FEDERAL INCENTIVES FOR INNOVATION

REPORT
R 75-04

Why Innovations Falter and Fail: A Study of 200 Cases

prepared for

Experimental Research and Development Incentives Program
Research Applications Directorate
National Science Foundation

Denver Research Institute University of Denver

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CHAPTER I

INTRODUCTION

"It was," said William Holden in the popular movie Executive Suite, "just one attempt in a hundred to make one improvement in a hundred." The "it" was a new molding process which presumably would mean an improvement in the Tredway Corporation's furniture line. Unfortunately, a key production test failed and the innovation was delayed. A failure of technology? Perhaps, but then Holden felt that the test may have been successful had he been there when a key management decision was needed rather than cooling his heels in the board room waiting for a hastily called meeting. A failure of management? In any case, it would have been called an innovative failure in the real industrial world.

The failure rate for technological innovations is high: one study found that although the rate varies among industries and companies, on the average ". . . it takes some 58 ideas to yield one successful new product."[1] The vast majority of ideas fail at the outset to make it through the initial screening and business analysis process. Only about 10 or 12 percent of ideas submitted for screening will ordinarily enter the development pipeline which leads to commercialization. This is a study of 200 innovations that passed initial screenings but failed after entering that pipeline.

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[1]Booz-Allen and Hamilton, Management of New Products, 1963 p. 9.

a high mortality rate. It can work to increase the birth rate so that sufficient numbers of people survive past the age of 30 despite the toll taken by disease and malnutrition, or it can take the steps necessary to see that its young people are allowed to grow old. Of course, both policies can be pursued simultaneously, and the same is true of innovation.

This study has addressed the second option. It examined actual industrial innovations that failed and attempted to determine why they failed with a view to suggesting public policies that might decrease the rate of failure. The study identified the obstacles to innovative success as identified by management officials involved in decisions to scrap innovations and related these obstacles to other aspects of the innovation process, such as the stages of development at which decisions were made to scrap innovations and the attitudes of management toward these decisions.

The findings and conclusions of this study cannot be taken as definitive because they are based on data from only one industrial segment--producer's goods. More study should be given to why innovations fail in other industries. Less is known about why innovations fail than about why they succeed;[2] the factors associated with successful

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[2]For a study of failures see:

B. Achilladelis, P. Jervis, and A. Robertson, Project Sappho: A Study of Success and Failure in Innovation. Science Policy Research Unit, University of Sussex, Brighton, England, 1971.

For studies of success see:

Sumner Myers, and Donald G. Marquis, Successful Industrial Innovations: A Study of Factors Underlying Innovation in Selected

CHAPTER II

METHODOLOGY

Data about the 200 innovations were drawn from interviews with the management officials involved in the decisions. The study was designed by the Institute of Public Administration and conducted jointly with staff members of the Denver Research Institute. There were 81 interviews with officials from 11 different producers' goods industries.

The Interview Technique

The premise underlying the decision to ask management officials to give case histories of specific innovative failures was this: if you want to know why something happened, ask the man who was there. There are other kinds of reliable data that are useful, of course, but there is no real substitute for experience in the field. In most cases the respondents were corporation presidents, vice-presidents in charge of R&D, or heads of R&D divisions within the corporations attempting the innovations. They had been involved in the hard decisions that scrapping any costly undertaking implies.

Those who are not regularly on the management firing line but who comment on the battle from a distance often take public positions on major problems, become identified with these positions, and find it hard to abandon them. If asked to discuss illustrative case histories, they are likely to select those that buttress their public positions. To exclude this kind of bias from the data in this study, respondents were sought out who were not regular members of any R&D "establishment" with a known point of view. The respondents were not asked to discourse

In any event, while decision-makers tend to be hazy about how an innovation got started, once it has succeeded they certainly are clear about the ones that got away.

Given the limitation of interviewing only management officials, the opinion of the investigators is that the interview technique used did yield reliable data in the sense that facts were correctly reported. Categorization and analysis of these facts were jobs for the researchers, not the respondents.

