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FEDERAL STRATEGIES FOR INDUCING TECHNOLOGICAL INNOVATION IN THE AUTO INDUSTRY

BY

ROBERT RICCI

BRUCE RUBINGER

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PREFACE

With the conclusion of activity by the Federal Task Force on Motor Vehicle Goals and establishment of fuel economy standards for the years 1981 - 1984, the focus of attention has shifted from establishment of National goals to identification of efficient, equitable policies for achieving these objectives. Consideration of the process for inducing technological innovation (i.e. "how") has replaced discussion of future automotive goals (i.e. "what") as the number one policy issue.

The present document is intended to provide background information on the innovation process and the spectrum of alternative Federal strategies for achieving National automotive goals in the areas of safety, fuel economy and emissions. A narrative style has been adopted in order to simultaneously convey the latest thinking on the subject while providing a summary of the literature. Successive reports in this series will examine in detail the parameters of the innovation process, and describe case studies of particular auto innovations.

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EXECUTIVE SUMMARY

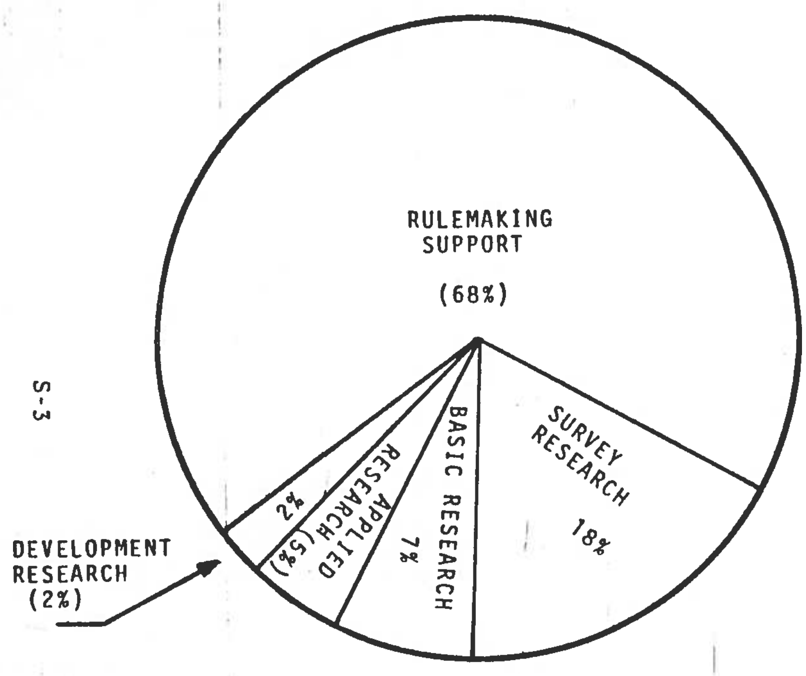
Federal efforts to bring about the development of socially beneficial auto technology have relied almost exclusively on regulations. Over the last decade, there has been an increase both in the number of vehicle attributes regulated, and in the degree of control the resultant actions have over the final product. Federal regulation of motor vehicles currently encompasses damageability, occupant protection, noise, fleet fuel economy, and emissions of hydrocarbons, carbon monoxide, and oxides of nitrogen. While there have been significant achievements in some areas (such as fuel economy), there have also been conspicuous failures. The litany of frequently cited regulatory flaws includes the absence of incentives for exceeding mandated standards, high administrative costs, obliviousness to vehicle integrity constraints, failure to make safety and emissions competitive variables, and lack of progress in the adoption of fundamentally new technologies. This critical questioning of motor vehicle regulations mirrors a broader national debate on the limits of traditional federal actions, and the need for a new policy approach.

The spectrum of potential federal strategies for promoting innovation consists of output oriented initiatives and process oriented initiatives. The former category includes regulatory actions, while economic incentives, institutional changes, information incentives, and R & D initiatives comprise the latter. Each strategy consists of a continuum of options, characterized by varying degrees of control over the final product. Thus, for example, regulatory actions range from government persuasion to technological standards, with product performance standards falling between these extremes.

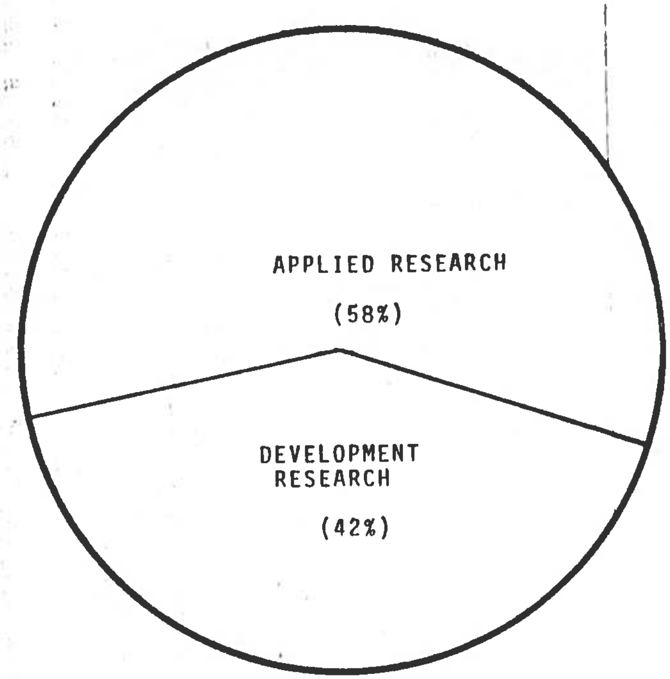
Examination of the innovation process reveals that technological change is brought about by two major forces, identified as technology push and market pull. The first force is a function of the knowledge environment, and can be modified through technology creation actions. Market pull on the other hand is derived from regulatory actions, economic forces, or changes in social attitudes. While these forces are necessary for initiating the innovation process, their presence is not sufficient to insure diffusion success. In general, technological innovation requires the convergence of six elements in addition to user need and a knowledge base; these are: an advocate or champion, existence of a strong industrial system for commercialization, inclusion of all parties needed for commercialization, availability of resources, favorable risk factors and favorable timing. Government incentives can support the innovation process by supplying or compensating for missing elements.

Among the process-oriented initiatives only R&D has been extensively employed. However, the majority of federal automotive R&D projects did not undertake the type of work which promises to advance technology. The R&D activity of the Department of Transportation is typical; here the major thrust has been information gathering and data analysis. In the area of safety this situation is even more pronounced, and the role of R&D has primarily been to support regulatory action. (See Fig. E-1.) Current federal R&D posture appears based on two underlying assumptions: (1) major technological innovations are required in such areas as engines, structures, transmissions and catalysts to achieve mandated fuel economy, safety, and emissions standards and (2) the industry has both the resources and motivation to pursue the necessary breakthroughs. At a time when the industry's technological skills and resources are strained to meet short term federally mandated goals, the validity of the latter hypothesis must be questioned. Futhermore, continuation of this policy carries several significant risks; (1) it leads to an emphasis on incremental innovation at the expense of more radical innovation, (2) the pace of innovation is largely determined by the regulated industry and (3) it fails to seek out and encourage innovations originating from non-industry sources.

A comparison of DOT's motor vehicle R&D funding patterns with those of the Department of Defense reveal fundamental differences.



NHTSA R&D ACTIVITIES



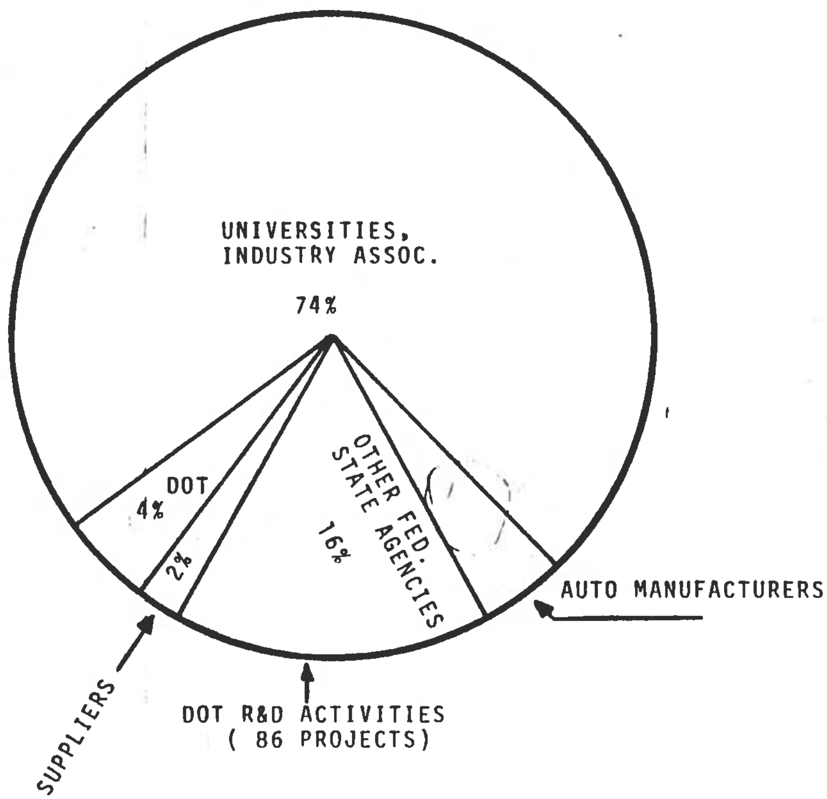
DOD R&D ACTIVITIES

FIGURE E-1 NATURE OF FEDERAL RESEARCH AND DEVELOPMENT

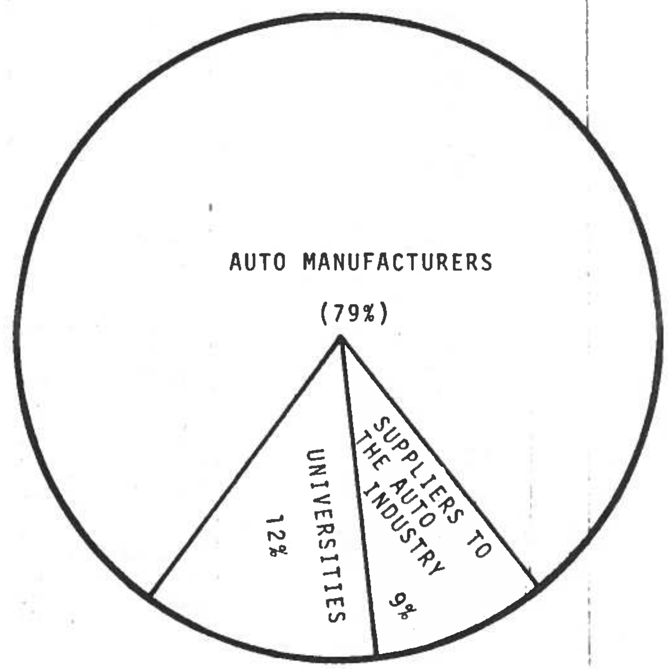
It is fair to say that DOD has the more extensive experience in successfully translating technological concepts into practice. This is reflected in an R&D posture which emphasizes larger projects and applied research. In contrast, close to 50 percent of all DOT sponsored projects were funded at levels below $20,000, which is appropriate for survey research but insufficient to achieve the critical mass needed for significant technological development. Another important difference was the performer of the research; most of DOT's automotive R&D effort (i.e., 74%) has been carried out by universities, research institutes, or other organizations not in the mainstream of the automotive sector (Fig. E-2). Since inclusion of all parties needed for commercialization is a basic tenet of successful technology transfer, the failure to involve the manufacturers and suppliers is disturbing. Work is needed to resolve the question of appropriate institutional involvement in the conduct of R&D, if future federal technology creation efforts are to be effective.

Efficient market behavior requires that both the buyer and seller understand the true costs and benefits of each transaction. Federal policies which support this process by lowering information acquisition costs or reduce information uncertainties can be very effective instruments for achieving national goals. This was demonstrated by the fuel economy labeling program which has been instrumental in making automobile fuel efficiency a competitive variable. The feasibility of using consumer education and information programs to promote other attributes, such as safety, reliability and life-cycle cost, should be investigated.

Information requirements also provide important guidelines for evaluating current and alternative policy options. Among the factors to be considered are: (1) the amount and type of information needed for establishing national goals and monitoring compliance, (2) the feasibility and cost of acquiring such data (3) quality of the available data, (4) sensitivity of the goal establishment decision-process to uncertainties in the data base and (5) the impact of the policy on uncertainties (e.g., technological,



DOT R&D ACTIVITIES
(86 PROJECTS)



AUTO MANUFACTURERS R&D ACTIVITIES
(33 PROJECTS)

FIGURE E-2 NATURE OF AUTOMOBILE R&D BY SPONSOR-PERFORMER cost, regulatory) faced by manufacturers and suppliers. Preliminary results suggest that optimal fiscal and informational policies require less information than mandatory product standards.

In a world of economic competition the use of markets and the price system as instruments of public policy would seem logical. Advocates claim market oriented solutions would harness individual self-interest for national benefit while minimizing reliance on coercion and cultural solidarity as motivating forces behind social change. They would shift the burden for making tradeoffs among competing private and social utilities from a centralized command-and-control module onto those (presumably) with the best information on costs and utilities. Simultaneously, the uncertainty faced by the private and public sector would be reduced and a continuing incentive to innovate is created.

However, with the exception of economic incentives oriented toward producers (e.g. capital depletion allowance) this approach has been given short shrift. Although economists claim that failure to employ the price system is a consequence of the domination of legislative bodies by lawyers, another important factor emerges from the literature. It appears that the prevailing attitude among lawmakers towards economic incentives reflects the ambivalence of the American public towards big business. While the high level of industrial efficiency is widely acknowledged, and the concept of minimum efficient size generally accepted, there is also a deep seated concern about potential abuses arising from such concentrations of power. This dischotomy appears throughout the literature on economic incentives; economists wax eloquently on the efficiency of markets while political scientists describe a "license to pollute." Work is needed to isolate the philosophic issues from the economic ones, and to identify efficient, equitable, economic incentives. Of particular interest is whether economic incentives can be identified which yield a significant national payback. An affirmative answer to this question would suggest a more aggresive federal posture is warranted. Attainment of national automotive goals is contingent upon our ability to create an environment which nutures innovation. Achieving this will require awareness of the limitations and strengths of traditional "centralized command centers" as instruments for social intervention, and the potential of process-oriented initiatives. It will be necessary that analysis supplant philosophy, and pragmatism replace dogmatism. However, by itself such insight will not bring about change. A new federal activism is required, incorporating such options as consumer education programs, information incentives, economic incentives, regulatory actions, technology creation projects, innovation centers, and elimination of institutional barriers. In essence, federal policy must become as innovative as the objective it seeks.

ITEM 1

WHY INNOVATION?

TO ACHIEVE THE NATION'S GOALS OF FURTHER REDUCTIONS IN FUEL CONSUMPTION, FATALITIES, AND EMISSIONS DUE TO AUTOMOBILE USE, IT IS NECESSARY TO ENCOURAGE THE DEVELOPMENT AND ADOPTION OF INNOVATIVE AUTOMOBILE TECHNOLOGY

EXAMPLES

- 40 TO 50 MPG FLEET FUEL ECONOMY
- CRASH SURVIVABILITY AT 50 OR 60 MPH
- 0.41 GMS/MILE FOR NO_x AND CONTROL OF CURRENTLY UNREGULATED EMISSIONS

BACKGROUND

1.0 TECHNOLOGICAL INNOVATION

"Technological innovation is the process by which an idea or invention is transformed to play a significant role in the economy."

