about 10 years before it became a technical and commercial success. It has been adopted for both trucks and, in the case of one automotive manufacturer, for cars. It is also ready for off-road vehicles. The primary problems in attaining large-scale commercialization are the legal uncertainties and the history of reluctance to innovate in this component area.

H5: Barriers

1. Ambiguity of the legal implications.
2. History of reluctance to innovate in this area.
3. Difficult technical problems to overcome during development.

H5: Facilitators

1. Less expense and lighter weight potential (fuel savings).
2. Innovative alternative much safer.
3. Durability of component increased.
4. Material shortage for existing component.

H6: Body Component. This innovation is currently under development and has a good market potential. If successful, it will save energy and it will also have increased environmental protection consequences. The existing process technology associated with this technology uses large amounts of natural gas, while this innovation will be easier to make with less energy and also easier to install. This innovation is a good example of technology which could be stimulated by Federal involvement.

H6: Barriers

Currently, no major barriers.

H6: Facilitators

1. Federal standard for a portion of the process related to this component.
2. Energy savings.
3. Innovation currently being developed by competition.

I1: Body Interior Component. The development and adoption of this innovation had several problems to overcome before it became a technical and commercial success. Although the Federal

Government vacillated on a safety regulation, it eventually became a prime facilitator. During development, however, this vacillation retarded the innovation process. Now the innovation is required by Federal mandate. The initial interference of this innovation with style considerations had to be overcome.

<u>I1: Barriers</u>

1. Public acceptance was low (only about 1 in 10).
2. Vacillation of Federal position on safety regulation -- lack of firm stand.
3. Additional cost.
4. Interference with styling considerations.
5. Other related safety considerations not taken into account by Federal mandate.

<u>I1: Facilitators</u>

1. Eventually, this innovation mandated by government.

I2: <u>Body Component.</u> Although this innovation was a technical success in the area of safety, its commercial success is still uncertain. It adds cost to the vehicle, and a strong lobby against standards in this area has prevented legislative mandate. The innovation still remains in the experimental stage of commercial use and cannot be classified as a commercial success. The public appears to have little interest in the increased safety this innovation could provide.

<u>I2: Barriers</u>

1. Cost.
2. Anti-safety lobby and no government action.
3. Safety not profitable.
4. Public apathy.
5. Cost of development is

<u>I2: Facilitators</u>

1. Potential for increased safety.
2. Pro-safety lobby.
3. Realization of the inadequacy of the regulation for the existing component.

L1: Body Component. This innovation involves a major steel company; the need for a corrosion-resistant structural material was recognized and well understood by this firm. The company tried several methods of producing a corrosive-resistant product, but all were uneconomical. Then another firm offered to share its process with company L in a joint venture. The result was both a technical and commercial success, which was eventually produced by an outside vendor.

L1: Barriers

1. Initially, process was uneconomical.

L1: Faciltators

1. Only a modest investment required.
2. Close working relationship between R&D and marketing groups.
3. Professional award given for development.
4. Demonstrated market need and potential.
5. Clearly defined project.

M1: Emission System Manufacturing Process. This innovation is an example of a new fabrication process. Initially, R&D management was going to discontinue the project, but marketing demonstrated the commercial potential, and development continued. The project was stimulated by a Navy contract and an OSHA regulation standard. The innovation that resulted was a technical and market success. It is an example of a supplier taking a shorter route to technology acquisition through buying a smaller firm for its technical potential.

M1: Barriers

1. Lack of top management support.
2. New market which firm was unfamiliar with.
3. Uncertainty concerning environmental impact.

M1: Facilitators

1. Marketing potential.
2. Role of the product champion.
3. Navy contract.
4. OSHA regulations.

M2: New Material. The innovation is an energy-controlling device. A patent was awarded to the firm on this project, and development was stimulated by an industry award. This case is a good example of technology push -- the innovation was stimulated by perception of a technical opportunity. As might be expected, problems with this innovation resulted from linking a product with a market and matching the product with the firm's existing line of business. The innovation is a technical success and has had some initial market success.

M2: Barriers
1. Market potential.
2. Fitting product with existing firm business.

M2: Facilitators
1. Industry award for development.
2. R&D climate.
3. Defense contracts.

3.3 CATEGORIZATION OF BARRIERS AND FACILITATORS

The purpose of this section is to summarize the barriers and facilitators that our respondents said influenced the development and/or adoption of these 32 innovations by combining them into categories. The categories are presented with the frequency counts that these barriers or facilitators were mentioned. Caution should be exercised in interpretation of these results because the "frequency of mention" of a factor is not necessarily the only measure of its importance. For example, the presence of one barrier or one facilitator often appeared to be more important than the other factors combined. Also, a particular factor may have been more important in one case than in another.

3.3.1 Categorization of Barriers

The barriers reported by respondents for these 32 cases were combined into categories and are summarized in Table 3-2. These categories are discussed below, including barriers that were only mentioned in one or two caselettes which do not appear in Table 3-2.

TABLE 3-2. CATEGORIZATION OF BARRIERS

BARRIER	NUMBER OF CASELETTES (INNOVATIONS) IN WHICH BARRIER ACTED	PERCENT (n = 32)
1. Federal Law or Regulation	15	46.875
2. Cost	14	43.75
3. Technical Reliability	14	43.75
4. Market Considerations	8	25.
5. Maintain Integrity of Vehicle	8	25.
6. Lack of Adequate Testing Procedure	7	21.875
7. Lack of Top Management Support	4	12.5
8. Changes in Manufacturing Process Required	3	9.375
9. Lack of Federal Interest or Competence	3	9.375

1. Federal Law or Regulation was reported by respondents as a barrier in 15 or about one half of these cases. This barrier acted in a variety of ways. Changes in a regulation or procedure required adjustment on the part of suppliers. The uncertainty of the regulatory climate or vacillation of the government's position caused many problems for suppliers in focusing development efforts and setting priorities for projects. In five of the cases in this category firms had difficulty meeting Federal standards. Many firms developing products in one area (e.g., energy) also recognized the need to meet other Federal standards (e.g., noise). This last circumstance is elaborated upon in a later, related category which is concerned with the problems of "maintaining the integrity of the vehicle" while still improving it.

2. Cost was mentioned as a barrier to be overcome in 14 of the 32 cases, or about 44 percent of the time. Cost is a barrier that is a more complex factor than might appear on the surface. It is not simply a matter of the supplier developing a new product or process that is then rejected by the automotive customer because the public will not pay the additional cost of an automobile. Occasionally, this does happen, but it is not representative of the cases in this sample. In many cases, cost is reduced over a period of time through development by the supplier working with the automotive customer. This was often done by making design changes, incorporating new materials and reducing cost by automating and otherwise improving the manufacturing process. In addition, the innovation may be first introduced in the more costly product lines of premium cars, either as an option or as standard equipment. Then, because of the large volume of cars that are manufactured, the learning curve may reduce the cost of the innovation even further. The negotiation of cost and the evaluation of public acceptance of the innovation involve a series of key decisions on the part of both supplier and automotive customer. There does not appear to be any set cut-off of a maximum increase in cost that will be acceptable. Cost decisions are not made independently from an evaluation of the consumer's

f) Adopting a foreign-developed technology;

g) Historical reluctance and resistance to innovate in a particular area;

h) Lack of public acceptance; and

i) Inability of an automobile customer to obtain an original process from a supplier.

All of these barriers are, of course, mentioned with the caselette descriptions in Section 3.2. The purpose of this section has been to summarize them and give an overview of all 32 innovations taken together.