The Data-Gathering Process

The 81 firms selected for interviews were not chosen to provide a national sample in any statistical sense. Criteria for selection were chosen, however, to give a cross-sectional look by size of firm, accounting for a major share of foreign trade industries with a deteriorating import/export trade balance during the past five years. Industries were also selected because their outputs affected the productivity of other firms. The result is a group of firms broadly representative of various segments of the American producer's goods industry and important in the U.S. foreign trade and balance of payments' picture. Most of the individual respondents were suggested by trade associations in producer's goods industries as knowledgeable, innovative managers. Table I indicates the number of firms interviewed and innovations discussed in each industry.

Since the size of the firm is generally considered a factor in innovation, a roughly equal number of large (over 2,500 employees), medium (500-2,499), and small (under 500) firms were included among the respondents. In addition, a number of officials representing new ventures, i.e., companies formed specifically to produce and market a particular new product, were interviewed. Table II gives the complete breakdown by size. (Table A-I in the Appendix summarizes the entire sample by type and size of firm.)

The respondents selected were contacted by letters which described the proposed research and its objectives. (See Table A-II.) Soon thereafter, appointments were made for the interviews to be conducted by telephone, sometimes with several corporate officials participating through inter-office hook-ups.

The interviews were largely open-ended in that the respondents, rather than addressing their remarks to a definite set of categories known to them in advance, were asked to talk about particular innovations that had failed in their firms. Although the interviewers followed a uniform interview protocol and guided the questioning to elicit the desired information, the answers were not evaluated and assigned to tabulable categories until later.

Interviews were conducted until enough patterns emerged to suggest that the data in hand were representative and would yield reliable findings indicating that further data would likely be repetitious. The interviewing was then terminated at a convenient point--in this case, 200 innovations.

The respondents were asked to describe at least two innovations that were far enough beyond the concept stage to have received specific decisive attention by company management. This study is thus limited to innovations that failed after they had been selected for funding and were in the pipeline; it does not address issues related to the conception of ideas for innovations prior to the initial funding of technical work.

This should not imply, obviously, that factors blocking potential innovations from being funded are unimportant in the overall scheme of things. However, if government policy is to increase the percentage of innovations that are subjected to the discipline of the marketplace, as opposed to the number that are begun, it must do so when the innovation is in the pipeline because only then is it clear that the innovative process has started.

Definitions and Data Categories

In the study design, an innovation was to be considered a failure (or "blocked") when the development and marketing processes were stopped. There are degrees of stoppage, however, and this is reflected in the data. Three categories were used:

- Cancelled. A decision was made to terminate all technical production and marketing of the product or process.

- Shelved. The innovation was put aside pending the occurrence of favorable events that might reactivate it or unfavorable events that might result in its cancellation.

- Delayed. In the judgment of the respondent, the innovation took significantly longer than it should have because of specific holds placed on it in making its way through the development process. If a project was shelved and then reactivated it would be classified as delayed.

All three kinds of failure are important if the aim is to stimulate the rate of successful innovation in industry.

"champion," might have quite a different view of "good" from that of a management official not so closely involved in development of the innovation.

CHAPTER III

SUMMARY OF FINDINGS

The findings and conclusions in this study are based on an examination of 200 industrial innovations that were stopped by management decisions sometime before successful commercialization, the stage that marks innovation success.

Obstacles to Innovation

Most of the obstacles to innovations reported fit into one of five broad categories--the market, management, laws and regulations, capital, and technology. In analysis of the relative importance of obstacles, respondents were asked if they thought the innovation the firm had decided to cancel, shelve, or delay was still a "good" idea or "not good." For policy purposes, primary attention should be given to obstacles blocking "good" innovations.

Table III summarizes the major obstacles to innovation, in total and categorized by the "good" and "not good" judgments of the respondents.