Source: Michael Michaelis [Ref. 22]

1.1 NEED FOR INNOVATION

"SEC. 502. (a) FINDINGS. - The Congress finds that -

(1) Existing automobiles are inadequate to meet all of the long-term goals of this nation with respect to providing safety, to protecting the environment, and to conserving energy.

(2) With additional research and development, several advanced alternatives to existing automobiles have the potential to be mass produced at a reasonable cost with significantly less environmental degradation and fuel consumption than existing automobiles while remaining compatible with other requirements of federal law.

(3) Insufficient resources are being devoted to research and development of advanced automobiles and automobile components both by the federal government and the private sector.

(4) An expanded research and development effort into advanced automobiles and automobile components by the federal government is needed to increase such efforts by the private sector and encourage automobile manufacturers to seriously consider such advanced automobiles and automobile components as alternatives to existing automobiles and automobile components."

Source: Senate Bill S.499, [Ref. 28]

"There is a pressing agenda ahead, we should look forward as the horizon is etched with optimistic signs: Instead of crash survivability at 30 mph into a fixed barrier, protection should be available at 50 or 60 mph. Instead of 27.5 mpg, it is not unrealistic to seek forty or fifty.------it (the automobile industry) can use the most generous lead time now available to improve fuel economy and install air cushions, to do the right job and face up to its responsibilities to meet the challenge---.

'The era of innovation must replace the era of warmed-over soup in automotive design, especially innovation for the consumer."

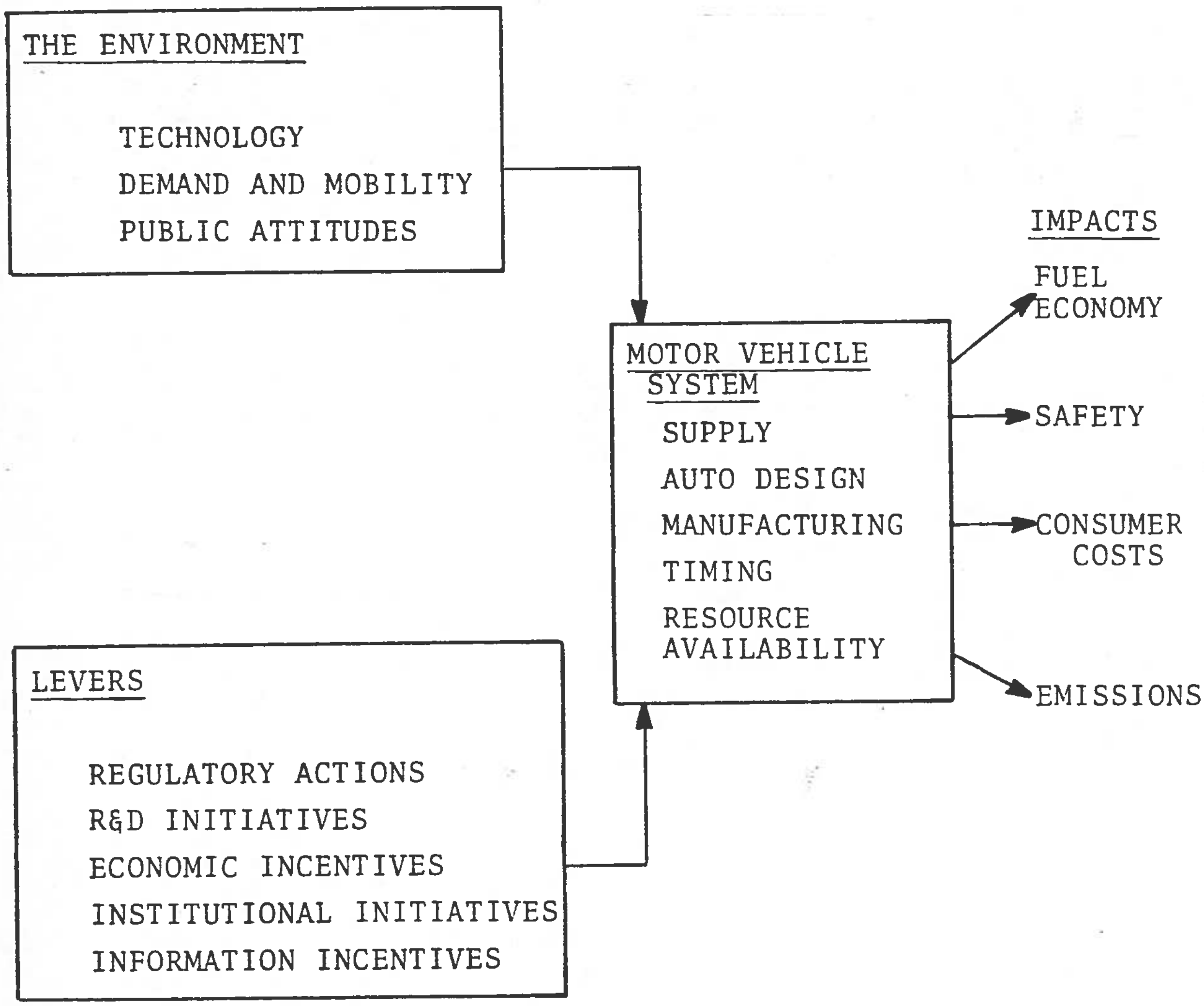
Source: Joan Claybrook, [Ref. 7]

"Innovation is generally regarded as essential to economic growth because it contributes importantly to increases in worker productivity, efficiency, and the competitiveness of the nation's products in the world markets. Innovation has special significance for the environmental movement because environmental laws often regulate technological change directly and because (in our opinion) the battle to improve environmental quality will not be won without healthy doses of innovation in both the products this nation produces and the processes through which they come into being."

Source: Nicholas Ashford and George Heaton, Jr. [Ref. 3]

ITEM 2

FORCES INDUCING INNOVATION



INNOVATION MODEL

2.0 FORCES INDUCING INNOVATION

"Conventional wisdom holds that technological innovation is a response to recognized demand or need. However, 'demand-pull' need not be the sole stimulant to innovation. 'Technological-push', though sometimes derided as 'solutions looking for problems', may be fully as influential!"

Source: Michael Michaelis [Ref. 22]

"The federal option to stimulate innovation and technological change seems to be jointly formed from three types of forces that the government influences directly or indirectly:

1. Federal support for research and development underlying technology creation.
2. Federal and state government regulatory intervention.
3. Market forces - a combination of change in societal attitudes and economic conditon.

Together with individual variations reflecting each auto manufacturer's attitudes, the manufacturer's response is in a sense determined by the equilibrium of the above forces."

Source: William J. Abernathy, [Ref. 2]

Evidence leads us to conclude that the possiblity of reward is the major force which induces firms in all industries to invest in research, development, and introduction of new technology. Kamien and Schwartz [Ref. 17] summarize their survey of the empirical economics literature on innovation as follows:

"...A picture of the relationship between resource allocation and technical advance, albeit fuzzy, does emerge from these studies. The quest for profit and devotion of resources does influence the rate and direction of inventive activity, despite the large role of serendipity and other goals motivating discovery.

Moreover, the relationship appears bidirectional, with the state of knowledge shaping and being shaped by profit opportunities and availability of resources..."

"If the prospect of profit induces firms to innovate, then the absence of profit would be an impediment to innovation."

Source: Hayden Boyd, [Ref. 5]

2.1 FACTORS NECESSARY FOR SUCCESSFUL INNOVATION

"Broadly speaking, technological innovation requires the convergence of six elements: (1) knowledge generated through R&D, (2) user need, (3) an advocate or champion, (4) availability of resources, (5) favorable risk factors, and (6) favorable timing. Government incentives can sometimes supply or compensate for missing elements. Where the need is high in national priorities, the incentive may be multipurpose, providing several elements, such as the resources needed as well as favorable risk factors."

Source: Michael Michaelis, [Ref. 22]

"Analysis of the case studies indicates that projects successful in innovation tend to have the following attributes:

1. *A technology well in hand.* Projects showing significant diffusion success were those in which the principal technological problems had been worked out beforehand.
2. *Cost and risk sharing with local participants.* The cases showing significant diffusion success involved nonfederal cost sharing, while those funded entirely by the federal government resulted in little or no diffusion.
3. *Project initiative from nonfederal sources.* Demonstration projects originating from private firms or local public agencies enjoyed greater diffusion success than did those directly pushed by the federal government.

4. *The existence of a strong industrial system for commercialization.* Diffusion proceeded more rapidly when there were obvious manufacturers and purchasers of the new technology, and when markets for similar products existed.

5. *Inclusion of all elements needed for commercialization.* Demonstrations showing significant diffusion success included in their project planning and operations potential manufacturers, potential purchasers, regulators, and other target audiences.

6. *Absence of tight time constraints.* Demonstrations facing externally imposed time constraints fared less well than did the others."

Source: Walter Baer [Ref. 4]

"The problems of successful technology transfer to mass production industries probably loom larger than those which arise in carrying out laboratory-oriented research work in the first place. Lessons from the aircraft and electronics industry, as represented earlier, suggest that innovative component developers must be intimately engaged in the process of successful system innovations. The whole question of appropriate institutional involvement in the conduct of R&D is a question worthy of close examination if the role of federal R&D is to be considered."

Source: William J. Abernathy, [Ref. 2]

ITEM 3

SPECTRUM OF FEDERAL STRATEGIES FOR PROMOTING INNOVATION

OUTPUT ORIENTED INITIATIVES	PROCESS ORIENTED INITIATIVES
REGULATORY ACTIONS	R&D INITIATIVES
	ECONOMIC INCENTIVES
	INSTITUTIONAL INCENTIVES
	INFORMATION INCENTIVES

BACKGROUND

3.0 NEED FOR A FRESH GOVERNMENT APPROACH

"Casual observation, the findings of opinion surveys, and the political rhetoric of the 1976 election campaign suggest that the public has become disenchanted with the ability of government, especially the federal government, to function effectively. During the 1960's the belief took hold that some kind of federal budgetary program or federal regulatory agency could be designed to deal with almost any social or economic problem – deteriorating central cities, juvenile delinquency, low reading scores of poorer children, rat infestation, unsafe lawnmowers, and inefficient police departments. Scores of programs were enacted to deal with such problems. This belief of a few years ago now seems to have been replaced by its polar opposite: most federal programs do not work well and consist principally of 'throwing money at problems.' In a similar vein, the rash of new regulatory mechanisms established in recent years – for pollution control, energy conservation, industrial health and safety, consumer-product quality and safety, and the like – have generated a backlash of resentment against excessive red tape and bureaucratic control.

There is a growing body of objective evidence that government is not performing its new tasks effectively. The counter-productivity of governmental regulation of transportation is well documented. Efforts to improve the environment, while far from a failure, are unnecessarily expensive and increasingly bogged down in Rube Goldberg regulations, legal snarls, and games between regulators and industry as enforcement deadlines draw near."

Source: Charles Schultze, [Ref. 27]

"While the nation's attention has turned to the need for new types of social policy, we have generally proceeded as if the legislative process and the techniques for governmental action suitable for an earlier set of problems could be carried over without change. But cleaning up the environment, relieving urban congestion and reforming the health care system are not the same kinds of tasks as building canals and highways and paying out social security benefits. And the legislative genius that finds ways to mold a coalition behind a piece of legislation, though still necessary, is no longer sufficient to devise the instruments of social intervention.

Throughout this study we have used the issue of environmental control to illustrate the failures of the traditional legislative approach to policy formulation and to suggest the kinds of changes that are needed. Our recommendations for reform can be briefly summarized. First, Congress can no longer get by on political skills alone. It must supplement those skills with staff resources competent to provide the technical and analytic help that is absolutely essential in dealing with difficult social issues. Second, the blunt instrument of central regulatory controls is not an effective legislative device to accomplish federal intervention in complex economic relationships. Far more than in the past, legislative action must emphasize the creation of new incentives and new institutions that harness the self-interest of individuals and business firms toward socially desirable goals."

Source: Allen Kneese and Charles Schultze [Ref. 18]

"As in most other areas of the private economy, the traditional pattern in our society has been to leave to private industry the task of researching and developing new product lines for sale in commercial markets. So long as markets function well, this pattern is rarely questioned, and indeed the great bulk of the R&D carried out in the United States takes place quite outside the direct concern of the Federal Government. However, problems arise when markets do not function properly -- when markets 'fail.' In the most general terms, this 'failure' occurs when the social evaluation of the costs and benefits of a particular action are not fully reflected in the private costs and benefits to which corporations and individual consumers respond, i.e., there are "externalities" involved. Where the incentives to private behavior are judged socially undesirable or inadequate, intervention by the government, as the agent of society as a whole, may be called for to correct the imbalance."

Source: L. Linden and D. Nerach [19]

"The Problem of Complexity

The design of public programs in the United States, especially outside the field of defense policy, is usually decided through an adversary process. On most policy issues there is a wide range of conflicting views reflecting the diversity of interests in a continental nation of 210 million people. The legislative process in the Congress is a marvelous device for negotiation, compromise, and ultimate reconciliation of views, so that on important decisions a large majority of the nation will be in agreement, or at worst not hostile to the ultimate outcome. The hearings, interest-group lobbying, back-room horsetrading, floor amendments, and conferences that characterize the way in which legislation is designed, are well suited to this purpose. Conflicting opinions on *what* goals public policy ought to set for itself are harmonized at the national level by these institutions of the Congress. As society becomes more complex and public goals more ambitious, however, technical problems of *how* government best goes about achieving its ends take on more importance. Deciding the magnitude of social security benefits or veterans' pensions or investment in national parks requires the reconciliation of divergent views, but imposes no major problems about the means of achieving the goals finally agreed upon. However, when the federal government sets about dealing with situations that are inherently complex, and that involve literally millions of interactions among individuals, state and local governments, and business firms, then *how* becomes as critical as *what*. Furthermore, since *how* can greatly influence costs, it becomes intermingled with the question of *what*."

Source: Allen V. Kneese and Charles Schultze, [Ref. 18]

"The net consequences of further Federal initiatives within the present narrow pattern may be to entrench current technologies, foregoing important energy options that are promised by alternative technologies."

Source: William J. Abernathy [Ref. 2]

"Federally funded civilian research and development is not sufficient to bring about technoloigcal change in the private sector to any significant extent."

Source: Michael Michaelis, [Ref. 22]

3.1 CRITICAL ISSUES*

A. Regulatory Actions

Do regulatory actions lead to incremental innovation at the expense of radical innovation?
How effective have past regulatory programs been in achieving their goals?
Would regulatory policies be more effective if they were formulated so as to be continually updated to reflect new information?
Are regulatory solutions better suited to certain classes of problems (e.g., air quality, safety, fuel economy) than others?
Under what circumstances are regulatory actions most efficient?
Who should regulate; the states, federal government or industries?
Relationship to collective bargaining?
Timing of implementation?