3.3.2 Categorization of Facilitators

On the other side are the factors that facilitated the development and adoption of many of these 32 innovations. These factors were combined in categories as were the barriers, discussed in the section above (3.3.1). A summary of these categories is presented in Table 3-3. A discussion of these categories follows.

1. Federal Law or Regulation was reported by respondents as being a facilitator in 14 (about 44%) of the cases. This category is rather straightforward. A Federal law or regulation concerning safety, the environment (usually an emission standard) or energy (usually fuel economy) stimulated development or adoption of a particular innovation. The actual content or substance of these laws or regulations was often commented on by respondents. The specificity of these mandates varied greatly. Some just set performance standards, others set standards and specified the means or methods by which these standards were to be met. There appears to be a trade-off between the type of facilitation that results from these two types of mandates. On the one hand, a very specific regulation or law focuses development efforts on a particular component or process, but, on the other hand, it may retard development of alternative and, perhaps, better solutions to the problem addressed by the mandate. As noted earlier in the barrier discussion (Section 3.3.1), the vacillation of the government's position on an issue can create uncertanity in the supplier firm. In addition, one regulation was eventually changed in response to

TABLE 3-3. CATEGORIZATION OF FACILITATORS

FACILITATOR	NUMBER OF CASELETTES (INNOVATIONS) IN WHICH FACILITATOR ACTED	PERCENT (n = 32)
1. Federal Law or Regulation	14	43.75
2. Challenge and Incentive of Solving a Persistent Problem	13	40.625
3. Recognition of Market Potential	10	31.125
4. Direct Government R&D or Grant	6	18.75
5. Technological Capability of Supplier	5	15.625
6. Federal Procurement Policy	4@	12.5
7. Availability of Federal Information	4#	12.5
8. Government Financial Incentives	3#	9.375

@ Only 2 firms reporting this facilitator.

Only 1 firm reporting this facilitator.

an application of a new technology. But regulatory lag can increase the time required for introduction of an innovation. No simple solution or guideline for regulation emerges from this exploratory study, but the caselettes do illustrate this trade-off as viewed by the suppliers.

2. Challenge and Incentive of Solving a Persistent Problem was a category of facilitator referred to by respondents in 13 of the cases, or about 40 percent of the time. Suppliers that have dealt with a particular product line or product lines over a period of years become aware of the chronic problems of the vehicle. From time to time, potential solutions to these problems emerge from related R&D, development in other fields or ideas from participants. The challenge to solve these problems appears to be a reasonably persistent incentive that acts in the innovation process. Many suppliers view these chronic problems as opportunities to innovate and, occasionally, opportunities to match a potential innovative solution to one of these persistent problems. The nature of the internal combustion engine is a good example here. Even though there is a long development history associated with this part of the vehicle, there are chronic problems associated with its performance which might be improved.

3. Recognition of Market Potential is a facilitator mentioned in 10 (about 31%) of these cases. Often this factor is called "market pull" in the innovation literature. In this setting, a typical case of market pull is the automotive customer requesting the supplier to develop an innovation to improve the vehicle, which can probably be sold to the customer--although not always. Another typical case is the supplier's recognition that a particular new product or process will be acceptable to the automotive customer, and this stimulates development.

4. Direct Government R&D or Grant stimulated and/or facilitated development of six (about 19%) of these innovations. However, interpretation of this category without considering some of the other comments of suppliers who avoid government R&D or grants would be misleading. The benefits of participating in

government R&D are limited because patents,etc., cannot be retained by the firm. In addition, some supplier R&D labs are already understaffed, and they are often reluctant to take on this type of additional workload.

5. Technological Capability of the supplier was mentioned as facilitating five (about 16%) of these innovations. Many of these firms have a long and strong track record of innovation in a particular area, and perhaps the modesty of respondents prevented this facilitator from being mentioned more frequently.

6. The remaining three categories of facilitators listed in Table 3-3 are Federal procurement policy, availability of Federal information, and government financial incentives. However, the comments on these factors refer to only two of these 13 firms. Discussion of these cases is more appropriate to and, therefore, included in Section 5 of the report.

7. The facilitators that were mentioned in fewer than three cases cover a wide range of factors. They include:

a. A state safety regulation;
b. The availability of a consultant;
c. Computer-aided design (CAD) capability;
d. The applied focus of two projects;
e. Increasing material costs;
f. The NSF (National Science Founcation) internship program;
g. Top management support;
h. Help in development from a raw-material supplier;
i. Ready supply of a new (to the component) raw material;
j. Ease in obtaining patents and licenses;
k. The supplier's ability to work with the automotive customer;
l. Availability of funds for development;
m. Lower cost of the innovation when compared to the existing component;
n. Actions of competitor suppliers;
o. Lobby activities;
p. Inadequate existing regulation;

q. - Capital savings;
r. - Style improvements accompanying the innovation;
s. - Communication between marketing and R&D departments;
t. - Professional awards for development;
u. - The role of the product champion;
v. - Government contracts; and
w. - The R&D climate of the supplier firm.

No attempt has been made to integrate these facilitators into earlicr categories because the categories might become more complex; it appears that this list of facilitators can stand alone, even though the items were mentioned less frequently by respondents.

All of these facilitators appear with the caselette descriptions in Section 3.2. The purpose here has been to summarize and provide an overview for all of the 32 cases when they are viewed together.

3.4 SPECIFIC DECISIONS, ACTIONS, AND PRECIPITATING EVENTS IN THE CASELETTES

As a result of summarizing the information provided by respondents on innovations and developing the caselettes, many decisions or actions of organizations and precipitating events were collected which appeared to have an influence on the development and adoption of these 32 innovations. Although some of these decisions and precipitating events might also be interpreted as facilitators or barriers, normally these latter categories are broader and might include a series of decisions, enabling conditions, or precipitating events.

In this section, the key decisions and precipitating events reported by respondents are discussed. It is often difficult to determine the relative importance of these decisions and precipitating events, but it should be sufficient to say that these respondents thought them to be important enough in any particular case to include them when recounting the short history of the innovation.

A key supplier decision in case A_1 was to enter the after-market first rather than go directly to the automotive customer. Later, when this innovation was eventually adopted by the auto customer, much of the control over the design function was relinquished by the supplier, as well as a portion of the profit margin. An important precipitating event in this case was the enactment of a state safety regulation.

In case A_3, an important precipitating event was the automotive customer's request of the supplier to develop a particular innovation. Not only does this provide clear direction to the supplier in development efforts and priorities, but it also provides market potential information which is sometimes difficult to obtain.

An interesting precipitating event occurred in case B_2, which involves a new material for an electrical system component. In this case, the raw-material supplier hired a new engineer who was evaluated by the automobile supplier as unusually competent. A close working relationship developed between R&D personnel in the auto supplier and this engineer. As a direct result of this engineer's help, the idea for incorporating a new material into an existing component was developed into both a technical and commercial success. Two other events occurred which also acted as facilitators in this case. First, a former technician who had worked in the auto supplier's R&D lab left the organization to obtain an advanced degree. Eventually, this individual was rehired by the organization and was transferred to another division -- but not before he was encouraged by his former R&D supervisor to introduce the idea for this new material on his new job. A key top manager in the other division finally supported the idea, and an interdepartmental barrier to communication was overcome. The second event was the decision of a major automotive customer to adopt a product which incorporated the component with the new material.