Considering all innovations, two factors--market and management--account for over half the blocked innovations. A substantial portion of management problems were related to poor market analyses and organization and staffing weaknesses in the marketing organization. Combining "the market" and "marketing management," market-related factors make up the single largest set of problems.

Laws and regulations and capital were about equal in effect as barriers. Perhaps surprisingly, considering the attention which has been paid to R&D as a factor in innovation, the area of technology offered the fewest obstacles identified in the study.

Of the 200 innovations studied, about equal numbers were judged to be "good" and "not good." Management factors blocked more good innovations than any other category, a somewhat surprising result with the expectation being that "good" innovations would be affected more often by factors external to the firm and thus more difficult to predict and control. In contrast, the market was the largest factor blocking "not good" innovations. This is at least in part due to the fact that when the market blocked an innovation, management tended to accept that fact and so tagged the innovation as "not good."

Laws and regulations, the least important factor blocking "not good" innovations, was the second most important factor blocking "good" innovations. Management, the largest factor blocking "good" innovations, is not as susceptible to government action, suggesting that laws and regulations, which are government actions, provides a promising area for government intervention.

The technology category ranked low for both "good" and "not good" innovations. Even more dramatic is the very low incidence of technology as a blocking factor for "good" innovations--if a "good" innovation is going to be blocked, it will be due to something other than technology.

Capital-related factors were not as significant as might have been expected. The problem was manifested more or less evenly among a number of specific obstacles including the high cost of pilot

Looking at the entire sample, there is little difference between "good" and "not good" innovations in terms of the phase at which they are blocked. Seventeen percent of the good ones make it to the final stage of production installation, but the same is true for 20 percent of those judged "not good."

Size of firm. Categorization was by large, medium and small firms and "new ventures," firms built around the product whose commercialization was being attempted.

Capital shows up as the major blocking factor for new ventures, but ranks only fourth or fifth for large, medium and small firms. Firms of all sizes suffer about equally from the effects of laws and regulations, but new ventures do not seem to be as affected as the others. None of the 19 innovations pursued by new ventures was blocked by technology, probably because new ventures were formed with the required technology in hand as a primary factor. The numbers of "good" and "not good" innovations, by size of firm, do not seem to vary greatly from their frequency in the overall sample.

The results of this survey point to a number of other findings concerning why innovations fail or falter. Because of the study limitations noted in Sections I and II, a number of these tentative findings cannot be definitively tested using the data developed in the study. However, some consideration of suggested findings seems productive. The following sections and supporting tables in the Appendix consider these in some detail.

CHAPTER IV

FINDINGS: OBSTACLES TO INNOVATION

Most of the obstacles to innovations reported fit comfortably into one of five broad categories--the market, management, laws and regulations, capital, and technology. In other words, the primary factor blocking an innovation could be found in one of these areas. (Only nine reported obstacles had to be assigned to a "miscellaneous" category.) Within the general categories, however, certain definite subcategories were discernible. Many of the management problems were clearly matters of organization and staffing, and patent and antitrust laws were recognizable sub-groups in the broad area of laws and regulations.

With this classification, the market and management could clearly be identified as the principal areas in which blockages to innovation occur. The two factors accounted for over half the blocked innovations reported in the interviews. Of this number, a little over half were attributable to the market and just under half could be assigned to management. Perhaps surprisingly, considering the attention which has been paid to R&D as a factor in innovation, the area of technology offered the fewest obstacles identified in the study. Table IV gives the complete breakdown by factor.

It should be noted that about 20 percent of the <u>management</u> problems occurred in the specialized area of organization and staffing, particularly in the marketing organization. As for general management, an interesting linkage between the management and market factors appeared:

poor market analysis was the largest single management failing, accounting for nearly 30 percent of that category. While poor market analysis might have been classed as a market factor, it was categorized as a management weakness because it is correctable only through actions of the firm. The distinction can be illustrated by the case of one firm that developed a special welding tool for use in repairing automobile bodies. Not one was sold. It turned out that the tool, which was to have been used inside the automobile body, could not be used because the automobile upholstery was already in place and the tool would have been a fire hazard. This was clearly a management failure and was so categorized, even though in the final analysis it was the market that rejected the tool. However, combining "the market" and "marketing management," market-related factors make up the single largest set of problems.