B. Economic Incentives

Can economic incentives work, or are they "just a license to pollute"?
Is it feasible to measure the cost of "externalities" and derive shadow prices?

*Source: Bruce Rubinger [Ref.26]

How effective have economic incentives been in those instances where they've been used? Are the results transferable to the motor vehicle sector?

Will the market provide stronger forces for innovation than other options?

How much should the federal government be willing to pay, through various economic incentive policies (e.g., subsidies, capital consumption allowance, foreign protection, etc.) to save a barrel of petroleum?

Will the reduction in competition resulting from a policy of import quotas retard or assist innovation?

Timing of implementation?

C. R&D Initiatives

If federal automotive R&D is undertaken, what areas should it focus on, e.g., applied research, survey research, rulemaking support, basic research?

Do direct technology creation actions play an important role in stimulating innovation?

What is the expected payoff from R&D initiatives?

What role can international R&D transfer play in innovation?

Should federal R&D go to a rich competitive industry while other industries (e.g., steel) flounder in obsolescence?

How should any results of federal R&D be shared, or even measured?

Timing?

D. Institutional Issues

Is some monopoly power necessary for innovation?

Do corporate attitudes towards risk rule out radical breakthroughs, and if so can this process be modified?

Are the lead time requirements for modifying complex systems incompatible with the time horizons of policy makers?

Are public perceptions of the energy crisis, auto passenger safety, and the air quality problem, consistent with the severity reflected in current and pending legislation?

State, local government and federal government relationship

Collective bargaining.

Current and projected business philosophy?

Projected changes in the overall structure of the automobile industry and in the corporate structure of individual firms

What are the sources of future innovations in the auto industry (e.g., suppliers, international R&D transfers, federal research programs)?

What are the most significant parameters of the innovation process (e.g., firm size, market concentration, character of industry, innovative input)?

Timing of implementation?

E. Information Incentives

Do information costs retard the introduction of innovative technology?

What are effective federal policies for lowering information costs and reducing information uncertainties?

Which vehicle attributes (e.g., fuel economy, safety, emissions, damageability) can be promoted with information incentives?

What information is required by congress, the manufacturers, and consumers to optimize policy, and is such information available?

Can information incentives achieve policy goals where external diseconomies exist?

Timing?

F. Integrated Incentive Policies

How should regulatory, R&D, economic, informational, and institutional incentives be combined for maximum effect?

Are technology creation or technology pull actions more important for innovation?

Should the vehicle attributes of fuel economy, safety, and emissions be regulated independently? For example, would it be more effective if a combined performance measure were used, which specified minimum performance requirements and allowed tradeoffs (e.g., superior fuel economy with some emissions degradations) among the attributes of interest?

Should anti-trust pressures against joint auto industry research undertakings be relaxed?

Timing?"

ITEM 4

REGULATORY ACTIONS

TECHNOLOGICAL STANDARDS
PRODUCT PERFORMANCE STANDARDS
VOLUNTARY PROGRAMS
MARKET FORCES ALONE

BACKGROUND

4.0 REGULATORY ACTIONS

"The array of possible government regulatory actions (shown in the accompanying figure) ranges from relatively weak persuasion to the fine detail of controlling the specific technology of a product through regulation. While the latter is potentially the most powerful option for immediately influencing product technology, its long-run effects on technological progress are still controversial."

Source: William J. Abernathy, [Ref. 2].

"The choice of regulatory form at this level determines the character of the detailed aspects of standard-setting and implementation. In the case of safety, it has not proved possible to define adequate standards which apply to the vehicle as a whole (though work goes on in this area), so the regulations consist of requirements for devices or design features which the regulatory agency can demonstrate are safer. In the case of emissions and fuel economy, on the other hand, it is possible to define numerical measures of performance (grams of pollutant emitted per mile, miles per gallon of fuel consumed) which can be related directly to national goals. Thus one determinant of differences in regulatory form is essentially a technical one: it may simply be impossible to define a reasonable performance standard for a whole vehicle or for the fleet."

Source: John Heywood, et. al. [Ref. 14].

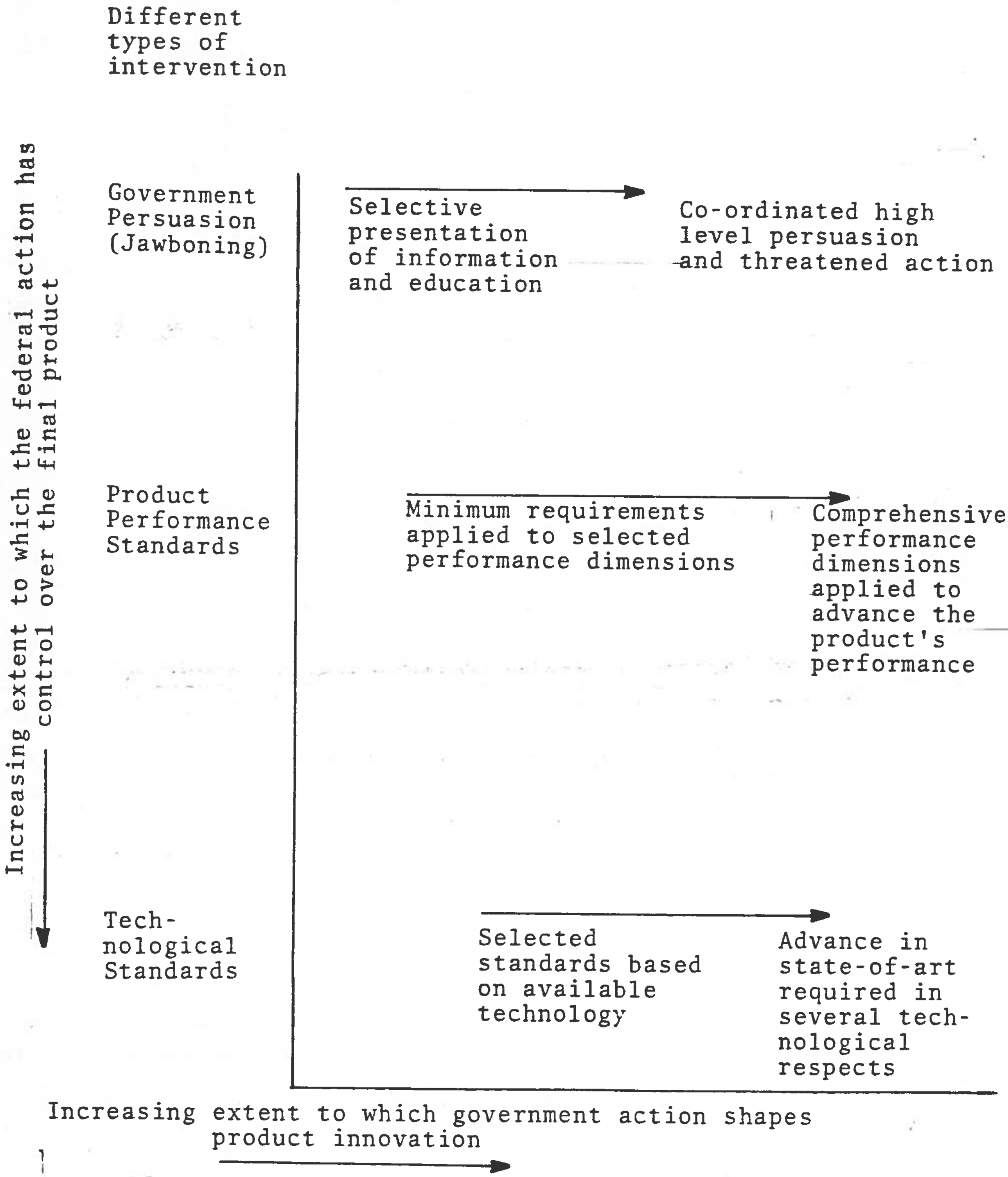


FIGURE 4-1. SPECTRUM OF FEDERAL REGULATORY ACTIONS

Source: William J. Abernathy, [Ref. 2.]

ITEM 5

R&D INITIATIVES

SIMULATION R&D
IN-HOUSE R&D
GOVERNMENT/INDUSTRY CO-FUNDING
INFORMATION EXCHANGE
NO GOVERNMENT R&D

5.0 R&D INITIATIVES

"The pattern of R&D investment does not seem sufficiently focussed in terms of resources committed, institutional context or technological objectives to bring forth fundamentally new technological concepts of automotive transportation which the U.S. may need in the 1990's and beyond. Coming at a time when the industry's resources are also diverted to immediate regulatory requirements, this issue looms as an important national problem."

Source: William J. Abernathy, [Ref. 2].

5.1 TYPES OF RESEARCH AND DEVELOPMENT

"One source of confusion in discussing R&D is the wide range of activities covered by this single label. It is ~~useful~~, therefore, to distinguish several sub-categories of activity that are important to the automotive industry...

Basic Research - The first category includes bench-scale laboratory work on scientific concepts and the associated theoretical research and mathematical modeling activities. In the automotive area, for example, this might include studies of the dynamics of flame propagation or the fundamental chemistry of catalysis. It is the type of work that takes place only at the most advanced scientific and engineering research laboratories.

Technology Development - Table 5.1 identifies five sub-categories of R&D that are relevant to technology development in a large-scale manufacturing industry. They are ordered in such a way as to indicate the sequential process by which knowledge and techniques evolve from preliminary concepts to large-scale commercial production. Naturally, no technical development (such as, a new engine design) actually moves in a purely sequential fashion, completing one level before proceeding to the next. But the table does show that these are distinct types of activity, and that latter stages cannot be carried out effectively (or will

TABLE 5-1

LEVELS OF ACTIVITY IN TECHNOLOGY DEVELOPMENT

Type	Nature of Activity	Where Performed
Applied Research	Exploration of scientific feasibility and problem solving directly or indirectly related to automotive technology -- including, for example, basic engine design and performance, emissions control, fuel economy improvements, alternative engine systems and alternative fuels.	Government laboratories, chemical and oil company laboratories, universities, R & D firms, vendors, and in auto industry research laboratories.
Exploratory Development	Proving technical feasibility of scientific concepts by building and testing a few engines, either on a dynamometer or in a vehicle.	Primarily in R & D divisions of auto manufacturers, also by oil companies, vendors, R & D firms, and to a limited extent by universities and government laboratories.
Advanced Development	Proving engineering feasiblity by building several engines and testing in serveral vehicles; and then making engineering changes in engine design, subsystems, or components to improve operating and emissions characteristics.	Primarily within the auto industry, as a necessary step in transfer of technology from R & D divisions to engineering divisions.
Engineering Development	Proving manufactureability and economic feasiblity, "soft tooling" and extensive testing of prototype vehicles with special attention to improving performance characteristics within cost constraints, making modifications that reduce production costs, and evaluating problems of marketability.	Within the engineering divisions of the auto manufacturers, with staff assistance from R & D and production divisions.
Product Improvement	Refinements made in the product which may add to marketing appeal (e.g., improved fuel economy) and/or and in reducing production cost.	Within the production divisions of the auto manufacturers, with staff assistance from the engineering divisions.

Source: John B. Heywood, et. al. [Ref. 14].

not be justified on economic grounds) without success in the earlier stages.

At one end of the scale is applied research, which takes place in a wide range of organizations. At the other end is product improvement, which encompasses the detailed day-to-day work of monitoring the performance of a mass-produced item, conducting R&D on minor corrections and improvements, and preparing them for introduction into the manufacturing process. This kind of work is carried out only by the production divisions of the manufacturing organizations themselves.

As a technical development proceeds down this chain, the amounts of money needed to conduct R&D increase dramatically. For example, exploratory development of a new engine concept might be done with a small laboratory and staff -- with a cost range per year between several hundered thousand and a million or so dollars, depending on how radical the concept. To carry out advanced development work, costs immediately jump into the several million dollars per year; for engineering development the costs jump again an order of magnitude. It has been estimated that to complete the advanced development stage for a new engine concept would cost about $10 million; to complete the next stage -- engineering development -- would cost an additional $50 million. As a new engine concept moves through these different phases, the activity tends to move to different parts of the manufacturing organization -- from research laboratories to engineering staff to production divisions. The closer the R&D comes to dealing with problems of manufacturing and marketability, the more heavily is the work concentrated within the automotive industry, because, of course, that is where the required expertise and experience is to be found.

Although a simple chart like Table 5.1 is a crude simplification, the table does suggest questions which should be asked of a program in alternative engine technology: First, where in the chain of research and development activity should the government program attempt to have its impact? And what level of resources does it take to make a contribution at that level? The sums of money required for advanced development or engineering development are large, as noted earlier, and what is achievable is therefore ultimately dependent on the overall size of the federal R&D program. Another consideration in evaluating the amounts of resources required is the existing level of industry expenditure in the area of concern. If the goal is to move beyond industry efforts in a particualar area, or to stimulate them, then clearly the resource commitments must be commensurate with existing (or former) industry programs."

Source: John B. Heywood, et al [Ref. 15]

TABLE 5-2. TYPE AND FOCUS OF FEDERAL AUTOMOTIVE R&D PROJECTS

TYPE OF RESEARCH	NUMBER OF PROJECTS SPONSORED BY FEDERAL AGENCIES FOR:							
	FUEL ECONOMY		POLLUTION CONTROL		PRODUCT SAFETY		TOTAL	
	No.	%	No.	%	No.	%	No.	%
Survey research	12	14	4	6.5	8	18	24	12.5
Basic research	8	9	11	18.0	3	7	22	11.5
Applied research	35	41	25	40.0	2	5	62	32.0
Developmental research	14	16	9	14.5	1	2	24	12.5
Research to support Fed. rule making	17	20	13	21.0	30	68	60	31.5
Total	86	100	62	100.0	44	100	192	100.0

"The above table shows that 44 percent of all federally-sponsored projects have not undertaken the type of work that promises to directly advance technology. Thirty-one percent of the projects supported federal regulatory efforts and the other twelve percent were for surveys of various types. The government has invested heavily in applied research (32 percent of all projects); virtually neglecting basic research. In terms of dollars, the emphasis is even more biased toward applied research since applied projects tend to be more expensive than basic research. In the area of safety, there seems to be a very strong emphasis on R&D to support regulatory action, as opposed to work that might more directly support innovation.

Of the government agencies supporting research, it is mainly the National Science Foundation, in its traditional role, that shows an interest in basic research. The major thrust of research and development by DOT has been to either sponsor R&D to back regulation or to undertake development work, most frequently to improve existing technology."

Source: William J. Abernathy, [Ref. 2].

"The vast majority of R&D projects have sought improvements based on technologies that are either currently in mass production or that rely on well-established concepts. A general idea of the project breakdown by the type of technology is provided in the table above."

"Over eighty percent of the projects supported by both NSF and DOT sought advances related to conventional technologies, in both categories above. Other government organizations, notably DOD, ERDA and EPA, sponsored a larger percentage of projects concerned with unconventional technologies. The automobile manufacturers and automobile supplier firms seem to have supported a larger percentage of projects related to unconventional technologies."

Source: *William J. Abernathy, [Ref. 2].