A barrier to further development of innovation B_4 resulted when the Federal Government's decision to relax a regulation eliminated the need for one automotive application of an electrical system component. The R&D management decision to focus development of this innovation on just the automotive application during the early stages of development also contributed to the death of projects related to it, after the regulation was changed.

Another rather unique event occurred in case C_1. Here, an industry meeting of suppliers in a particular area was called by a major automotive manufacturer to discuss a particular safety problem. Most of the suppliers eventually developed an innovation to solve the problem, including Company C, but this same automotive customer rejected all of the suppliers' solutions as too costly.

In case D_1, a precipitating event caused a chain reaction of decisions. In this case an owner of an automobile complained to the manufacturer about a safety problem. Because this problem was not unique to this particular car, the complaint was perceived by the auto manufacturers as representing perhaps 100 dissatisfied customers. The auto manufacturer requested that this supplier (D) develop a solution to the problem, and this innovation (D_1) resulted. Then the cost-negotiation period began. The supplier quoted a new price for the component involved, and the manufacturer then had to decide if additional cost to the car outweighed the benefits of satisfying the consumer dissatisfaction. Eventually, after a period of negotiation, a cost was quoted by the supplier that was acceptable, and the innovation became a market success.

In case D_2, a Federal safety regulation stimulated development of a new material for an interior component. The suppliers in this industry were anticipating this regulation and had been working on development of this innovation for about five years before it was enacted. However, development activity on the innovation greatly increased when the regulation became a reality rather than just a forecast. Federal mandates of this type also acted in cases F_1, F_2, G_1, H_1, H_2, H_3, H_4, K_3, and M_1.

In cases E_1 and L_1, two similar decisions on the part of the auto supplier were made that greatly facilitated development of these two innovations. In company E, the decision was made to work with three other suppliers (not exclusively automotive suppliers) in development of the innovation. One of these other companies as a basic electronics firm, and individuals there greatly aided development -- especially in the areas of reducing the size and cost of the innovation. Although the idea of the innovation originated with the automotive supplier and this idea was accepted by the automotive customer, the innovation would not have been adopted if the size and cost had not been reduced. Similar circumstances occurred in the case of innovation L_1. Here, the supplier had developed a process that was a technical success but was not an economical alternative to existing methods. Another firm offered to share its process in a joint venture, and eventually the process became a market success. The decision to share information and enter a joint venture greatly facilitated the introduction of this innovation commercially. In addition, a professional award was given for development. A similar award also acted to stimulate case M_2. The importance and timing of these awards is often underestimated. A project that suffers from temporary lack of marketing interest can often be sustained when awards of this type are granted.

Defense contracts were obtained by suppliers in cases M_1 and M_2, which appeared to be important decisions. However, in case J_2, when defense interest evaporated, the innovation failed to become a sustained commercial success.

Overall, the two types of decisions that are made in the automotive supplier's environment which appear consistently throughout these cases are 1) the automotive customer's decision to accept, encourage development of, and/or adopt innovations, and 2) the government's decision to mandate changes in safety, environment or energy-related regulations or legislation.

3.5 GENERAL COMMENTS AND OBSERVATIONS

The following are some general comments and observations made by automobile suppliers on the innovation process and the attendant relationships between themselves and manufacturers. The purpose of this section is not to restate comments verbatim but to convey their general sense and flavor. Although we cannot distinguish the specific impact of suppliers' attitudes and beliefs on the innovation process, it is safe to say that the following comments and observations are integral in shaping and screening choices for research, development, and marketing.

Cost. As previously mentioned in Section 3.3.3, cost is a factor whose importance in the innovation process figures differently across the product life-cycle. Recognition of the dynamic character of negotiated cost partially reconciles the highly contradictory comments and observations concerning the effects of cost on the adoption of innovations. Some suppliers felt that even if there is a clear threat to safety or the environment, the automotive industry will not adopt the innovation if it adds to the price of the car. Only strict regulatory enforcement that enjoins the manufacturer to accept the innovation is effective. Others perceived the cost issue as a first-cost question, tempered over time by two factors: 1) the reduction in uncertainty of design features as the supplier and client negotiate and cooperate; and 2) the increasing role of Federal regulation - a factor far outweighing the others and supplanting "cost-only" considerations.

Innovative Decision Making. On the relationships of the Big Three to innovative decision making, some suppliers felt that one of the Big Three is a prime motivator and adopter of innovations. Of the other two, one vertically integrates to its detriment - thus losing out on many new ideas; the other tries hard, is less cautious, and continues to foster competitiveness within the supplier group for the best innovations.

Failure of Suppliers. The failure of many suppliers is felt by some to be the result of "their blowing their horns too loudly" to their automotive customers or "stealing their thunder."

Sensitivity to Innovation. On the issue of sensitivity to new ideas, there is almost complete consensus that the automotive manufacturers are willing to hear out ideas and never suppress new ideas. They are often very anxious to give new ideas a full hearing. The real problem arises when suppliers "pull back" because of their reluctance to present ideas that might be very innovative but too costly. However, some expressed the view that this self-restraint keeps the suppliers' "feet on the ground" with regard to what is marketable.

Second-Level Suppliers. Second-level suppliers and inventors have a very low probability of getting their innovations adopted by the automotive manufacturers. The relationships between first-level suppliers and the manufacturers is more or less a closed one. This is not to say that new ideas are not given a full hearing, but rather that they may have already been considered by suppliers or manufacturers and rejected.

Regulations. In the regulatory arena, sides line up on philosophical and practical bases. Some feel that the automotive industry is already overregulated. Others feel that manufacturers will adopt safety/environment/energy-saving technologies only when the Federal Government wields the big stick. It was generally agreed, however, that performance standards and specifications are preferable to product or design specifications, the latter becoming completely counter-productive. Many recognized the need to understand the trade-offs (see Section 3.3.2) that result from varying degrees of regulatory specificity.

Supplier and Congress. Some suppliers with new technologies would like to go over the head of manufacturers directly to Congress or to the people. This might improve the imperfect market information gap. However, fear and reluctance of antagonizing the manufacturers is a major deterrent and forces the supplier to take a "wait and see" attitude on some innovations.

In-House Linkages. The one in-house linkage mentioned most often is the alignment of R&D with marketing efforts, especially at the early stage of new product development. Another important linkage that is presently absent and acts as a general barrier is the lack of any attempt to integrate the computer-aided design (CAD) with computer-aided manufacturing (CAM), in spite of the chronic problem of increasing labor costs.

4. BARRIERS/FACILITATORS/INCENTIVES AMENABLE TO FEDERAL INTERVENTION

4.1 THE GENERAL LITERATURE ON BARRIERS/FACILITATORS/INCENTIVES AMENABLE TO FEDERAL INTERVENTION

Since the stimulation of research and experimentation on the subject of "Barriers and Incentives to R&D/Innovation" in the early 1970's, several dozen studies have been carried out in both the public and the private sector on the barriers/facilitators/incentives to innovation and possible roles the Federal Government (and, in some cases, state and local governments) might play in helping to stimulate and speed up the innovation process.

Some of these have been field studies and field experiments, some have been theoretical and speculative studies, and others have been primarily literature reviews, with a framework for categorizing or listing or portraying barriers/facilitators/incentives. (Note: the terminology in the field is far from uniform, so that we are using the terms barriers/facilitators/incentives in general terms, rather than in a strict technical sense - that is, one firm's "barrier" may be another firm's "incentive").

Although the study we are reporting was essentially an empirical one, involving obtaining caselettes on actual innovation projects by suppliers to the automotive industry, we felt it would be useful to provide a sample, in this report, of the results of some of these other studies, most of which did not involve the auto industry directly.