The kind of blood, sweat, and tears represented by this bare enumeration of failures can be illustrated by a few case studies. Each of the cases cited illustrates a separate cause of innovation failure and points out a particular moral concerning the risks of innovation.

Case 1: The search for the capital necessary to develop an innovation through the marketing phase can end in a "Catch 22." A company developed a new diagnostic X-ray machine with government R&D funding. Before the machine could be produced in marketable form, extensive field trials were required. Government funds could not be used to conduct such trials, and other possible suppliers of capital

Justice will not provide this information until the process is in operation! (The barrier in this case was classified as regulatory.)

Case 4: There may not be a viable market for an innovation in the public interest. A major supplier of automobile components tried to introduce an anti-skid brake-control system for passenger vehicles. The firm carried the project almost to the production phase but was unable to arouse enough public interest in voluntary adoption of the system to market it. (The barrier in this case was classified as market.)

Case 5: Lack of technical capabilities in the staff of a firm may delay solution of technical problems so long that a product may have lost its competitive advantage by the time it is marketable. A firm developed some prototype engines using a piezo-electric ignition system but sold the rights to the system to another firm. The second firm had to solve some technical (noise and time-delay) problems before the system could be marketed. Because of lack of technical expertise, the firm took so long to solve these problems that by the time the system was marketable, the market was no longer penetrable. Concomitantly, the opportunity to achieve economies through large-scale production techniques was lost; delay meant loss of exclusivity because the optimal time for market entry was allowed to pass. The product was withdrawn after the costly, two-year delay; and new techniques were used to develop an acceptable low-cost ignition system. (The barrier in this case was classified as organization and staffing.)

One way to look at the general factors producing innovative failure is whether they are internal or external to the firm attempting

The division of factors assumes, of course, that no firm controls enough of its market (or of government, for that matter) to be able to "internalize" that as a factor. This assumption might be questioned, but it seems to hold true for the firms involved in this study. In any case, the internal/external dichotomy seems to form little basis for any public policy.

Another way to arrange the factors is in terms of the degree to which they are susceptible to public policy intervention. To do this, it is necessary to make a basic assumption that will be discussed later--that the market, management, and technology are relatively difficult for government to affect directly, while regulations and capital can be significantly impacted. Figure 2 presents this picture.