"It is clear from Table 5-4 that the Federal sponsorship of auto R&D has not included organizations

whether

To the extent that federal R&D programs intend to stimulate technological change in future cars, failure to involve major production firms in this process is of serious concern. The problems of successful technology transfer to mass production industries probably loom larger than those which arise in carrying out laboratory-oriented research work in the first place. Lessons from the aircraft and electronics industry, as represented earlier, suggest that innovative component developers must be intimately engaged in the process of successful system innovations. The whole question of appropriate institutional involvement in the conduct of R&D is a question worthy of close examination if the role of federal R&D is to be considered."

Source: William J. Abernathy, [Ref. 2].

5.2 TECHNOLOGY CREATION ACTIONS

"Figure 5-1 lists six different type of technology creation actions, arranged in an order that suggests differences in their characteristics. Six different types of actions from research (to define criteria) and needs (to direct production) are described along the left-hand side of the figure. The rank order of each action on the page is intended to roughly suggest the increasing extent to which the characteristics of the final product are determined by the specified type of R&D program. Stated another way, the order concerns how far the action takes the product concept toward "reduction to practice."

Basic research is shown as the most removed from product application while production or control over production quite obviously takes the concept closest to practice. The scale going across the page on the other hand shows the increasing extent to which government control over the action places the government itself in a position to shape the product innovation. This horizontal scale also reflects different intensities of government involvement within each type of action. For example, a demonstration program with a minor percentage of government funding or control may still not greatly influence the product, since the outcome will be shaped significantly by normal economic and market incentives. On the other hand, a demonstration program that is completely funded by the government, as depicted by the righthand extreme on the scale, represents a high degree of government control over the new product.

The criteria for rank ordering each possible government action and the intensity scale within each activity are obviously closely related. The step-like graph in Figure 5.1 illustrates this relationship. For different types of government action along a left to right downward sloping diagonal, down the vertical scale and towards the right on the horizontal scale, there is increasing governmental influence in shaping the final product.

FIGURE 5-1

TECHNOLOGY CREATION ACTIONS*

Nature of Govt. expenditures/ investments to create technologies		
Criteria and Needs Research (to identify research areas)	Information collection and analysis	Evaluating alternate areas of research
Basic Research and Advanced Development (Non-mission)	Education	Specific Research programs
Research and Development (to advanced relevant scientific and engineering concepts)	Individual performance sponsored on merits of each case	Sponsored on the basis of belonging to a mission-oriented project
Mission R&D Program (leading to prototype or feasibility model)	funding on the basis of each cases's risk/benefit profile	funding only certain prototypes, likely to fulfill desired performance goals
Demonstration Program	Co-sponsor with industry	completely sponsored by government
Govt. controlled Product Production	specifying product function	specifying product completely

over the final product

Government's Control in Shaping Product Innovation

Increasing control

Source: William J. Abernathy, [Ref. 2].

Other changes will also typically accompany the movement down the diagonal: whereas the action's influence on the product becomes more immediate and visible, the cost per program also grows significantly. In a sense moving down the diagonal from the upper left to the lower right of Figure 5.1 involves increasing government support for immediate technological change."

Source: William Abernathy [Ref. 2].

TABLE 5-3

TYPE OF TECHNOLOGY UNDERLYING R&D PROJECT*

	Projects with Fuel Economy Focus (%)	Projects with Emission Improvement Focus (%)
1. Improvements for current technology	61.0	72.1
2. Incremental advances based on current technologies	4.3	4.9
3. Different combustion technologies		
a) External combustion	2.4	5.7
b) Rotary engine	1.8	1.6
c) Turbine	4.9	7.4
4. Electric vehicle and related technology	11.0	4.1
5. Fuel research	13.4	4.1
6. Weight reduction by material substitution	1.2	
Total	100.0%	100.0%

*Based on analysis of projects in sample

TABLE 5-4

ANALYSIS OF AUTOMOBILE R&D BY

SPONSOR AND PERFORMER

Sponsor / Performer	NUMBER OF PROJECTS SPONSORED/PERFORMED IN THE PERIOD 1973-77					
	DOT	Other Federal & State Government Agencies	Auto Manufacturers	Suppliers to the Auto Industry	Universities, Industry Assoc. & Others	Total
DOT	3	2	0	0	0	5
Other Federal & State Govt. Agencies	14	31	0	0	0	45
Auto manufacturers	3	4	26	0	0	33
Suppliers to the auto industry	2	12	3	70	1	88
Universities Industry Ass. & Others	64	63	4	1	30	162
Total	86	112	33	71	31	333

5.3 APPROPRIATE DIRECTIONS FOR FEDERAL R&D EFFORTS

"Based on this description of the context in which Federal programs must operate, it is possible to draw some preliminary conclusions about the role that R&D activities might play in the alternative automotive powerplant area. Table 5.3 summarizes the taxonomy of objectives and R&D activities developed in this section. Across the top of the table are listed the four principal objectives of programs in this area; down the left side are listed the different types of R&D that are relevant to the automobile industry. The table indicates which of the different objectives are compatible with the various types of R&D activities.

...The greatest controversy in this area of government expenditures on automotive engine R&D surrounds the appropriateness of government attempts to advance the state-of-the-art or open new options in circumstances where no regulatory or procurement functions are directly involved. The crucial question here is the extent of the divergence between industrial and social interests. The fact that the standards and deadlines under the Clear Air Act have had to be adjusted to the levels achieved by the ICE, and will almost certainly continue to be adjusted in the future, implies that the incentives to industry to develop a low-pollution alternative powerplant are not as large as the potential benefits to society. There may, therefore, be a serious divergence of interests. On the energy side, the national benefits are not nearly as clear, but there is no reason to assume that the forces of the marketplace are commensurate with them. Therefore, as the preceding analysis has shown, there may be solid grounds for federal R&D even in the context of an industry that is committing significant resources to work of this type."

Source: John B. Heywood et al [Ref. 15]

"Finally, there was the question of who can carry out the work. For applied research and exploratory engine development, there are a variety of competent research institutions; with additional funds the capacity in these areas could be increased.

But when the work comes closer to the manufacturing process, then tradeoffs with other aspects of overall system design, the integration of the engine into a vehicle, extensive field testing, suitability of the design for mass production and marketing questions become important, and the expertise is more and more the province of the automobile industry. This means that the latter stages of R&D can only be done in a cost-effective way by the major automobile manufacturers themselves, or by other industries with similar close contact with this or a similar marketplace. This fact presents an inescapable dilemma to federal authorities in a circumstance where the R&D activity is closely associated with regulatory activity, as it is in the automotive case." (Also see Figure 5.1).

Source: John B. Heywood, et al [Ref. 15]

TABLE 5-5

APPROPRIATE DIRECTIONS FOR FEDERAL R&D EFFORTS

TYPES OF RESEARCH	OBJECTIVES: ADVANCE STATE-OF ART	SUPPORT PROCUREMENT	DATA FOR POLICY REGULATION AND PUBLIC INFO.	"LEVERAGE" ON PRIVATE EFFORTS
Basic Research	Appropriate		Not usually relevant	Not relevant
Technology Development				
Applied Research Exploratory Development	May be ap-priate when problems or options are not being explored.		Appropriate when information not or credibility questioned	
Advanced Development		All these types of research are appropriate to support procurement		Limited impact on industry R&D programs
Engineering Development	High cost, questionable		Unlikely to be appropriate	
Product Improvement	Not appropriate		Not appropriate	
Assessments and Impact Studies	Not usually relevant		Appropriate	
Performance and Emission Testing	Supports technology development		Appropriate	

Source: John B. Heywood, [Ref. 15].

ITEM 6

ECONOMIC INCENTIVES

TAX INCENTIVES
PROTECTION AGAINST FOREIGN COMPETITION
SUBSIDIES
INVESTMENT TAX CREDITS
LOAN GUARANTEES

BACKGROUND

6.0 ECONOMIC INCENTIVES

"A second reason for the failure to devise effective instruments of social intervention lies, we believe, in the reluctance of the Congress to use markets and the price system as instruments of public policy. The need for social intervention often arises because private markets are not working well--or because, as chapter 1 pointed out, they work with marvelous efficiency, but in the wrong direction. But rather than correct the price system-by levying effluent charges, for example--and thereby redirect incentives toward socially desirable ends, the Congress is most likely to reach for the old tried (if not true) remedies. In the case of environmental control this tendency led to emphasis on regulation and construction subsidies. And when this approach did not appear to be working well the response was simply to intensify it by increasing the power of the regulators and enlarging the grants, rather than by undertaking a basic reexamination of its efficacy."

Source: Allen J. Kneese and Charles Schultze, [Ref. 18].

"We acknowledge the power of economic incentives to foster steadily improving efficiency, and we employ it to bring us whitewall tires, cosmetics, and television sets. But for something really important like education, we eschew incentives. We would laugh if someone suggested that the best way to reduce labor input per unit of production was to set up a government agency to specify labor input in detail for each industry. But this is precisely how we go about trying to reduce environmental damage and industrial accidents.

Quite apart from the maximizing characteristics elaborated in formal economic theory, the buyer-seller relationships of the marketplace have substantial advantages as a form of social organization.

In the first place, relationships in the market are a form of unanimous-consent arrangement. When dealing with each other in a buy-sell transaction, individuals can act voluntarily on the basis of mutual advantage.

Market-like arrangements not only minimize the need for coercion as a means of organizing society; they also reduced the need for compassion, patriotism, brotherly love, and cultural solidarity as motivating forces behind social improvement. Societies seeking to achieve a high standard of living have three major options in organizing individual citizens toward that end: coercion (by democratic majority rule or authoritarian dictate), self-interest incentives, and what we might loosely call the "emotional" forces listed above. Every society relies on some combination of the three, but in the matter of emphasis there are vast differences. Maoist China is unique in placing its chips heavily on cultural solidarity and an encompassing egalitarianism. It is far too early to tell whether this approach will succeed, and what its costs will be. Far less than China, but far more than the West, Japan relies on cultural solidarity as a principle of social organization. In any event, cultural solidarity as a central organizing theme is hardly relevant for Western nations, especially the United States with its heterogeneous ethnic population. And, however vital they may be to a civilized society, compassion, brotherly love, and patriotism are in too short supply to serve as substitutes. Harnessing the "base" motive of material self-interest to promote the common good is perhaps the most important social invention mankind has yet achieved. Turning silk into a silk purse is no great trick, but turning a sow's ear into a silk purse does indeed partake of the miraculous. In the abstract we accept that view, but sometimes in discussing the specifics of social intervention we are loath to apply it. If I want industry to cut down on pollution, indignant tirades about social responsibility can't hold a candle to schemes that reduce the profits of firms who pollute. If I want drivers to economize on gasoline usage, advertising appeals to patriotism, warnings about the energy crisis, and don't be fuelish slogans are no match for higher prices at the gas pumps. In most cases the prerequisite for social gains is the identification, not of villains and heros but of the defects in the incentive system that drive ordinary decent citizens into doing things contrary to the common good."

Source: Charles Schultze, [Ref. 27].

"Probably the most important single feature of the regulatory system is that it utilizes mandatory standards applied to the particular attribute of concern, rather than a system of monetary incentives. Many analysts have claimed the superiority of "emissions taxes" over fixed standards, ever since serious analysis of environmental issues was first undertaken. In a world of economic competition, emissions charges could offer the incentive to attain economically efficient levels of control, so that the trade-off between pollution costs and costs of control is optimally made. A taxation scheme would offer a continuing incentive to install pollution control devices and modify motor vehicle designs, and, over the long run, to develop new automobile technology to replace that which evolved in an age when pollution was not important. The annual confrontations, where industry and government threaten each other with the dire economic consequences of quantum changes in emmissions levels, could be avoided."

Source: John B. Heywood, [Ref. 14]

"The policy ought to encourage both the adoption of existing technology which is socially efficient and innovation to create socially more efficient technology. While mandatory standards encourage changes in automobile attributes, they can stifle innovation. This is due to the great penalities associated with failures to meet the standards, if only by a small amount, and the lack of rewards for exceeding the standard, no matter by what amount."

Source: Hayden Boyd, [Ref. 5].

ITEM 7

INSTITUTIONAL STRATEGIES

CONSTANT EXAMINATION AND REVISION OF FEDERAL POLICIES TO REFLECT NEW DATA

FEDERAL PLANNING HORIZONS WHICH PROVIDE SUFFICENT LEAD TIME TO INDUSTRY

BETTER UNDERSTANDING OF THE INNOVATION PROCESS

IDENTIFICATION AND ELIMINATION OF POTENTIAL POLITICAL BARRIERS, (e.g., MORE FEDERAL, STATE AND LOCAL GOV'T COOPERATION)

ANTI-TRUST PHILOSOPHY

REVISE PROCEDURE FOR DETERMINING AUTOMOBILE INSURANCE COST

PATENT LAWS

TAX LAWS

GOVERNMENT - INDUSTRY "ADVERSARY RELATION"

BACKGROUND

7.0 INSTITUTIONAL ISSUES

"Institutions evolve to provide a structure within which a society's members can function. The relationship between a society and its institutions is both dynamic and interactive: institutions change in response to new elements of society, while evolving institutions can stimulate structural changes in the society. At any given point in time, however, institutions are likely to reflect the structure and elements of society predominating in the present or the recent past.

In this context, the major societal institutions of the United States clearly reflect a transportation-oriented society in which the internal combustion engine (ICE) vehicle predominates. Institutions appropriate to conventional vehicles, however, may create biases against alternative vehicle systems with significantly different characteristics.

... The institutional sources of bias specifically defined by the (Electric and Hybrid Vehicle Research) Act include taxes, regulations, traffic control, urban design, and rural electricity. To these were added federal policy and programs, automotive industry structure and a miscellaneous group most conveniently classified separately. Areas of impact at which bias might occur were classified in terms of the life cycle of automotive vehicles: manufacture and distribution, purchase and ownership, and operation. This analytical structure led to the matrix depicted below"(see Table 7.1)

<u>Source</u>: Norm Rosenberg, et al. [Ref. 24].