Consequently, we are reproducing, in Appendix B, some excerpts from a selected sample of such studies which list categories of barriers/facilitators/incentives in the R&D/Innovation process. We have selected primarily factors from the private sector; there is an approximately equal number of such lists for the public sector (e.g., adoption of innovations by Federal, state, or local governments).

Many of the factors listed in the excerpts in Appendix B correspond with our Figure 5-1 from the proposal for this exploratory study. In the next section, we reproduce that figure and indicate how the data gathered in the caselettes would modify it, in terms of additional or more specific factors related to innovation by suppliers to the auto industry.

No one format can best "sum up" or categorize Federal methods of stimulating the development and utilization of technological innovations. The many existing and proposed Federal incentives to overcome barriers to innovation in the private sector differ widely with regard to nature, scope, cost and timing. Some of the most frequently cited incentives concern: the nature, scope, cost, and timing of government regulations; the granting of exclusive patent rights; Federal procurement and financial incentives; direct Federal sponsorship and/or transfer of R&D results; and others.

4.2 WHAT THE FEDERAL GOVERNMENT COULD DO

The relationship between the auto manufacturers and suppliers has evolved over a long period of time. One thing that appears to be common is for auto manufacturers to distribute some of their risk (e.g., product development) to their suppliers by encouraging development of ideas that have unproven market potential.

Over the same period ot time, and especially during the past ten years, the influence of regulation on auto manufacturers has increased. But the suppliers may be getting a distorted picture of the impact of regulation and other government action on auto manufacturers because this government influence is passed through the "auto" filter - it might be distorted, amplified, or dampened (buffered).

The question arises: What future impact will this increase in regulatory and government action have on the auto manufacturer-auto supplier relationship?

There are three specific areas in which the Federal Government might effectively intervene to stimulate innovation. These involve the specificity and timing of regulations, maintenance of vehicle integrity, and standard acceptance testing. 1) As previously discussed, (see Section 3.3.2), the Federal Government could facilitate innovation if it made its regulatory actions more specific and tied in closer to project timing and capabilities of suppliers. 2) Many respondents felt that the Federal Government could do better in appreciating vehicle integrity. This involves both the understanding of technological interdependence in the production and operation of motor vehicles as well as a "broadening" of regulation to include trade-offs among energy, safety, and environmental aspects. 3) Of all the Federal "coulds" suggested to stimulate innovation, the establishment and enforcement of consistent testing standards was mentioned the most often. In this area, the Federal Government could mandate specific testing criteria which would reduce the uncertain and inconsistent results that emerge when several labs work independently on design and control specifications. Improved test standards and methods could improve uniformity of data in the vital areas of safety, environment, and fuel consumption.

5. THE MODEL REVISITED AND MODIFIED

In the original proposal for this brief exploratory study, a rough, abbreviated conceptual model was presented of the potential role of Federal agencies in influencing the R&D/Innovation process in industrial firms. It is reproduced here as Figure 5-1. That model was derived from our many studies of the R&D/Innovation process across a wide spectrum of fields of technology and industry; it was not specific to the automotive industry.

Now that we have obtained the data represented by the caselettes described in the previous sections of this report, it is appropriate to re-examine the model and see how the data from the actual caselettes of automotive innovations relate to it.

In Figure 5-2, we have retained the basic structure of the model (the five "factor boxes") but have substituted factors from our caselettes for some of the general barriers/facilitators/constraints. For example, in place of the general factor "regulations" in box "A", we have listed some general classes of regulations pertinent to the auto industry which have turned up as "barriers/facilitators/incentives" in the caselettes.

Figure 5-2 does not contain a complete and exhaustive listing of all possible factors which can act as barriers/facilitators/incentives to innovation in the auto industry. It does, however, reflect some of the more salient factors as represented in our caselettes: the background information on general factors which was supplied by our respondents in the industry, in addition to the data on specific caselettes. A more extensive list is given in the caselettes themselves, in Sections 4.3.1 and 4.3.2, and in Table 3-2 and 3-3.

In addition to the model of Figure 5-1, the proposal for this study also contained a generalized list of "decision points and actions" which has emerged from our other studies of the R&D/Innovation process and which reflects many of the "critical juncture points" in the R&D/Innovation process. This original list

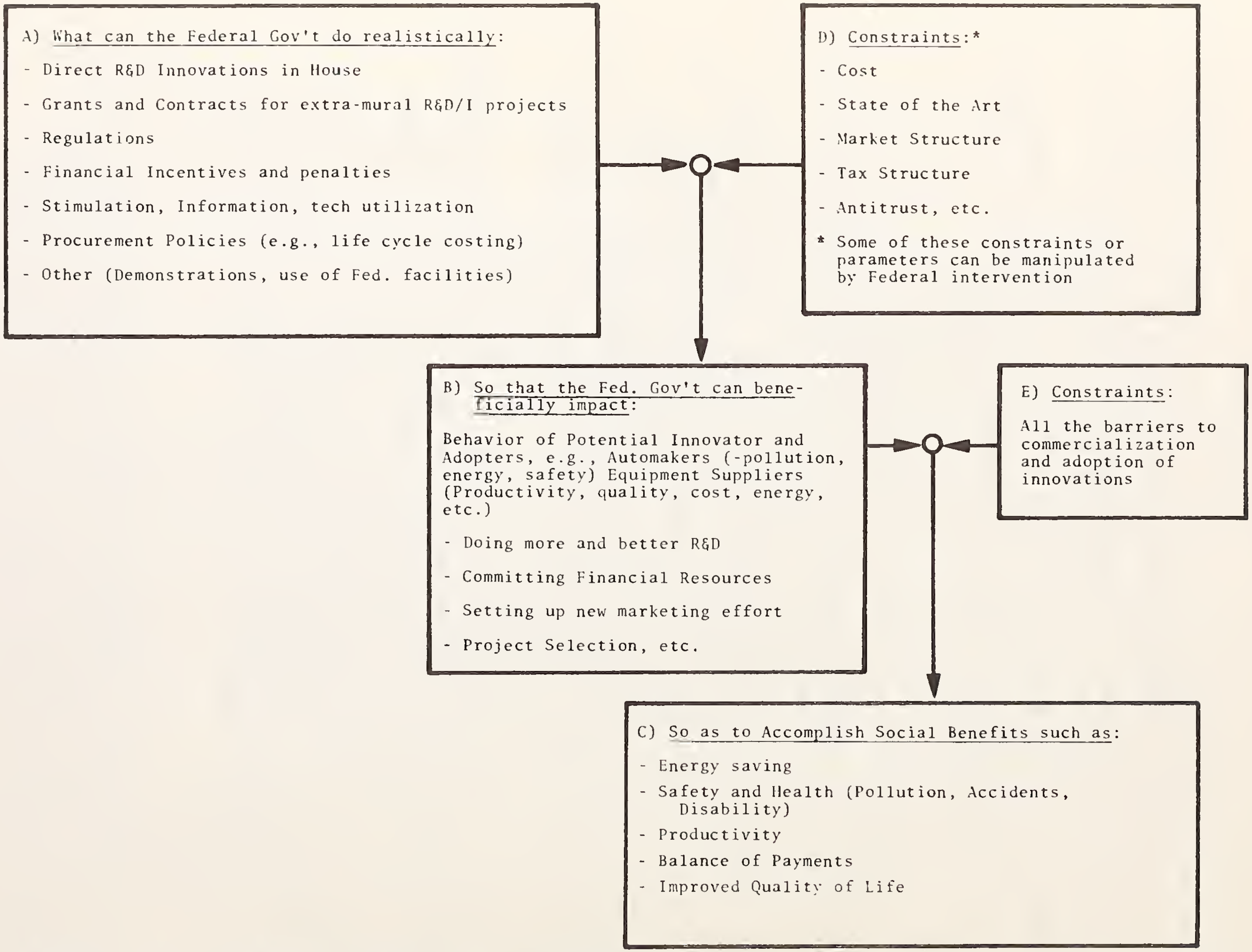


FIGURE 5-1. A ROUGH, ABBREVIATED CONCEPTUAL MODEL OF THE POTENTIAL ROLE OF FEDERAL AGENCIES IN INFLUENCING THE R&D/INNOVATION PROCESS IN INDUSTRIAL FIRMS