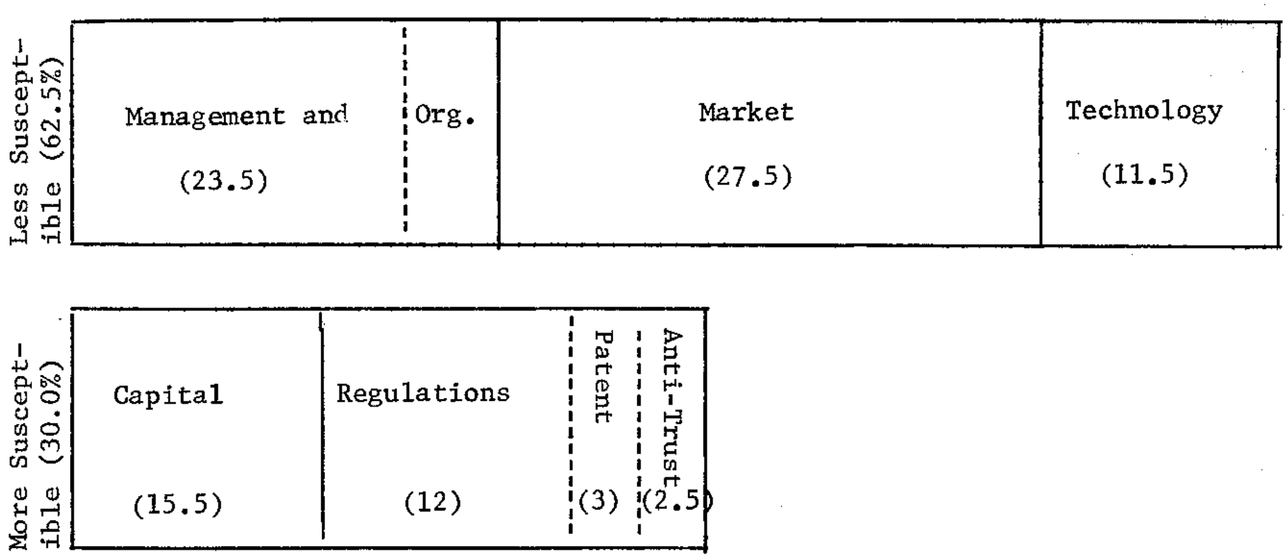


Figure 2

BLOCKING FACTORS AND SUSCEPTIBILITY
TO GOVERNMENT INTERVENTION

the problem was that some other firm had come up with a competitively superior technical approach.

The analysis of management problems was discussed at the beginning of this section. As noted there, organization and staffing and market analysis failures were the most significant components in this category.

The capital problem was manifested more or less evenly among a number of specific obstacles, including the high cost of pilot production and changeover, insufficient resources, and opportunity costs. Only one innovation was blocked because of insufficient capital to develop a high-risk market. Again, this low number may reflect the existence of a preemptive, pre-pipeline blockage.

As for the regulatory area, the most striking finding was that the uncertainty of federal requirements, rather than their stringency, was perceived as the most important blocking factor. Only one innovation bowed to the length and cost of federal tests. Interstate variability of regulations is of marked importance. Many respondents complained about both patent and antitrust laws. But, in fact, both areas presented relatively few obstacles. Regulations blocked 2.5 percent of the innovations, and patents 3 percent. Here again, the figures probably understate the severity of the problems. Innovations that are obviously in violation of antitrust regulations don't get funded. Similarly, innovations with obvious patent problems are rejected at the outset. Finally, union opposition, listed in the miscellaneous category, was found to be a negligible factor, being mentioned twice in 200 innovations. In both cases, the anticipated union opposition was in the customer's company, not the innovating firms.

CHAPTER V

FINDINGS: PERSPECTIVES ON INNOVATION FAILURE

In addition to identifying the factors blocking innovations, the study was designed to examine certain facets of innovation that, although not necessarily blocking factors themselves, were relevant to innovation failure and thus could increase our overall understanding of the process. The three areas chosen were respondent evaluation of unsuccessful innovations, stages at which innovations were blocked, and the size and type of firms experiencing innovative failure.

Respondent Evaluation of Innovations

Respondents were asked if they thought the innovation the firm had decided to cancel, shelve, or delay was still a "good" idea or "not good." In this somewhat Manichean classification, discussed earlier, respondents were not directly evaluating the intrinsic merit of a particular product or process, only its potential benefit to the firm. Thus a certain product (quieter lawn mowers, for example) may have social value, but if the market will not accept it, and if those responsible fail to judge this correctly, then the innovation will be unsuccessful. From the viewpoint of the firm, it was not a good innovation because it would not have been funded had the market potential been correctly assessed at the beginning.

On the other hand, if an innovation looked promising at every stage in the development process, only to be defeated by a process no one could have predicted, an unexpected shift in the market, a little-known government regulation, then the innovation might be judged "good."