TABLE 7-1. INSTITUTIONAL FACTORS MATRIX

AREA OF IMPACT / SOURCE OF POTENTIAL BIAS	TAXES AND REGULATIONS	TRAFFIC CONTROL	URBAN DESIGN	ELECTRICITY SUPPLY	FEDERAL POLICIES AND PROGRAMS	AUTOMOTIVE INDUSTRY STRUCTURE & PRACTICE	MISCELLANEOUS INSTITUTIONAL FACTORS
1. VEHICLE PRODUCTION AND DISTRIBUTION	o FEDERAL MOTOR VEHICLE SAFETY STANDARDS o FEDERAL MOTOR CARRIER SAFETY REGULATIONS o AIR POLLUTION CONTROL LAWS o FEDERAL NOISE STANDARDS o STATE NOISE CONTROL				o AUTOMOTIVE RESEARCH	o ECONOMIES OF SCALE o CAPITAL REQUIREMENTS o IN-PLACE INFRASTRUCTURE o RESEARCH & INNOVATION o PRICING	o OPEC o INTERNATIONAL ENERGY PROGRAM o MATERIAL CARTELS o CAPITAL AVAILABILITY
2. VEHICLE PURCHASE AND OWNERSHIP	o REGISTRATION FEES/ LAWS o SALES TAXES o PROPERTY TAXES o INSURANCE LAWS o INCOME TAX DEDUCTIONS o CUSTOMS AND TARIFFS o RURAL ELECTRIFICATION ACT		o URBAN DENSITY o PARKING AND CHARGING FACILITIES	o UTILITY CAPITAL o UTILITY REGULATIONS	o FLEET PROCUREMENT PROGRAMS o ENERGY RESEARCH		o INSURANCE AVAILABILITY o FINANCING AVAILABILITY o OPEC o INTERNATIONAL ENERGY PROGRAMS
3-A VEHICLE OPERATION-FUEL	o MOTOR FUEL TAXES o EMERGENCY PETROLEUM ALLOCATION o UTILITY TAX o ENERGY POLICY AND CONSERVATION ACT			o UTILITY RATES o ELECTRICITY DISTRIBUTION INFRASTRUCTURE			
3-B MAINTENANCE	o LUBRICATING TAX o TIRE & TUBE TAX o POLLUTION CONTROL LAWS			o BATTERY EXCHANGE			
3-C OPERATING CONDITIONS	o MINIMUM SPEED LAWS	o HIGHWAY TRAFFIC SPEED o HIGHWAY ACCESS RAMPS o TRAFFIC LIGHT TIMING o PREFERENTIAL TRAFFIC LANES o TOLLS AND CONGESTION PRICING o VEHICLE SEGREGATION POLICY	o INTERMODAL PLANNING o ACCESS POLICY o COVERED AUTOMOBILE FACILITIES				

7.1 Current Institutional Environment

"Federal Policies and Programs

o Due to the Electric and Hybrid Vehicle Research, Development, and Demonstration (RD&D) Act (PL94-413) current and planned federal RD&D programs are biased in favor of electric and hybrid vehicles. Pending legislation may lessen or eliminate this bias.

o The present overall energy RD&D emphasis on electricity generation rather than synthetic liquid fuel development creates a bias in favor of electricity as the primary intermediate fuel source and therefore in favor of electric vehicle systems.

o The federal motor vehicle fleet procurement program, in its requirements for minimum initial cost, 19,300 km (12,000 miles) per year usage objective, and lack of comprehensive duty cycle information, has been biased against vehicles such as electrics with high first cost and modest performance capabilities, but potentially low life cycle costs. This historical bias, however, may be eliminated by the Electric and Hybrid Vehicle Act, which requires the introduction of electric and hybrid vehicles in appropriate federal applications at the earliest practical date.

Automotive Industry Structure and Practices

o Economies of scale, large capital requirements, and market demand uncertainties in the U.S. automotive industry create major barriers to entry for new domestic firms and restrict the ability of existing firms to introduce innovative technology. These factors slow the rate of technological change and therefore are biased in the short run towards the status quo.

o Economies of scale also favor vehicles and flexible performance capabilities to meet a variety of applications. Vehicles with major performance limitations (such as current EV's) are at a disadvantage because demand is too small to permit mass production.

o The automobile manufacturers' research and development programs heavily emphasize refinements and modifications to conventional technology. In several instances, however, manufacturers have reached the introduction stage for radical new technology and appear generally willing to make such introductions when justified economically. There is no clear evidence, therefore, of a long-term structural bias toward vehicles of particular characteristics.

Miscellaneous Factors

o In many foreign countries, high gasoline prices and population densities make electric and hybrid vehicles more attractive than in the United States. As a result, Western Europe and Japan have a greater incentive for electric vehicle technology development. Foreign R&D and marketing programs could well stimulate a more rapid introduction of electric vehicles in the U.S. under appropriate circumstances.

o Lack of investment capital creates a bias against the introduction of electric vehicles by new firms. This bias, however, is a consequence of the efficient functioning of capital markets in response to the risks such an investment would represent, and may be partially offset by the loan guarantee provisions of the Electric and Hybrid Vehicle Act. Moreover, existing firms, both within and outside the auto industry, could internally finance the introduction of electric vehicles if such an investment appeared profitable.

o Automobile loans made by banks and financing companies are based much more strongly on the credit worthiness and income of individual purchasers than on vehicle characteristics. But while the financing industry does not appear to be institutionally biased, current uncertainties about the resale value of electric vehicles can cause discriminatory practices by individual agents. In particular, loans for electric cars may be offered only to persons with high credit ratings, may require higher than usual down payments, and may require repayment over a shorter term than the average."

Source: Norm Rosenberg, et al. [Ref. 24].

7.2 Barriers to Innovation By Suppliers

A recent study of barriers to innovation by suppliers to the automobile industry found the following factors were most significant:

TABLE 7-2 Barriers to Innovation

BARRIER	NUMBER OF INNOVATIONS IN WHICH BARRIER ACTED	% OF TOTAL CASES
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 Intergrity 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%

> ..."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, the federal government could facilitate innovation if it made its regulatory actions more specific and tied in closer to project timing and and capabilities of suppliers. 2) Many respondents felt that the 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.

Source: Albert H. Rubenstein [Ref. 25].

7.3 Auto Industry Response to Safety Regulations

"In summary, there is no question but that the automobile industry has responded positively toward regulations imposed by the Vehicle Safety Act of 1966. Table 7-2 shows its current attitude toward the standards. Thirty of the 46 standards are considered 'good' or 'acceptable'; eight are 'questionable value'; only two are considered 'nuisances.' The industry had no opinion or felt it was too early to know the benefits/cost relationships for six of the standards.

A cursory examination of the standards considered by the industry to be of questionable or nuisance value indicates that the following conditions prevailed:

- o Promulgation was hasty and without significant R&D
- o Standard is of recent history.
- o Industry was not involved in the problem definition."

Source: Howard H. Bunch and Michael Kubacki [Ref. 6].

7-

TABLE 7-3. INDUSTRY APPRAISAL OF MVSS STANDARDS VERSUS THE DEVELOPMENT SOURCE.

Development Source	Industry Appraisal (number of standards)					
	Good	Acceptable	Questionable	Nuisance	Unknown	Total
Government	21		5	2	5	33
Industry	4		1			5
Other	4	1	2	_	1	8
Total	29	1	8	2	6	46

ITEM 8

INFORMATION INCENTIVES

IDENTIFY FEDERAL POLICIES WHICH LOWER INFORMATION ACQUISTION COSTS AND REDUCE INFORMATION UNCERTAINTIES.

EVALUATE ALTERNATIVE POLICIES IN TERMS OF THEIR INFORMATION REQUIREMENTS

-- FUEL ECONOMY LABELS

-- MANDATORY CRASHWORTHINESS RATINGS

-- LIFE CYCLE COST DATA, ETC.

BACKGROUND

8.0 INFORMATION INCENTIVES

"Once the decision to intervene has been taken, there remains a critical choice to be made: should intervention be carried out by grafting a specific command-and-control module--a regulatory apparatus--onto the system of incentive-oriented private enterprise, or by modifying the informational flow, institutional structure, or incentive pattern of that private system?

..Market transactions cannot be an efficient method of organizing human activity unless both the buyer and the seller understand the full costs and benefits to them of the transactions they undertake, including any side effects that impinge on their own welfare. If, for example, the legal principle of caveat emptor prevails, consumers are responsible for judging the reliability and safety of the products they buy. If, at reasonable costs in time, money, and mental effort, they can acquire and interpret information about the quality of products, then safer and more reliable brands will command a premium over dangerous and less reliable products. The premium will reflect judgments by consumers about the value to them of safety and reliability. Producers in turn will find it profitable to push safety and reliability up to the point at which the costs of doing so begin to exceed the premium; in short, an efficient outcome will be assured.

..One concomitant of growing affluence has been the introduction of complex and potentially dangerous consumer products--power tools, power lawnmowers, microwave ovens, powerful drugs, and so forth. In making a one-time purchase of such items the individual consumer is hard put to acquire and interpret information about their safety characteristics. The experiences of friends and neighbors are helpful but such anecdotal evidence is likely to be imperfect or misleading. Although commercial testing firms conceivably could fill this gap, there is an inherent limitation to the efficiency of developing and disseminating information on consumer products in this way. The overhead costs of buying and testing consumer products in sufficient numbers to give reliable results are quite large. Models proliferate and are likely to be changed frequently. As a consequence, the subscription price that a private testing firm has to charge to cover the costs of its services is apt to be so high as to discourage its widespread use. Government-sponsored research and testing, or labeling requirements, may be needed to overcome the high costs of information."

Source: Charles Schultze, [Ref. 27].

"We contend that alternative regulatory policies exist, placing greater reliance on market forces, product information and fiscal incentives, which are more likely to lead to the development and introduction of socially more efficient automotive technology than present mandatory standards. These alternative policies shift more of the burden for tradeoffs among competing private and social utilities onto those with the best information on costs and utilities, manufacturers and their customers, while providing proper incentives in those instances where market incentives do not fully reflect gains and losses to society as a whole.

..Not only must the policy mechanism allow for tradeoffs among utilities, but the information needed to calibrate the regulation to bring about an improvement in social welfare should be reasonable in extent and cost. Optimal policy must achieve the desired social results at least cost, and also maximize net benefits.

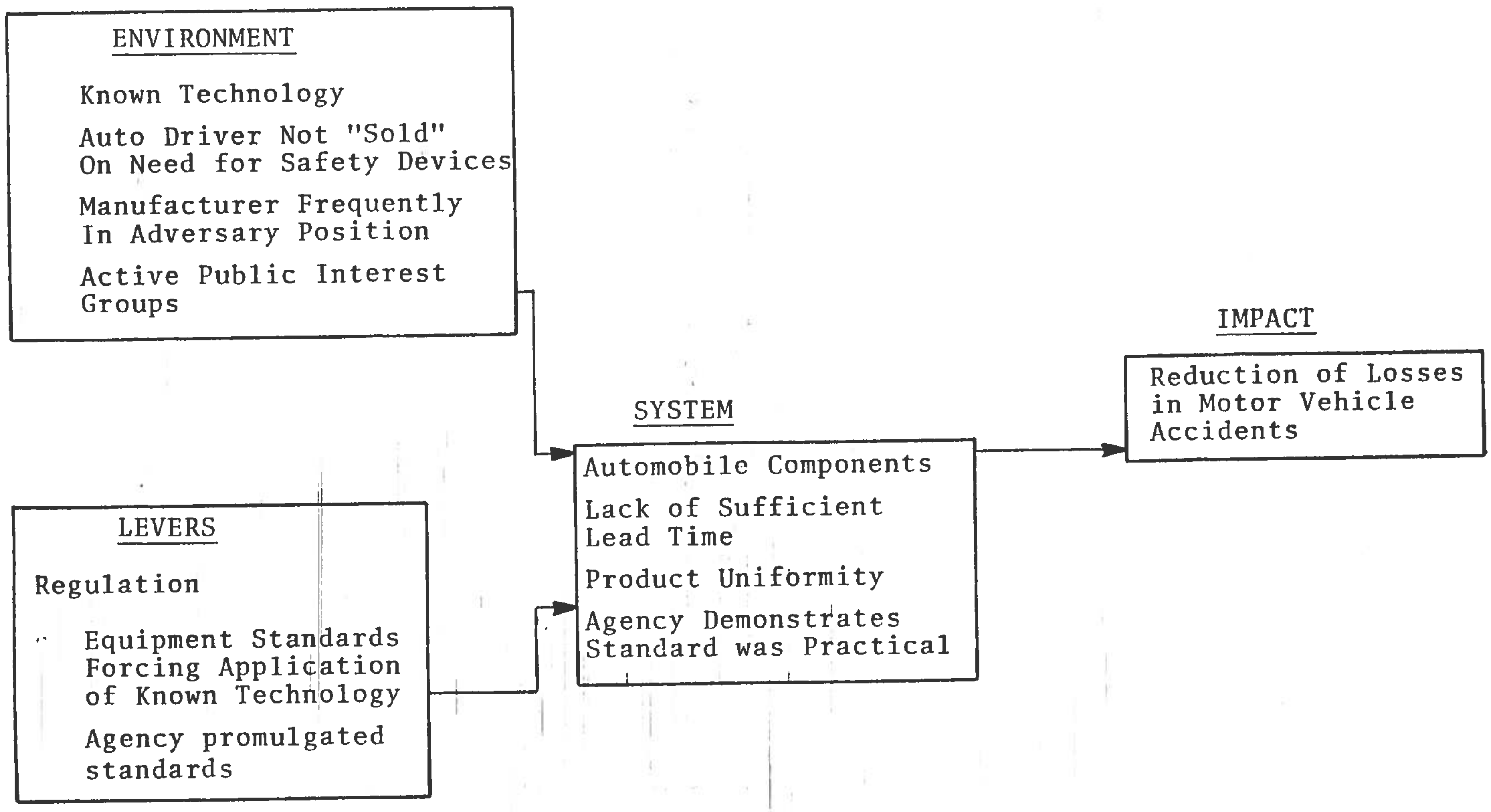
If Congress or an administrator were in possession of complete information about the full range of consequences of different kinds and levels of mandatory standards, then it would be feasible to design an optimal set of standards. Since public officials are not omniscient, policies ought to consider information requirements needed to optimize or come reasonably close to an optimum policy. We argue below that optimal fiscal and informational policies require less information than mandatory product standards.

..The policy ought to reduce, not increase, uncertainty faced by the public and private sectors. Uncertainties faced by policy makers include the cost and other effects of different levels of the policy, such as the effects on automobile prices and consumer acceptability, and the effects on such social goals as reducing fuel consumption, accident deaths and injuries, and air quality. Uncertainties faced by manufacturers include costs of new technology, consumer acceptance, and the nature and magnitude of future regulations. Uncertainties faced by consumers include operating costs, performance, and other attributes of the automobile. Policies can be designed to reduce these uncertainties, rather than to exacerbate them."

Source: Hayden Boyd [Ref. 5]

ITEM 9

SAFETY



BACKGROUND

9.0 SAFETY

9.1 THE NATIONAL TRAFFIC AND MOTOR VEHICLE SAFETY ACT OF 1966

Safety standards were selected as the way to deal with motor vehicle safety. The preface to the act states:

"To provide for a coordinated national safety program and establishment of safety standards for motor vehicles in interstate commerce to reduce accidents invovling motor vehicles and to reduce the deaths and injuries occurring in such accidents."

In Section 102, the use of performance standards rather than design standards was specified:

"A minimum standard for motor vehicle performance, or motor vehicle equipment performance, which is practicable, which meets the need for motor vehicle safety and which provides objective criteria."

9.2 SAFETY IMPACTS

"In terms of stated goals, i.e., reduction of loses in motor vehicle accidents, it is not possible to demonstrate conclusively that the program has been effective."

"Because of the emphasis on performance standards and the difficulties of writing such standards, research is directed at components rather than systems."

"The federal government program of R&D is based on a policy of rapid introduction of existing technology."

Source: Michael Michaelis [Ref. 22].

"Safety features found on autos made this year (1977) coincide closely with ones that could be found on 1968 models."

"Source: P. Orange and L. Linden [Ref. 23].

Bunch seems to support the auto manufacturers' contention that the time available for implementing a federal standard often fails to adequately consider the complicated procedures that industry must follow to introduce change efficiently in the production of cars.