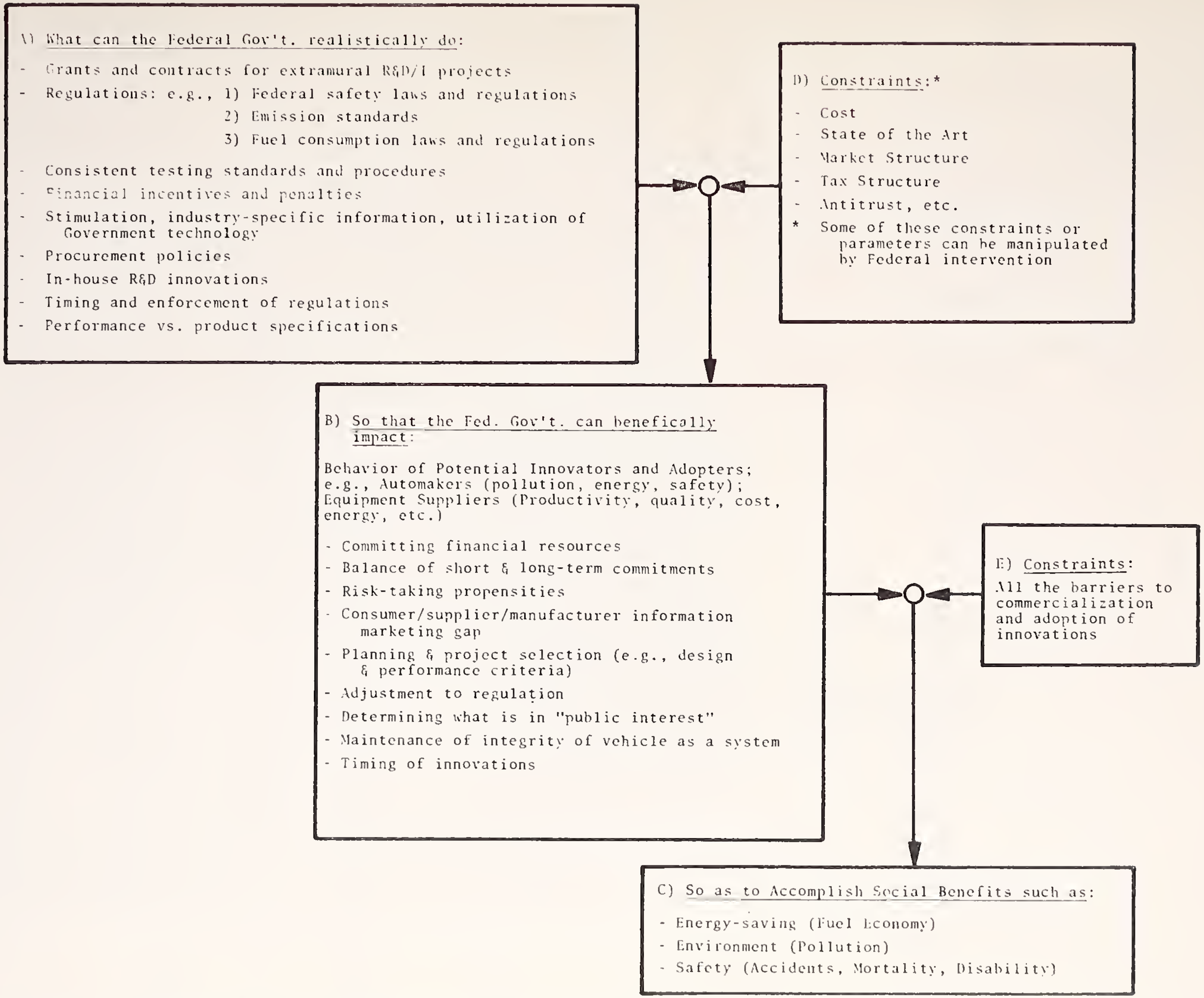


FIGURE 5-2. REVISED MODEL OF THE POTENTIAL ROLE OF FEDERAL AGENCIES IN INFLUENCING THE R&D/INNOVATION PROCESS IN THE AUTOMOTIVE INDUSTRY, BASED ON THE CASELETTE DATA

is reproduced in Table 5-1. Analysis of the caselettes for the current project yielded the set of specific actual "decision and action points" listed in Table 5-2.

Recalling that the results of this study reflect a quick three-month exploratory study, conducted primarily by telephone at a very low funding rate (under $10,000), we believe that the revised model reflects fairly well the general innovation situation in this field as it affects suppliers to the auto industry and that further, more probing work can now proceed in the direction indicated by the findings.

TABLE 5-1. ILLUSTRATIVE LIST OF GENERAL DECISION OR ACTION POINTS IN THE R&D/INNOVATION PROCESS (not in any order of importance or sequence)

1. Decision to bid on a development contract
2. Decision on whether to set up a special organization - e.g., a project group
3. Whom to assign
4. How much resources to allocate
5. Key man assignment or less capable person
6. Full entrepeneurial responsibility to project leader or less
7. One shot vs. follow on
8. Go into it on a full scale or not
9. Make or buy components, materials, services, facilities, products, equipment
10. New facilities or equipment
11. Merger or acquisition to obtain technical, production, or marketing capability
12. Tooling - new, extent, quality
13. Market research - degree of effort and commitment
14. Set up new distribution system or change existing one
15. Reps, direct selling, other forms of distribution set up on a project basis
16. Initiate or accelerate R&D
17. Hire specialists
18. Bid high or low - but into it for sake of follow on or building credibility or reputation in the field
19. Decision to innovate beyond the specific order
20. Critical path behaviors or events: tooling, letting sub-contracts
21. Entry into a new field or just moving slightly to one side
22. Set up separate government product division or group
23. Optimize profit on a particular order
24. Separate/integrated organizational form
25. Project/functional set up of R&D and related innovation activities
26. Assignment of personnel

TABLE 5-1. ILLUSTRATIVE LIST OF GENERAL DECISION OR ACTION POINTS IN THE R&D/INNOVATION PROCESS (not in any order of importance or sequence) (continued)

27. Level in the organization (how important is the project)
28. Investment level and allocation to different phases of the R&D/I process
29. Source of funds - cash flow, reserves, go to bank, long-term debt
30. Search or devoting selective attention to opportunities
31. Pursuit of an RFP or solicitation a bit afield from regular lines of business
32. Investment of time, manpower, money, executive attention in search/bid activities
33. Firm's awareness of RFP. Extent and level in organization
34. Decision to set up program in organization on major footing
35. Decision to engage in R&D beyond RFP delivery needs
36. Decision to tool, etc., for longer run production
37. Perceived opportunities and costs of specific procurement and commercial follow up