TABLE V

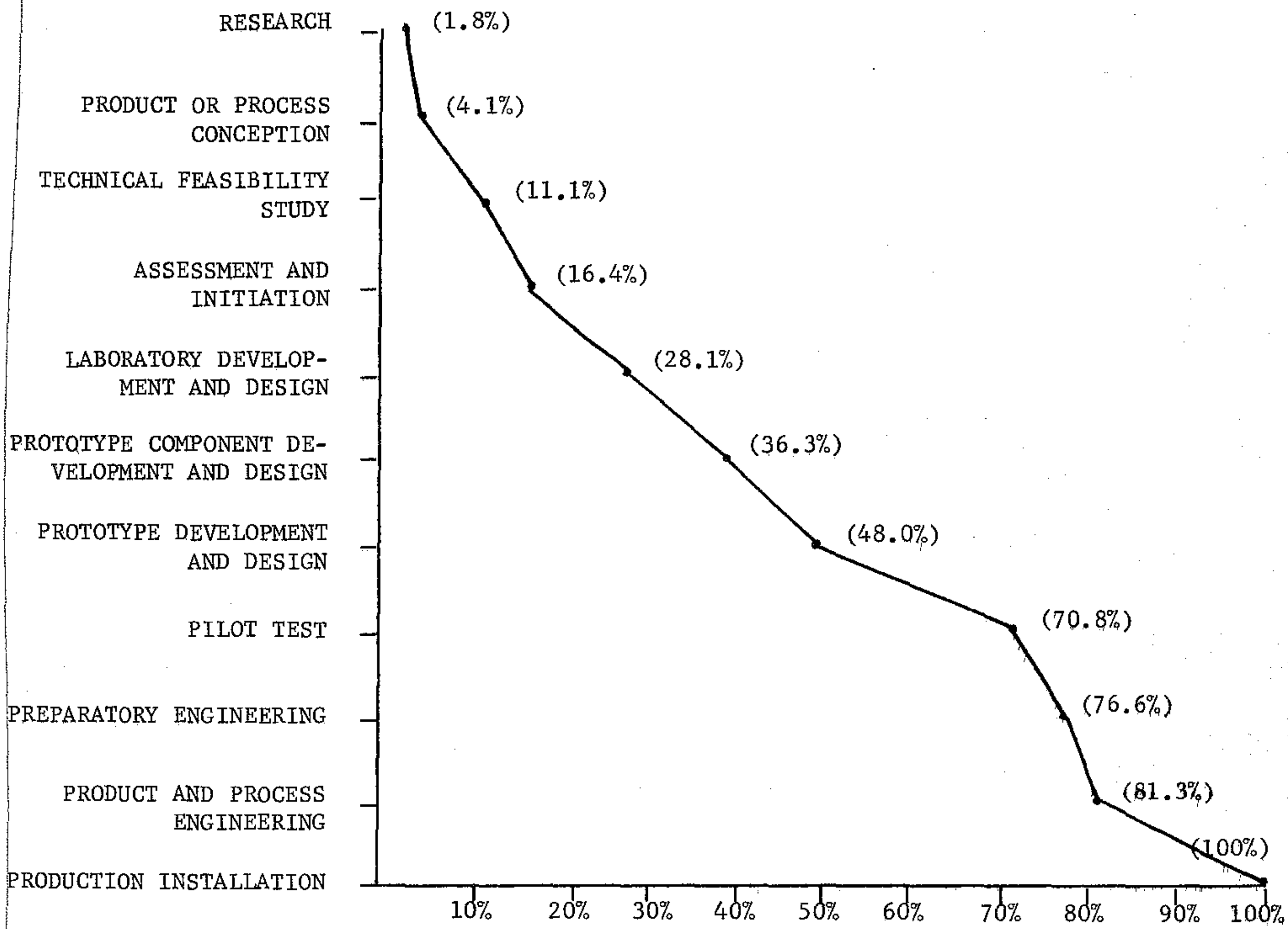
RESPONDENT EVALUATION OF INNOVATIONS

Respondent Evaluation	"Fate" of Innovation: Cancelled	Shelved or Delayed	Totals
"Good"	34	58	92
"Not Good"	56	52	108
TOTAL	90	110	200
PERCENT	45	55	100

TABLE VI

RESPONDENT EVALUATION OF BLOCKED INNOVATIONS
RELATED TO OBSTACLES

Obstacle Category	Number	Percent of Innovations	Obstacle Category	Number	Percent of Innovations
Management & Organization	26	28.3	Market	38	35.2
Laws & Regulations	23	25.0	Management & Organization	21	19.4
Market	17	18.5	Technology	18	16.7
Capital	16	17.4	Capital	15	13.9
Technology	5	5.4	Laws & Regulations	12	11.1
Miscellaneous	5	5.4	Miscellaneous	4	3.7
	92	100.0		108	100.0



*Based on 171 innovations. Phase at which innovation blocked not reported in all cases.