Specifically:

"Explanations of lead time requirements are the most common responses of motor vehicle manufacturers to proposed standards. Often these explanations are minutely detailed and quite lengthy. Their schedules are important to them. Indeed, one almost gets the feeling that manufacturers would have no objection to any standards as long as they were given adequate lead time.

Related to lead time objections were responses that sought a more lenient standard. Manufacturers rarely claim that a proposed standard is impossible to meet. Rather, they relate changes to the time required to effect them. A small change could be made more quickly than a large one. This means they are oftem more interested in the effective data of a proposed standard than the standard itself. They tend to look at the date and decide what they can do within that time, rather than look at the proposed standard and determine when they can comply with it as written."

Source: Howard Bunch and Michael Kubacki [Ref. 6].

TABLE 9-1.

Laws Regulating Product - Performance in the Auto Industry

Safety

1963-Roberts Bill - requiring cars bought by the Federal Government to meet safety standards (P188-515).

September 9, 1963-National Traffic and Motor Vehicle Safety Act (PL89-563).
Required the establishment of interim federal motor vehicle safety standards by January 31, 1967 and revised standards one year later to be effective on all new cars within 180 days to one year after publication. Included also a fire safety program.

January 31, 1967 National Traffic Safety Agency issued 20 auto safety standards for 1968 models.

October 13, 1967 Transportation Secretary Boyd made public 47 proposals to broaden existing safety standards: 18 standards to become effective on Jnauary 1, 1969 and 29 to become effective after that date.

March 18, 1970 Transportation Secretary announced his intention to require installation of air bags on the dashboard facing the front passenger seat as of January 1, 1972 (subsequently postponed date to January 1, 1973).

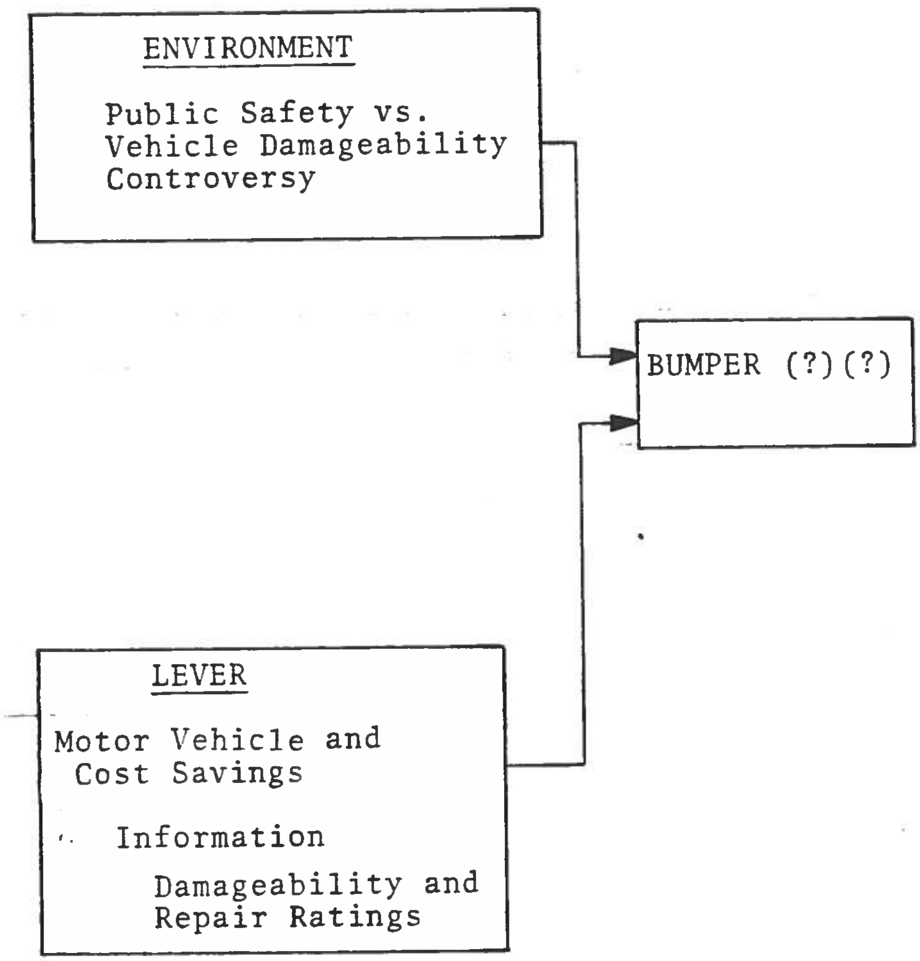
September 29, 1971 Douglas Toms, Administrator of NHTSA announced a modification of the passive restraint standard Air bags would be required for all seating positions on the 1976 models. Seat belts, under the new version, would have to be buckled before the car would start on 1974 models.

October 1972 Motor Vehicle Information and Cost Saving Act (P192-513) - new bumper standards to reduce low speed collision damage

October 1974 Motor Vehicle and School Bus Safety Amendments (PL93-492) - Required that manufacturers repair safety-related auto and fire defects free of charge to the owner. Stipulated that ignition-interlock system for seat belt would no longer be mandatory.

ITEM 10

VEHICLE DAMAGEABILITY



BACKGROUND

10.0 VEHICLE DAMAGEABILITY

Legislation

- o Motor Vehicle Safety Act (1966)
- o Motor Vehicle Cost Savings and Information Act (1972)

NHTSA General Council John W. Barnum, discussed the Department of Transoportation's position on the Motor Vehicle Information and Cost Savings Act in a letter to Casper Weinberger, Director of the Office of Management and Budgets [Ref. 22]. In this transmittal DOT recommended against a veto but noted that the provision of the bill:

> "would result in the diversion of personnel and other resources currently devoted to the motor vehicle safety programs unless sufficient additional funding and personnel were provided. Such diversion would be completely unacceptable given the relative value of lost life and a dented fender."

The letter went on to state:

> "Second, government intrusion into the marketplace should be limited to matters of necessity involving public health and safety. Nuisance problems associated with consumer products, such as vehicle damageability, would be most appropriately solved by marketplace processes, aided as necessary by a government information program."

Summing up this situation, Michaelis noted:

> "It is clear that there is considerable controversy over the importance to be placed upon nonhuman loss aspects:

Source: Michael Michaelis [Ref. 22].

ITEM 11

EMISSIONS

ENVIRONMENT

- o Forcing Technology
- o Environmental Groups
- o Public concern Air quality
- o No Individual Demand

SYSTEM

- o Constant Delay
- o More Resources Needed by Manufacturers
- o Manufacturers Demonstrate Technology not Available
- o Incremental Technical Change

IMPACT

- o Reduction of Emissions
- o Health Consequences

LEVERS

Regulation

- o Vehicle Performance Standard
- o Congress Dictated Standards

BACKGROUND

11.0 EMISSIONS

Regulatory Action

"For the first time standards of performance were set by the Congress........ The fact that the burden of proof was on the manufacturer (to demonstrate that the technology was not "available") and not on the regulatory agency (to demonstrate that the standard was "practicable") made a great difference........ The effects from the changed procedure include more resources invested in active research by the manufacturers to meet the standard (as compared to resources invested in arguing with the agency proposals) and a more aggressive implementation of the standards by the agencies which are in a position to demand progress from manufacturers.:

"In fact, a major flaw in the safety and emissions regulatory systems is their inability to stimulate, or even accept, major technological innovations,"

Source: L. Linden and D. Iverach [Ref. 19].

EMISSIONS IMPACTS

"At each delay, interim standards of increasing stringency have been established. Thus, while the attainment of the original goals remains elusive, substantial progress in controlling new car emissions have been made."

Source: L. Linden and D. Iverach [Ref. 19].

TABLE 11-1

LAWS REGULATING PRODUCT PERFORMANCE IN THE AUTO INDUSTRY

Exhaust Emissions

1965 Motor Vehicle Air Pollution Control Act (PL89-272) Authorized Secretary of HEW to set standards limiting amount of pollutants that could be contained in auto emissions. Prohibited domestic sale of engines not conforming to standards.

1967 Air Quality Act (PL90-148) Research on pollution caused by fuels combustion including auto emissions.

December 5, 1969 Air Quality Act Amendments (PL91-137) Research on control of air pollution.

December 31, 1970 Clean Air Act Amendments of 1970 (PL91-604). Provided that model year 1975 cars must emit 90% less carbon monoxide and hydrocarbons than model year 1970 cars. Nitrogen oxides in 1976 model cars must be reduced 90% compared with model year 1971.

March 27, 1973 Clean Air Act Extension (PL93-15) Authorization for air pollution and auto emission control programs established in 1970.

June 22, 1974 Energy Supply and Environmental Co-ordination Act of 1977 (PL93-319) Delayed CO and Hydrocarbon emission standards until September 30, 1977 and final standards for nitrogen oxides until September 30, 1978.

ITEM 12

INDUSTRY RESPONSE TO FUEL ECONOMY STANDARDS

JULY, 1975

"THE 1985 28 MILES PER GALLON CANNOT BE ACHIEVED THROUGH TECHNOLOGICAL DEVELOPMENTS....THE VAST MAJORITY OF OUR CARS WOULD HAVE TO BE THE SIZE OF THE VEGA OR OUR NEW SUBCOMPACT [CHEVETTE]."

E. M. ESTES, PRESIDENT OF G.M.

JULY, 1977

"..WE WILL BE ABLE TO MEET THE FUEL ECONOMY AVERAGES IN THE 1980'S AND STILL PROVIDE A REASONABLE MIX OF ATTRACTIVE VEHICLES..."

E. M. ESTES, PRESIDENT OF G.M.

BACKGROUND

12.0 FUEL ECONOMY

"The current and projected improvement in U.S. automobile fuel economy is truly an American success story. Of course, its success is a relative one, made larger by past failures in U.S. automobile innovation and by the present disappointment with other U.S. initiatives in energy production and conservation. But in the development of the EPCA, in its administration, by DOT/NHTSA, and in its physical implementation by the U.S. auto industry, American institutions have demonstrated the ability to adapt constructively to a practical problem of immense importance. The law, and the U.S. automakers, now state that the new automobiles of model year 1984 will, on average, go twice as far (27 miles) on a gallon of fuel as did the new cars of 1973. And these 1984 cars will be far safer, cleaner, and less expensive to repair and maintain. This success may not be sufficient, but it is immense and relatively assured."

Source: P. Coonley and J. Horrigan [Ref. 8].

However, the public debate on the "success" of the Energy Policy and Public Conservation Act is far from over. Statements, such as the ones below, challenge the ability of the automobile industry to reach fuel economy goals:

"From the data on past regulations it is probable, for instance, that the fuel economy legilsation requiring 27.5 miles per gallon in the new car fleet will not be fully realized." February 1977.

Source: Eugene Goodson, [Ref. 10].

"Analysis by the Congressional Budget Office indicates the automobile industry will produce cars that average 23.3 miles per gallon in 1985." March 1977.

Source: Alice Rivlin, [Ref. 12].

On the other hand, the automobile industry has undergone a radical change in its predicted capabilities. In March 1977 industry representatives argued the following:

"Plans to meet this schedule in Ford's view include an unreasonable risk."

Ford Motor Co.

"We would use technology we believe is feasible, and with that technology we are not able to get up to the 27½."

General Motors Corp.

"You are assuming going to 27.5 by 1985. Just with class 1 improvements, we do not believe you can obtain those numbers."

American Motors Corp.

"It would be as low as 23 miles to the gallon if we are meeting emission standards of 4 tenths, nine, and one by 1985."

Chrysler Corp.

Source: Hearings [Ref. 12]

By July of the same year, however, opinions had changed. When, at the Senate Hearings on Automobile Fuel Economy, Senator Adlai Stevenson asked the following question:

> "In order to try to clarify this situation once and for all, will all the autombile companies be in compliance with the 1985 standard and all of the interim standards?"

the U.S. firms, facing the possibility of higher civil penalties and for a 'gas-guzzler tax' responded in the affirmative.

> "I can speak for Ford Motor Co., the answer is:
> "Yes, we will."

Herbert L. Misch, V.P. Environment
and Safety Engineering Staff,
Ford Motor Co.

> "...We will. We have to. We have to meet the average fleet fuel economy standards that are set for these years.
> ...So we are never going to schedule the cars that put us in a position so we won't meet the average fleet fuel economy.

We just won't build them."

S.L. Terry, V.P., Public Responsibility and Consumer Affairs, Chrysler Corp. (p. 55)

"We will meet the standards. Our problem is whether we are going to meet it with a marketable line of products."

Henry L. Duncombe, Jr., V.P. and Chief Economist, General Motors Corp. (p. 57)

"Well, there is no question, as far as American Motors is concerned, too, Mr. Chairman, that we will meet the standards."

Frederick Stewart, V.P., Governmental Affairs, American Motors Corp. (p. 5)

Source: Hearings [Ref. 13].

"We had to determine on our own that the manufacturers could meet these standards and go to 27.5 miles per gallon. It was based on a tremendous effort that was started way before I came to DOT to analyze the technological feasibility and economic practicability of complying with these standards. In terms of whether the manufacturers have come to us and said, yes, we can do this, or whether they told us during the course of the rulemaking, no, they didn't. They have subsequently told you that they intend to meet the standards.