TABLE 5-2. SPECIFIC DECISION AND ACTION POINTS DERIVED FROM THE CASELETTES

A. Precipating Events

1. Enactment and change of safety/environment/energy regulations
2. Automotive customer's request (see E2)
3. Hiring competent engineer
4. Supervisor backing of new product idea
5. Industry meeting of suppliers
6. Relaxation of regulations
7. Automotive customer's (consumer's) complaint
8. Joint development
9. Reduction of size and cost
10. Sharing of information
11. Professional recognition of product idea
12. Contracts, grants, and government incentives

B. Decision Events

1. Incorporate a component/process/method
2. Reject a component/process/method
3. Initiate and/or continue development - (e.g., commit resources)
4. Slow down and/or halt development

APPENDIX A: INTERVIEW GUIDE FOR STUDY

CONFIDENTIAL

Interviewers ______

______

Interviewee ________________________

Organization ______________________

Date ________________

Time ________________

Staple Business Card Here if Available

Purpose of Study: to explore barriers or facilitators to introduction and selling of innovative products/items/concepts to the automotive companies. We are especially interested in innovations related to energy, safety, and environment and particular barriers that might be amenable to Federal initiatives (incentives, regulations, etc.). All information will be kept confidential.

CAN YOU GIVE US SOME SPECIFIC EXAMPLES OF ENERGY/SAFETY/ENVIRONMENT INNOVATIONS WHERE YOU HAD PARTICULAR SUCCESS OR DIFFICULTY SELLING TO AN AUTOMOTIVE COMPANY?

List:

		SUCCESS FAILURE
Innovation (CASE #1)	____________________	____________________
Innovation (CASE #2)	____________________	____________________
Innovation (CASE #3)	____________________	____________________
Innovation (CASE #4)	____________________	____________________
Innovation (CASE #5)	____________________	____________________

CASE # _____. Innovation name ____________________________________.

History. BARRIERS or FACILITATORS involved. Those BARRIERS that might be amenable to Federal initiatives. (See check list on next page.)

CASE # ________

CHECK LIST OF BARRIERS: What did or could the Federal Government do to help or hinder?

Candidate Barrier	Description
1. Direct R&D/Innovation in-house.	1.
2. Influence innovation through grants, contracts, etc., for R&D or innovation projects.	2.
3. Stimulate or impede innovation through regulation.	3.
4. Influence the innovation process with financial incentives and/or penalties.	4.
5. Stimulate innovation with information or impede innovation by failing to provide information.	5.
6. Influence innovation by procurement policies.	6.
7. Any other influence. (e.g., demonstration projects, use of federal facilities)	7.

APPENDIX B

SELECTED EXCERPTS FROM THE LITERATURE ON THE R&D/INNOVATION PROCESS, CONTAINING LISTS OF BARRIERS/FACILITATORS/INCENTIVES

TABLE B-1. THE "GIVEN" BARRIER CATEGORIES

1. UNCLEAR SCOPE OR IMPLICATIONS OF REGULATIONS
2. DISAGREEMENT WITHIN THE AGENCY ABOUT THE APPLICATION AND MEANING OF REGULATIONS
3. LACK OF MECHANISMS WITHIN THE AGENCY FOR EXPLAINING REGULATIONS
4. PROHIBITIVELY HIGH COST OF COMPLYING WITH REGULATIONS
5. UNWILLINGNESS OF AGENCY TO EXPLAIN REGULATIONS
6. REGULATORY TIME PRESSURES LEADING TO NON-OPTIMAL INNOVATIONS
7. INABILITY OF FIRM TO MEET PRESCRIBED DEADLINES IN REGULATIONS
8. DELAYS BY THE AGENCY IN PROMULGATING GUIDELINES REQUIRED BY THE LAW
9. INABILITY OF FIRM TO DEVELOP OR ALLOCATE THE RESOURCES NECESSARY TO COMPLY WITH REGULATIONS
10. CONFLICTS AND INCONSISTENCIES BETWEEN REGULATIONS
11. DIFFERENTIAL TREATMENT BY THE AGENCY OF THE ENTITIES AFFECTED BY THE REGULATIONS
12. INCONSISTENCY OVER TIME IN THE AGENCY'S APPLICATION OF REGULATIONS
13. INABILITY OR UNWILLINGNESS OF AGENCY TO MODIFY REGULATIONS IN VIEW OF ALTERED CIRCUMSTANCES
14. LACK OF EFFECTIVE APPEAL PROCEDURE

SOURCE:

PREPARED BY: WAYNE BOUCHER, ET AL. (DRI), THE IMPACT OF EPA ADMINISTRATIVE PRACTICE ON THE INNOVATION PROCESS IN U.S. COMPANIES: A CASE STUDY OF REGULATORY BARRIERS TO INNOVATION, PREPARED FOR:NSF (CONTRACT NO. C860, 1/75).

TABLE B-2. THE "GIVEN" INCENTIVES

1. GUARANTEE BY AGENCY THAT IT WILL NOT CHANGE ITS RULINGS ON REGULATIONS FOR A SPECIFIED PERIOD

2. ESTABLISH MECHANISM FOR ACHIEVING COMMON INTERAGENCY INTERPRETATION OF REGULATIONS

3. CREATE THE OFFICE OF OMBUDSMAN SO THAT INDUSTRY CAN BETTER COMMUNICATE WITH REGULATORY AGENCIES

4. PROVIDE FOR FEDERAL COMPENSATION IN CASES WHERE REGULATORY DECISIONS SHUT DOWN A COMPANY OR DIVISION

5. ASSIST IN THE ESTABLISHMENT PUBLIC LAW AND ACCOUNTING FIRMS TO HELP FIRMS TO SATISFY OR TO TEST REGULATORY REQUIREMENTS FOR INTRODUCTION OF AN INNOVATION

6. ESTABLISH A VOUCHER SYSTEM TO ENABLE SMALL FIRMS TO OBTAIN OUTSIDE SERVICES REQUIRED TO COMPLY WITH REGULATIONS

7. INCREASE RELATIVE NUMBER OF TECHNICAL PERSONNEL ON AGENCY STAFFS

8. CONDUCT GOVERNMENT-SPONSORED REGIONAL SEMINARS FOR EXPLAINING NEW REGULATIONS

9. GRANT EXCLUSIVE PATENT RIGHTS TO FIRMS DEVELOPING NEW PRODUCTS UNDER GOVERNMENT CONTRACTS

10. CREATE REGIONAL GOVERNMENT-SPONSORED CENTERS WHERE BUSINESSMEN CAN BE TRAINED IN WAYS TO LEARN ABOUT AND COMMERCIALLY EXPLOIT NEW PRODUCTS

11. ESTABLISH A PROGRAM WHICH EMPLOYS CORPORATE EXECUTIVES FOR INTERIM PERIODS TO HELP ADMINISTER AGENCY REGULATIONS

SOURCE:

PREPARED BY: WAYNE BOUCHER, ET AL. (DRI), THE IMPACT OF EPA ADMINISTRATIVE PRACTICE ON THE INNOVATION PROCESS IN U.S. COMPANIES: A CASE STUDY OF REGULATORY BARRIERS TO INNOVATION, PREPARED FOR: NSF (CONTRACT NO. C860, 1/75).