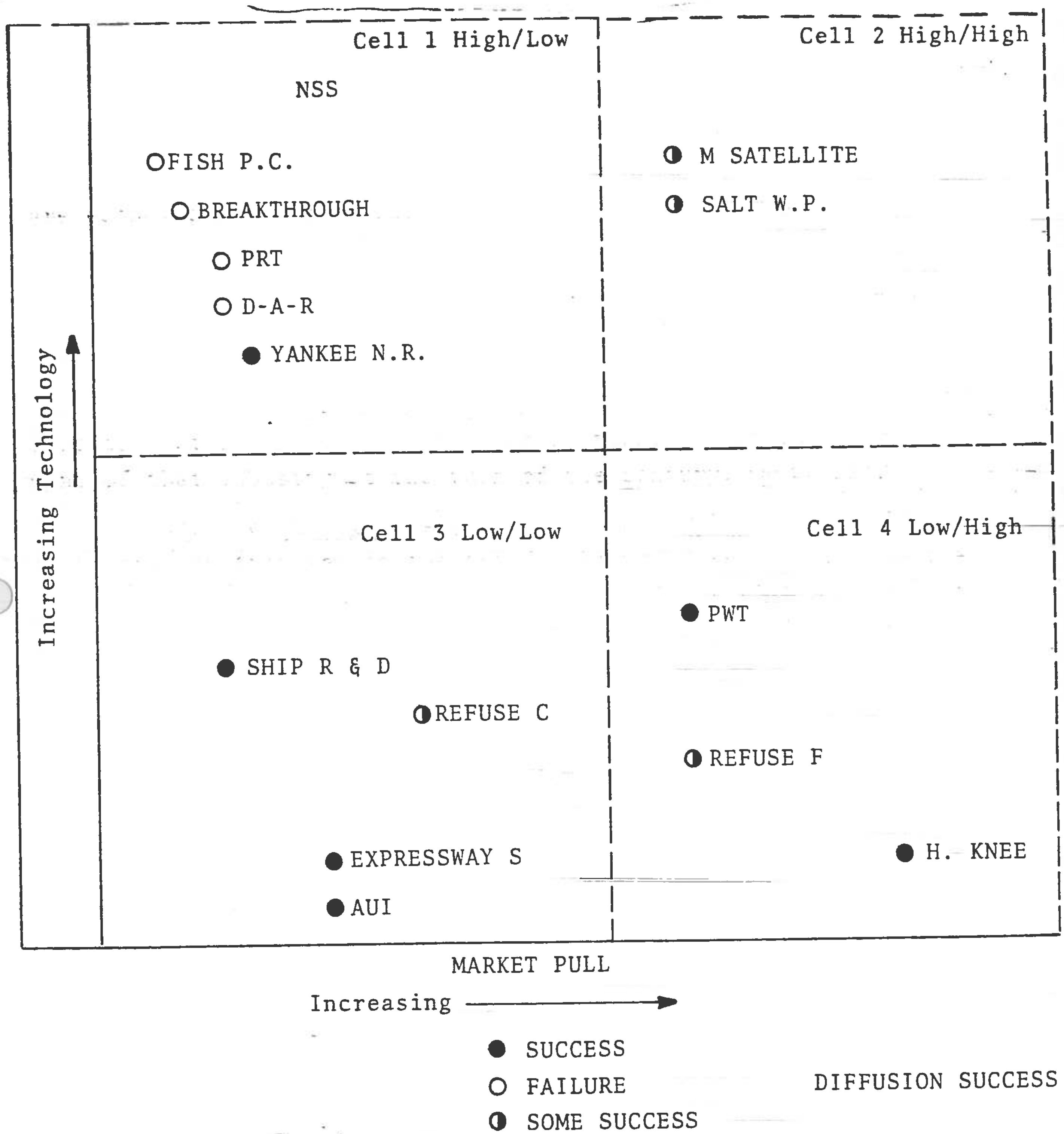
...We met with Ford Motor Co., yesterday in Detroit and they told us that for legal reasons, as well as competitive reasons, that they intend to comply. And so I presume they intend to comply.

Source: Joan Claybrook, [Ref. 7].

7

ITEM 13

DEMONSTRATION PROJECTS



DEMONSTRATION PROJECTS SUCCESS AND FAILURE PATTER VS. DEGREE OF TECHNOLOGY PUSH/TECHNOLOGY PULL

Source: William J. Abernathy [Ref. 2]

BACKGROUND

13.0 GENERAL CONCLUSIONS FROM THE CASE STUDIES OF DEMONSTRATION PROJECTS

"1. *Demonstration projects have a narrow scope for effective use.* They are most appropriate when diffusion is hampered by lack of knowledge in the hands of potential adopters about the use of the technology under commercial operating conditions. Demonstrations are not cost-effective substitutes for laboratory experiments, field tests, or pilot projects when technological uncertainty is high. They are unlikely to speed commercialization when demand is weak. Nor are they strong tools for directly tackling institutional barriers to diffusion.

Moreover, if levels of uncertainty are high in most or all the five dimensions discussed above, the prospects for successful demonstration outcomes are dim. Yet, if levels of uncertainty are low in the five dimensions, the question is why a federally supported demonstration project is warranted-that is, why the private sector itself cannot undertake whatever further development is needed. It is for the middle ranges of uncertainty, combined with a strong rationale for government involvement, that federally funded demonstration projects are most appropriate and effective.

2. *Diffusion depends on 'market pull' rather than 'technology push.'* Each of the above attributes appears to be a necessary but not sufficient condition for a demonstration's success in speeding commercialization. Taken together, they reinforce the greater importance of the marketplace over the technology as the principal factor determining diffusion. Like many past studies, this analysis confirms the danger of 'technology push.' A number of past federal demonstration projects have promoted a new product or service in the face of scant evidence of demand. As a result, even when technical feasibility was shown, the demonstration attracted little commercial interest.

To be sure, government may find a technology so socially attractive that it is worth generating a wholly new market for it. Personal rapid transit systems and synthetic fuels may be two current examples. But creating new markets and the supplier industries to serve them will almost certainly require subsidies, new regulations, and other government interventions beyond demonstrations. In the absence of well-articulated market demand, the pursuit of demonstration projects is an especially risky activity; whatever successes are achieved will be accompanied by many failures.

3. *Demonstration projects appear to be weak tools for tackling institutional and organizational barriers to diffusion.* Labor union practices, industry structure, government subsidies, and regulations can pose barriers to or reduce incentives for innovation. Although only three cases in this study- Operation Breakthrough, Savannah, and Shipbuilding-faced significant institutional and organizational problems, their experience suggests that demonstration projects by themselves are feeble weapons against those barriers. Other government interventions, such as changes in regulations or loan guarantee policies, may be more effective than demonstrations in stimulating diffusion in such situations.

The Maritime Administration's Shipbuilding research, development, and demonstration program provides one positive illustration of how to deal with institutional problems. Facing an industry with low incentives to innovate, the Shipbuilding program has sought to restructure industry R&D by forming a consortium of shipbuilding firms to propose and help manage innovative projects. Demonstrations constitute an important part of the Shipbuilding program, but the program's main impetus lies in supporting change in the industry's R&D patterns rather than supporting demonstration projects per se.

4. *Large demonstration projects with heavy federal funding are particularly prone to difficulty.* The cases in which the federal government invested most heavily tended to do poorly in

terms of information, application, and diffusion success. The federal investment in Operation Breakthrough (over $70 million), PRT (over $60 million), and Savannah (over $100 million) made these projects highly visible and vulnerable to political pressures. The pressures tended (a) to impose goals that were unrealistic in the light of what could be expected with the time, money, and technology at hand; and (b) to subject the project to the vagaries of changes in administration, federal agency staff, and budget priorities. In general, the most damaging result of political pressure is the push to demonstrate before the technology is well enough in hand.

5. *On-site project management is generally effective.* In the cases studied, project management was not a major source of trouble. Two of the most complex demonstrations- Savannah and Yankee- are examples of good project management. Whatever management problems arose in the less successful projects were overshadowed by other, more serious problems noted above-such as tendencies to push a new tecnhology into the demonstration phase before it is ready, severe time constraints imposed at the federal level, and the absence of strong private sector commitment to the project.

6. *Dissemination of information from demonstration projects is generally not a serious problem.* The case studies indicate that information channels from the project to potential adopters operate well. One might conjecture that some demonstration projects contain 'good' ideas that somehow do not get into the hands of potential adopters because of inadequate or weak information dissemination links. That seems not to be true, however. The projects that failed to achieve diffusion success did so not because of weakness in the information network but for the other reasons discussed above. Of course, dissemination of information is important, but past experience suggests that if the results are good, diffusion is likely to take place. If the results are poor, diffusion will not take place-and for good reason."

Source: Walter Baer [Ref. 4]

ITEM 14

INTERACTION OF FEDERAL ACTION

DIRECT FEDERAL TECHNOLOGY PUSH			
	HIGH	1 Extreme Risk (High Failure Rate)	2 Radical Innovation (High Risk/High Payoff when successful)
	LOW	3 Normal Process Of Industrial Innovation- Enabled (Low Risk and Moderate Success)	4 Incremental Innovation- Accelerated (Low Risk and Moderate Success)
		LOW	HIGH

INDIRECT TECHNOLOGY PULL

Source: William J. Abernathy, [Ref. 2]

14.0 INTERACTION OF FEDERAL INITIATIVES

"The joint effects of direct government technology push, and indirect technology pull, are illustrated by the two-by-two matrix (on the preceding page). Each cell is summarized in turn.

1. Intense Technology Push, Weak Technology Pull. The troublesome failure to success pattern that is so apparent in the high/low cell is not just an artifact of the particular sample of cases that has been used to illustrate the present framework. Earlier experiences with other programs like the Eisenhower administration's Atomic Aircraft program, the Breeder Reactor, or the Supersonic Transport, are suggestive of the present pattern. This does not imply that all Federal programs which undertake a technology-based initiative are failures. From a broad perspective the space program might be characterized as a Federal action of this type and on a different level so might TVA and the original Atomic Energy Program. The outcome of these programs has certainly been important but even so successful industrial diffusion has come very slowly. The programs where technology push alone has been successful seem to have involved funding levels measured in fractions of the Gross National Product.

On balance it seems appropriate to characterize normal projects within this category as extremely risky. This does not mean they should not be undertaken. The benefits to society may greatly outweigh the cost even when adjusted for risk.

2. High Technology Push, High Technology Pull. This cell is perhaps the most interesting. Beyond the present sample this category represents the environment of origin for many major innovations that have strengthened the US economy in the post-World War II era. For products like the computer, the jet engine, and advanced semi-conductor devices among others as well as the present cases, the federal government has been a major factor in the innovation process through its joint initia-

tives in market modification and direct investments in technology. In particular within the market modification category, government procurement seems to have been critically important in creating a market for advanced technologies at a time early in their life cycles when prices were very high vis-a-vis competitive technologies, and the range of applications was limited. Such support during a technology's infancy stage helps to nurture evolutionary development to the point that broadbased commercial applications are economically justified.

Government action within this category was apparently not only a factor in major innovations in the 1950's and 1960's but it also seems to represent an important influence for many less well-known innovations in the more distant past as well as the present. In his classic study of the radio industry McLaurin reports that government support was critical in the early development of that industry at the turn of the century. [Ref. 21].

3. Weak Technology Push, Weak Technology Pull. The effect of Federal initiatives in the third cell would seem to enable the normal process of industrial innovation in industrial environments where it is otherwise retarded. In terms of government policy goals this may be an important achievement. In some industries, most notably segments of electronics or high technology segments of the medical equipment industry, existing competitive conditions already induce a high rate of innovation. In other industries that are highly fragmented, or technologically stagnant such stimulus may be needed to encourage innovation. In such cases intense regulatory or market modification actions would probably not have a favorable effect. It is encouraging to note that moderate policies in these cases acted to stimulate higher levels of innovation.

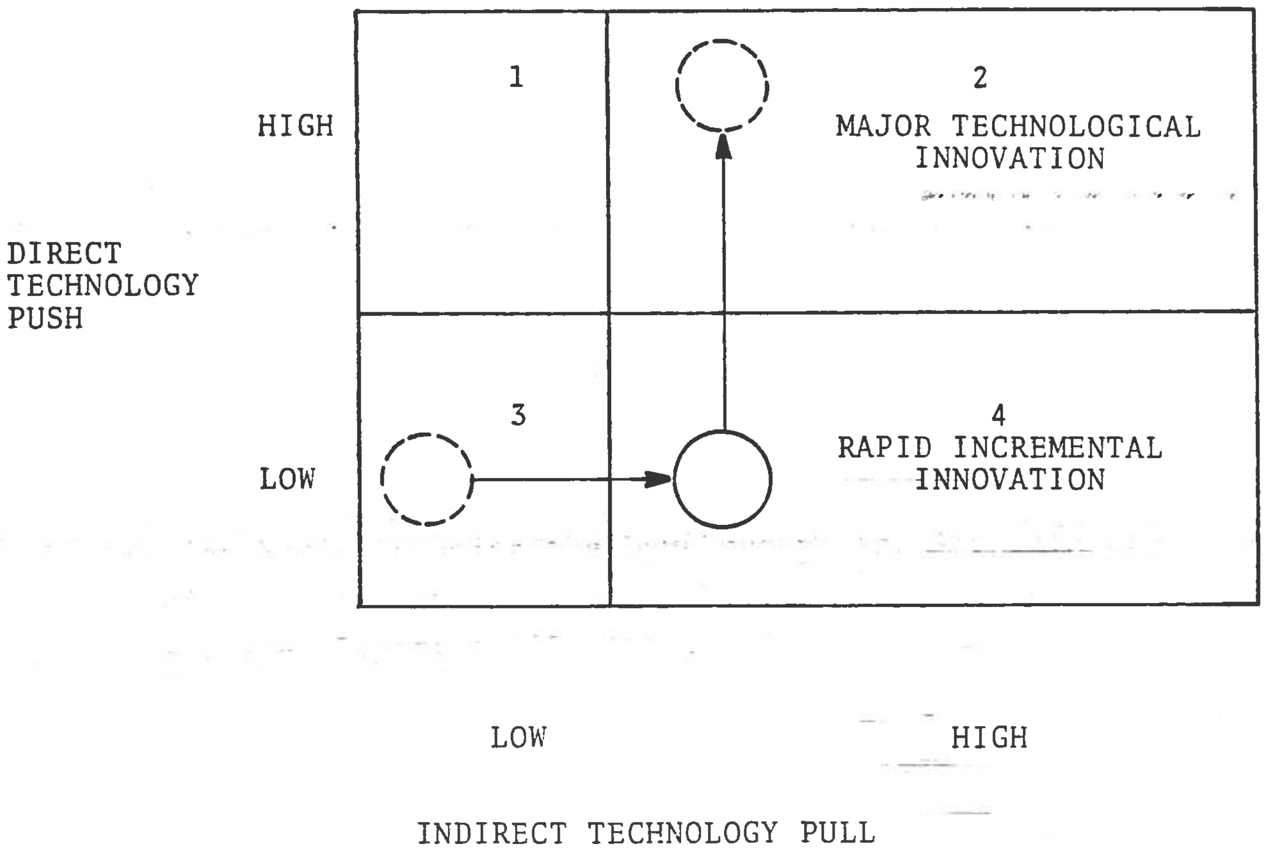
4. Weak Technology Push, Strong Technology Pull. The effect of federal initiatives which induce strong technological pull relative to technology push would seem to be an acceleration of technological change but through incremental innovation. The emphasis in this mode is on perfecting and refining established technologies rather than innovating with new ones.

The innovations in this cell that were analyzed earlier, acted to perfect and refine approaches and equipment that had already been introduced. This pattern of response would seem to be more pervasive than might be suggested by just the few cases that have been presently considered. Solutions required by safety, water and air pollution regulations have frequently been sought by capital equipment manufacturers through add-on components, minor adaptions and incremental changes. The effect is most pronounced in mass production industries, like automobiles where the cost of change is very high. [Ref. 1] One industry where product innovation is competitively important, that has recently come under increased regulation, is pharmaceuticals. Emerging performance trends here suggest that government action may have increased the cost of major technological change in the product and thereby slowed it. A similar chilling effect of regulation on major automotive innovation was predicted by Jacoby and Steinbruner in their book, Clearing the Air. [Ref. 16]. They made the point regarding pollution control and the internal combustion engine. The argument is that intense pressure for rapid change acts to increase the risk of failure from undertaking new approaches and thereby causing entrenchment in established technologies. In other words the prospects for the introduction of a radically new technology are likely to be weakened by intense pressure for rapid change. Another reason for this entrenchment phenomenon is illustrated in other industries by patterns of competitive responses by established firms to market invasions by new products. When established firms find their traditional markets invaded by radical new products, as did mechanical calculator and vacuum tube producers some years ago, the response is often to compete through cost reductions and incremental innovations in established technologies. Incremental innovation is accelerated under this pressure; and in some cases the current advantage of established technologies over prospective new competing ones may be actually widened even further in the process. [Ref. 9] An intense pressure for modification can therefore postpone the application of a technology that might be superior in the long run."