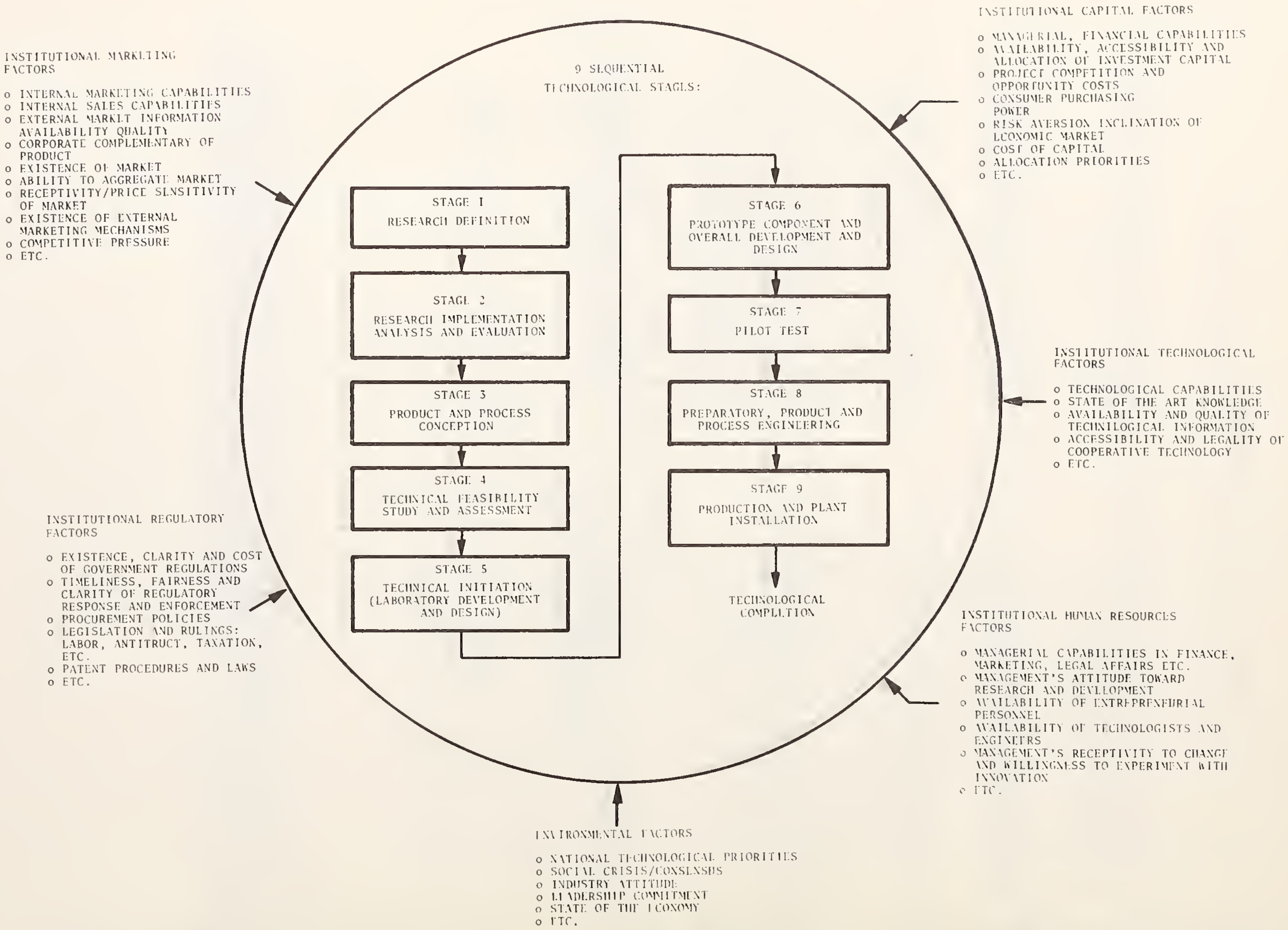


FIGURE B-1. THE SEQUENTIAL STAGES OF THE PRIVATE SECTOR INNOVATION PROCESS LEADING TO THE FIRST APPLICATION OF NEW TECHNOLOGY AND SELECTED INSTITUTIONAL AND ENVIRONMENTAL FACTORS

TABLE B-3. DISTRIBUTION OF OBSTACLES IN PRODUCERS' GOODS INDUSTRIES OF THE UNITED STATES

(Percent of Innovation Affected)

OBSTACLE CLASS	PERCENT OF OBSTACLES REPORTED PRODUCERS' GOODS n=200 ORIGINAL	 ADAPTED*
MARKET	26	32
TECHNOLOGY	11	14
MANAGEMENT	18	23
CAPITAL	16	20
ORGANIZATION	6	7
REGULATIONS	20	*
OTHER	4	4

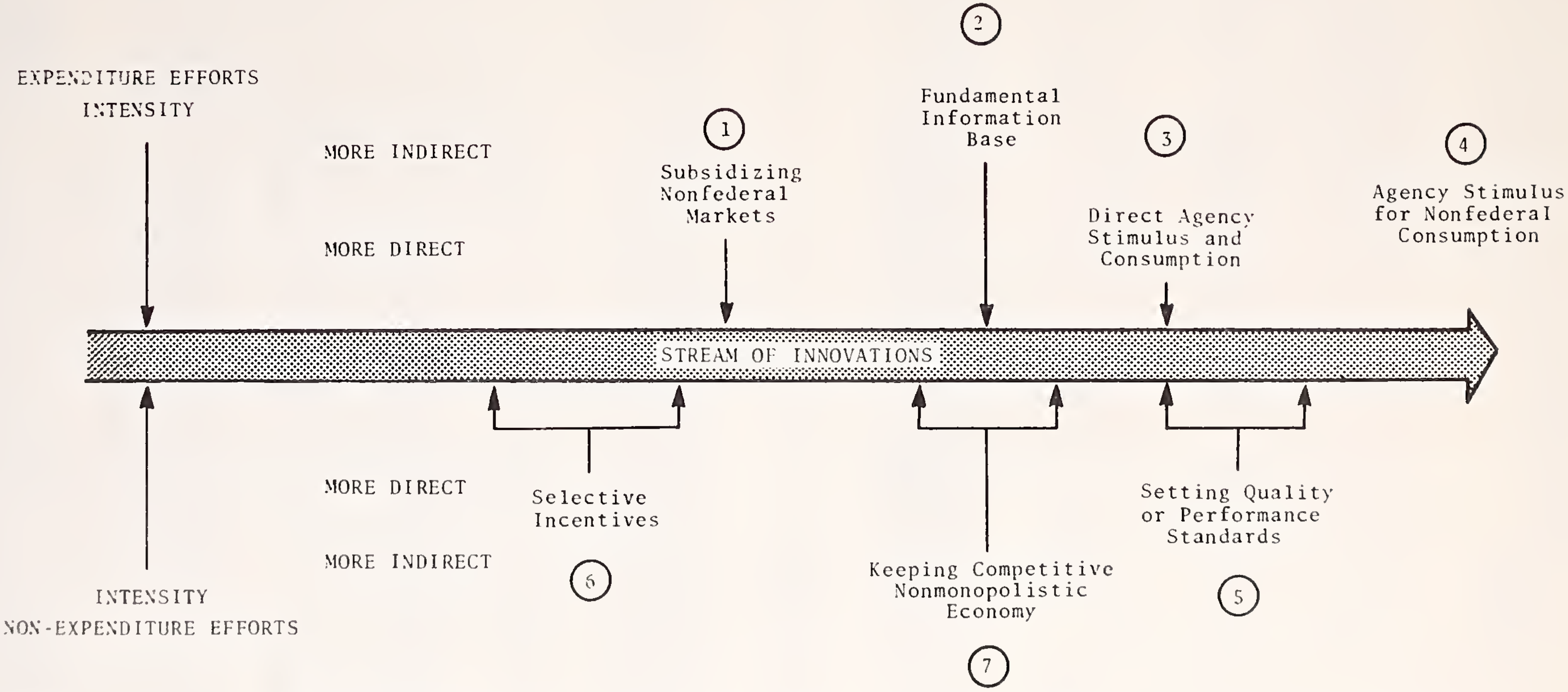
*Recomputed after excluding all regulatory obstacles

SOURCE: PREPARED BY E. SWEEZY AND JANICE HOPPER, OBSTACLES TO INNOVATION IN THE SCIENTIFIC AND TECHNICAL INFORMATION SERVICES INDUSTRY, PREPARED FOR NSF (CONTRACT NO. GN-42300, 10/76).

TABLE B-4. FACTORS RELATED TO THE COMMERCIAL SUCCESS OF TECHNOLOGICAL INNOVATIONS IN THE INDUSTRIAL FIRM

a) Level of profitability
b) Level of interdepartmental communication
c) Relative advantage of the innovation
d) Recognition of need
e) Degree of urgency of the problem
f) Level of project team communication
g) Availability of information about sales potential
h) Degree of uncertainity about Federal regulatory policies or future rulings
i) Financial risk
j) Level of top management support
k) Level of interaction with external sources of information: summary variable
l) Availability of information about the cost of gaining market acceptance and desired market share
m) Anti-trust complications in marketing
n) Availability of information about the characteristics of potential market
o) Degree of congruence with corporation's marketing goals
p) Estimated probability of market success
q) Level of project personnel authority
r) Level of resources available

SOURCE: PREPARED BY INNOVATIVE SYSTEMS RESEARCH, INC. A SPECIAL REPORT CONCERNING PROPOSITIONS AND VARIABLES FOR THE NATURAL EXPERIMENT, PREPARED FOR: INDUSTRIAL PROGRAMS OFFICE OF THE NSF, SUBMITTED JUNE 30, 1976.



SOURCE: Prepared by Charles Williams, et al. (Stanford Research Institute), Planning and Evaluation Assistance to the NSF Experimental R&D Incentives Program, prepared for: NSF (Contract URU-72-66, SRI Project 2291, June 1973).

FIGURE B-2. CLASSES OF FEDERAL GOVERNMENT INTERVENTION IN INNOVATION

TABLE B-5. FEDERAL FUNDING OF CIVILIAN RESEARCH AND DEVELOPMENT, SUMMARY OF FINDINGS

1. Federal R&D funding, absent a mix of supportive incentives and rewards, has not been efficient in achieving technological change in the private sector to any significant extent.

2. Federal policies for the support of civilian R&D are effective where procurement has leverage on adoption and utilization of the R&D products (as in Central Station Nuclear Power and Motor Vehicle Safety).

3. Federal funding for R&D is insufficient to offset regulatory constraints on civilian industrial innovation (as in biological pesticides--testing and registration; and as for all industry sectors in regard to patent policy).

<u>There is no feasible alternative to Federal R&D funding to produce major mass transportation technology changes such as the development of new systems.</u> Private industry is both unable and unwilling to make the large investments required for the following reasons:

1. The absence of a predictable, long-term market for its product.

2. Domination of the metropolitan area market by the Federal Government, combined with the fears of whether the Federal Government will continue to support qualifying products.

3. High costs of the R&D.

4. Low-volume market for new systems products.

Metropolitan areas are unable or unwilling to fund new systems R&D for the following reasons:

1. Lack of funds to undertake the R&D.

2. Lack of technical skill to supervise the R&D.

3. Unwillingness to assume R&D costs out of local budgets to meet nationwide transportation needs.

4. Uncertainty that any manufacturers would bid, given the market uncertainty and high risks.

SOURCE: PREPARED BY ARTHUR D. LITTLE, INC., <u>FEDERAL FUNDING OF CIVILIAN RESEARCH AND DEVELOPMENT</u>, VOL. 1: <u>SUMMARY PREPARED FOR EXPERIMENTAL TECHNOLOGY INCENTIVES</u> PROGRAM, U.S. DEPARTMENT OF COMMERCE (CONTRACT NO. 4-35956, NATIONAL BUREAU OF STANDARDS, FEBRUARY 1976).

TABLE B-6. KEY FACTORS AFFECTING THE SUCCESS OF THE TECHNOLOGICAL INNOVATION PROCESS

A. Factors related to both technical success (TCNSUC) and project success (PRJSUC)

1. Clarity in communication of project demands and responsibilities
2. Degree of effectiveness of communication among organizationally independent groupings
3. Level of dissatisfaction with cost
4. Frequency of contacts with customers
5. Level of probability
6. Level of interdepartmental communication
7. Relative advantage of the innovation
8. Recognition of need: summary variable

9. Degree of urgency of the problem
10. Level of project team communication
11. Rate of adoption of an innovation
12. Availability of information about sales potential
13. Clarity of performance requirements
14. Degree of success in meeting time schedule

B. Factors related to technical success (TCNSUC) only

1. Level of antonomous control
2. Degree of bureaucratization
3. Degree of success in meeting cost estimates
4. Occurrence of a feasibility demonstration
5. Level of dissatisfaction with internal forecasts
6. Maintenance of rate of growth
7. Response to government action or tariffs
8. Degree of management satisfaction with marketing information for a project stage transfer decision
9. Level of cooperation in the organization
10. Degree of use of outside technical/scientific advice
11. Level of dissatisfaction with price erosion
12. Reorientation required in the potential user's production process/organization
13. Amount of resources needed
14. Sufficiency of resources (dollars and manpower) allotted to the project
15. Firm's evaluation criteria relative to short-term payback over long-term opportunities
16. Availability of technical information
17. Degree of top management interest

TABLE B-6. KEY FACTORS AFFECTING THE SUCCESS OF THE TECHNOLOGICAL INNOVATION PROCESS (CONTINUED)

C. Factors related to project success (PRJSUC) only

1. Consumer and environmental safeguards
2. Degree of financial risk
3. Degree of uncertainity about federal regulatory policies or future rulings
4. Degree of goal congruence
5. Financial risk
6. Level of top management support
7. Level of interaction with external sources of information: summary variable
8. Ease of accommodation of the innovation by the user
9. Level of complexity/sophistication of the item
10. Importance of lack of top management support
11. Availability of information about the cost of gaining market acceptance and desired market share
12. Anti-trust complications in marketing
13. Degree of congruence with corporations's marketing goals
14. Availability of information about the characteristics of potential market
15. Estimated probability of market success
16. Level of explicitness of need
17. Recognition of needs: user-market origin
18. Level of project personnel authority
19. Level of project planning
20. Level of resources available
21. Degree of personal risk
22. Presence of a technological gatekeeper
23. Technical sophistication of the project

SOURCE: PREPARED BY ALBERT H. RUBENSTEIN, ALOK K. CHAKRABARTI, AND ROBERT D. O'KEEFE, FINAL REPORT OF FIELD STUDIES OF THE TECHNOLOGICAL INNOVATION PROCESS, PREPARED FOR: THE NATIONAL SCIENCE FOUNDATION (GRANT NO. DA-39470, SEPTEMBER 1974).

APPENDIX C

REPORT OF INVENTIONS

This report analyzes the effect of Federal actions on research and development of innovative technology in the automotive supplier industry. Although Barriers and facilitators of the innovation process are identified, these are not covered under the category of "new inventions"; thus, no new inventions occurred.

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