Source: William J. Abernathy, [Ref. 2]

ITEM 15

FUTURE POLICY OBJECTIVES



BACKGROUND

15.0 FUTURE POLICY OBJECTIVES

"There are many indications that further developments of the internal combustion engine can lead to modest improvements. Industry and the public have the better part of a century invested with this engine. They are familiar with it - they have confidence in it - repair know-how is readily available - and inventories of parts are plentiful. There is a strong tendency for industry to continue its momentum in this low risk direction.

But there are alternatives which are superior. With refinements expected from research and development, alternative engines such as the Stirling, turbine, or diesel are projected to be significantly better from the standpoint of the efficiency vs. emissions than the internal combustion engine.

We need to find ways to take advantage of the promise of these alternatives in a time frame that addresses the critical energy-pollution problem the nation now faces. We need to find the best ways for the federal government to help in achieving a relatively rapid change, without damaging the strength and vitality of our automobile industry.

We are convinced that a vigorous, well-managed research and development program in cooperation with industry can help us achieve our goals."

Source: Hon. Mike McCormack [Ref. 11]

"The need to encourage successful innovative solutions for national transportation problems presents a significant challenge for federal policy. The problem can be viewed as one of creating new conditions that support major technological innovation in future automobile manufacturing. As illustrated below (in Fig. 15.1) this is equivalent to a change in federal initiatives from cell 3 to cell 2 in terms of our framework.

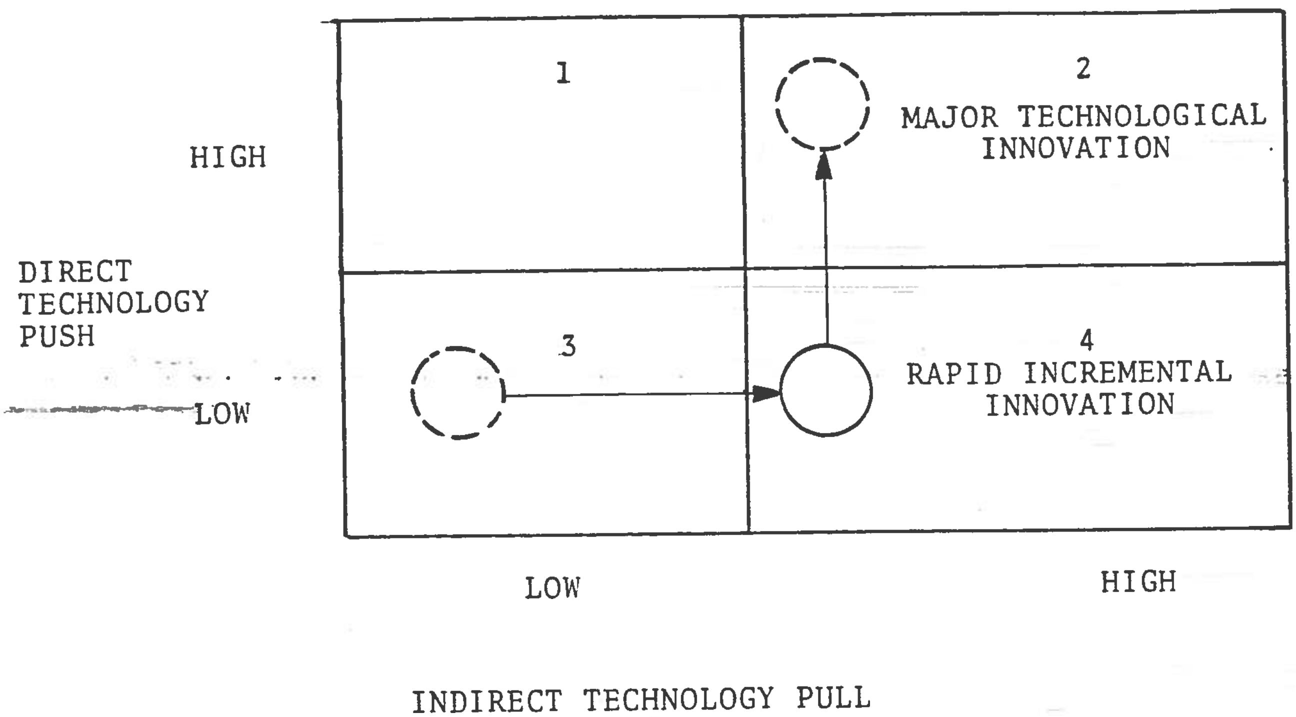


FIGURE 15.1. FUTURE POLICY OBJECTIVES

A change in the current patterns of federal initiatives regarding future automobile development, will be required to achieve these objectives. There is no one-best-way to create conditions that are sufficient to induce innovation but implications raised by the present analysis suggest several important steps toward such a goal. A fresh approach in both Federal R&D programs and special incentives is required.

1. Federal Committment to Research and Development

A stronger federal commitment to research and development results is needed. There are good reasons to question the old idea that 'the industry can and should do it', on their own. The necessary commitment will require the Federal organization, management and resources to support innovative concepts and bring advanced development programs much closer to practice than has been achieved in the past.

2. Creating an Appropriate Infrastructure for R & D

The problems which arise in coupling R & D programs to the solution of practical problems cannot be overemphasized. R & D programs should be conducted to capture the potential of innovative capabilities within the major automobile industry and important supply firms. Universities and independent research institutions have an important role to play but it is unrealistic to expect that new technology will be created and then transferred into practice. To promote effectiveness, firms with strong industrial capabilities should be engaged in the process of creating effective new technology to a greater extent than in the past.

3. Federal Incentives

Special incentives are needed to help nuture products that are derived from new technologies, in the early stages of their product life cycle. Federal procurement has played such a role successfully for many important innovations in other industries. Alternatively special incentives could be created to stimulate market acceptance of innovative products.

Several attempts to create such incentives are evident in past federal initiatives. The electric and hybrid vehicle procurement program is a recent example. A problem seems to have arisen, however, because these past programs have not been planned and integrated within the context of larger related R & D and Production programs.

The potential of such incentives as part of a larger program has therefore not really been properly tested. The use of incentives to stimulate innovation is an important option that remains untapped."

Source: William J. Abernathy, [Ref. 2]

"Apart from the (debatable) inducements to strenghtening the national technology base provided by the IR&D allowances in government contracting policies, little concern has been shown for exploiting federally-funded R&D to enhance civilian technological innovation. Federal R&D is dominated largely, though not entirely, by the requirements process, which has its roots in the statutory missions of the funding agencies. An agency typically conducts or contracts for R&D to get solutions for which the agency is the single customer or 'lead' agency. There is rarely any federal strategy aimed at propagation and application of research and development results in the industrial society. Indeed, there is some evidence that the rules of practice for industrial participation in mission-agency R&D create built-in barriers to commercialization of this technology, such as the non-exclusivity policy on patents.

Thus federal R&D funding obviously carries no fail-safe assurance that the business agent will pursue the innovation. In most cases, it is but one factor in the complex calculus of business behavior in risk-taking for innovation. The effect of federal R&D funding, per se, turns out positive to the extent that it escalates the firm's priority of R&D, or to the degree that it overcomes the problems of adverse risk and opportunity cost, or to the extent that it pre-organizes market interest and demand.

On the other hand, federal R&D funding, per se, is ineffective if its behavior is erratic and unreliable; if it carries the R&D too short of the transfer point, relying on momentum or poorly understood market forces to do the rest; and if it takes institutional factors for granted and misjudges them.

ADL's recent work on Barriers to Technological Innovation (Ref. 20 provided indicative information to the effect that where innovation goes slowly, it is largely because of market uncertainties, risk considerations, and anomalies in the decision-making behavior of the firm. To a degree, sentiment emerged from the business community as suggesting that the rate of innovation might be higher if government removed some of the constraints and uncertainties it imposes on innovation, than if it provided more R&D support — or, in other words — if more attention were given to the 'pull' rather than the 'push' mode.

The point of these observations is that the ability of business to perform as the agent of technological change is dependent upon a very wide range of factors and influences which *interact* among each other: timing, perceptions of the market, the calculus of opportunity and risk, the objectives of the firm, expectations of returns, the structure of competition — and to some degree, the role of government wearing its several hats as policy-maker, R&D funder, and regulator (and purchaser, though this role is specifically excluded from consideration in this study).

We therefore conclude that federal R&D funding policies must be formulated as one possible component in this complex framework of interacting factors which trigger the process of innovation, and some of which are significantly influenced through government policies and actions other than R&D funding."

Source: Michael Michaelis [Ref. 22]

REFERENCES

1. William J. Abernathy, The Productivy Dilemma: Roadblock to Innovation in the Automobile Industry, Harvard, 1976.

2. William J. Abernathy, and Balaji S. Chakrovarthy, Technological Change in the U.S. Automobile Industry: Assessing Past Federal Initiatives, January 1977.

3. N. Ashford and G. Heaton Jr., Environmental/Safety Regulation: Technological Responses and Innovation, AIChE Symposium Series. Vol. 73, Number 170.

4. Walter S. Baer, Leland Johnson, and Edward W. Merrow, Analysis of Federally Funded Demonstration Projects, RAND, April 1976.

5. Hayden Boyd, Inducing the Development and Adoption of Socially Efficient Automotive Technology, Charles River Associates Report # 233, April 1977.

6. Howard H. Bunch, and Michael Kubacki, An Analysis of Industry Responses to Federal Regulations in Safety Requirements For New Automobiles, March 1977.

7. Joan Claybrook, Administrator NHTSA, DOT, speech before the Automotive News World Congress, Detroit, July 13, 1977.

8. P. Coonley, and Horrigan, J., Inducing Automobile Fuel Economy Innovation: A Case Study of U.S. Government and Industry Relations 1970-1977, (DOT/TSC Report, March 1978).

9. S. C. Gilfillan, The Sociology of Invention, Follett Publishing Co., 1935.

10. E. Goodson, Federal Regulation of Motor Vehicles: A Summary and Analysis, Purdue University, Feburary 1977.

11. Hearings, House of Representatives, Committee on Science and Technology, Subcommittee on Energy Research, Development and Demonstration, March 17, 1976.

REFERENCES (CONTINUED)

12. Hearings, Public, 1981-1984 Average Passenger Automobile Fuel Economy Standards, March 22-24, 1977.

13. Hearings, Senate, Automobile Fuel Economy, July 12 + 14, 1977.

14. John B. Heywood, Henry D. Jacoby, Lawrence H. Linden, Howard Margolis, David Iverach, E. Allen Jacobs, Frank Lerman, and Michael K. Martin, Regulating the Automobile. Energy Laboratory Report No. MIT-EL77-007, November 1977.

15. John B. Heywood, Henry D. Jacoby, Lawrence H. Linden, "The Role for Federal R&D on Alternative Automotive Power Systems, Report # MIT-EL-74-013, November 1974.

16. Henry D. Jacoby, and John D. Steinbruner, Clearing the Air, "The Role of the Federal R&D on Alternative Automotive Power

17. Morton I. Kamien, and Schwartz, Nancy L., Market Structure and Innovation: A Survey, *Journal of Economic Literature* 13 (1975): 31.

18. Allen V. Kneese, and Charles L. Schultze, Pollution, Prices, and Public Policy, Brookings, 1975.

19. L. Linden and D. Iverach, "The American System of Regulating the Automobile", NSF Report, Grant No. OIP 76-00284, November 1977.

20. Arthur D. Little, Inc. Barriers to Innovation in Industry: Opportunities for Public Policy Changes, Report to the National Science Foundation, Sept. 1973.

21. Mac Laurin, W. R. Invention and Innovation in the Radio Industry, The MacMillan Company, 1949.

22. Michael Michaelis, editor, Federal Funding of Civilian Research and Development, Westview Press Inc., 1976.

23. P. Orange and L. Linden, Automobile Safety Regulation: Technological Changes and the Regulatory Process, 1977.

24. Norm Rosenberg, Allan Buffered, Phillip Coonley, William Hamilton, Robert Kaiser, and Frank T. Rabe, Institutional Factors in Transportation Systems and Their Potential For Bias Toward Vehicles of Particular Characteristics, Report No. EC-77-A-31-1043, August 1977.

25. Albert H. Rubenstein, Analysis of Federal Stimuli to Development of New Technology by Suppliers to Automobile Manufacturers: An Exploratory Study of Barriers and Facilitators, March 1977.

26. Bruce Rubinger, editor, Federal Initiatives to Induce Innovation in the Auto Industry: A State of the Art Assessment, DOT/TSC, January 1978.

27. Charles L. Schultze, The Public Use of Private Interest, Brookings, 1977.

28. Senate Bill S.499, "Title V-Research and Development", January 30, 1975.

GLOSSARY

Technological innovation	The technical, industrial and commercial steps which lead to the marketing of new manufactured products and to the commercial use of new technical processes and equipment. Subset definitions of innovation include:
o product innovation	The activities which culminate in the commercial realization of new goods and services.
o process innovation	The activities leading to the advent of new methods and added efficiencies for producing existing items.
o incremental innovation	The gradual and progressional improvement of an existing product or process.
o radical innovation	The introduction of new technological concepts or the drastic alteration of existing systems.
Technology Push	The inducement of change through the creation of superior, new technology.
Market Pull or Technology Pull	The inducement of change through the modification of market demands.
Research and Development	The process by which a concept is transformed into a marketable product. The different stages of research and development include: survey research, basic research,

	applied research, exploratory development, advanced development, engineering development, and product improvement. These stages are described below:
o survey research	exploratory search of existing technical and market information.
o basic research	systematic acquisition of structured information. With the emphasis being on knowledge rather than on practical application.
o applied research	practical application of systematically acquired data for the purpose of developing a technical abiling.
o exploratory development	proving of technical feasibility by building experimental prototype.
o advanced development	proving technical feasibility by building several working models and then making engineering changes reflecting test experiences.
o engineering development	proving manufacturability and economic feasibility, "soft tooling" and extensive testing of prototypes with emphasis on improving performance characteristics within cost limitations.

o product improvement	refinements of product which might add to market appeal or lower production costs.
Demonstration Project	The final stage of "scaling up" from the laboratory to commercial use. Synonymous with engineering development.
Demonstration Project Success	Achievement of project performance criteria in the areas of adaption, diffusion and information. These criteria are defined below:
o Diffusion sucess	The introduction of technology into general use as a result of research, development and demonstration projects.
o Application success	The successful application of a technology within a demonstration program environment.
o Information success	The reduction of uncertainties to the point where a lack of information does not prevent adoption.
Economic Externalities	The costs or benefits not taken into account in a system of economic transactions.
Vehicle Integrity	The interaction of car components as they relate to overall vehicle performance

Federal initiatives	The policy options by which the government can pursue goals perceived to be beneficial. Such options include: regulatory actions, economic incentives, institutional incentives, R&D incentives, information incentives and integrated incentives.
o Regulatory action	The establishment of product, process or performance standards.
o Economic incentives	Policies which modify market pull through financial penalties and reqards.
o Institutional initiatives	Policies which alter organization functions and structures.
o R&D Initatives	Federal policies design to expand the technical knowledge base.
o Information incentives	Policies which stimulate information dissemination.
o Integrated incentives	Combination of two or more of the above policy options.