Figure 3

PERCENTAGE OF INNOVATIONS HAVING FAILED AT EACH PHASE OF DEVELOPMENT*

TABLE VII

"GOOD" AND "NOT GOOD" INNOVATIONS
AND PHASE OF DEVELOPMENT

PHASE AT WHICH INNOVATION BLOCKED	NUMBER "GOOD"	NUMBER "NOT GOOD"	TOTAL	PERCENT OF TOTAL
Research	1 (1.3)**	2 (2.1)	3	1.8
Product or Process Conception	1 (1.3)	3 (3.2)	4	2.3
Technical Feasibility Study	6 (7.8)	6 (6.4)	12	7.0
Assessment and Initiation	3 (3.9)	6 (6.4)	9	5.3
Laboratory Development and Design	9 (11.7)	11 (11.7)	20	11.7
Prototype Component Development and Design	4 (5.2)	10 (10.6)	14	8.2
Prototype Development and Design	12 (15.6)	8 (8.5)	20	11.7
Pilot Test	20 (25.9)	19 (20.2)	39	22.8
Preparatory Engineering	5 (6.5)	5 (5.3)	10	5.8
Product and Process Engineering	3 (3.9)	5 (5.3)	8	4.7
Production Installation	13 (16.9)	19 (20.2)	32	18.7
TOTAL	77	94	171*	100.0

* Based on 171 innovations. Phase at which innovation blocked not reported in 20 cases. Nine miscellaneous obstacles also excluded.

** Those numbers bound by parenthesis are percentages.

more, in proportion, and new ventures somewhat fewer. This does not mean, of course, that firms of differing size have the same rate of innovative failure, because respondents were not asked to report how many failures their firms had experienced in total, but only to report on some innovations that had failed.

When the factors blocking innovation are related to firm size, there are some minor surprises, as seen by Table VIII.

Capital, for example, usually thought of especially as a problem for small companies, shows up as a blocking factor across the board but with major effect upon new ventures. Presumably, companies of all sizes could benefit from some capital infusion. Likewise, although the ability to marshal technology is commonly thought to be an advantage of large companies, technology shows up as a blocking factor much more often in large firms than in medium and small ones in this study. Firms of all sizes suffer about equally from the effects of laws and regulations. However, new ventures did not seem to be as affected as the others.

The numbers of "good" and "not good" innovations, by size of firm, do not seem to vary greatly from their frequency in the overall sample. (Table A-XVII.) Phase of development is something more of a factor. A charting by size of firm of the decreasing percentage of "good" innovations surviving successive phases shows that good innovations tend to be blocked earlier in new ventures and small firms. (Table A-XVIII.) Medium-sized firms seem more likely to hold onto their good innovations through more phases of the development process than large firms, which lose innovations rapidly after the prototype development and design stage.

CHAPTER VI

SOME IMPLICATIONS OF THE STUDY

Findings of the study were discussed in the previous sections. Some reflection on the results of the study suggests to the authors some implications as to the role of the federal government in technological innovation.

Failure is costly, because most failures are scrapped quite late in the development process. What's more, fully half of the innovations that failed were judged by management to be "still good" ideas. Such variation as there was between "good" and "not good" innovations seemed to be related to what caused the failure itself. For example, failures due to marketing were accepted as being poor innovations. In those cases, the judgment of the marketplace was readily taken to be final. Similarly, technology provides a basis for judging the worth of an innovative project. A majority of technological failures were judged, by hindsight, to be "not good" innovations. On the other hand, capital shortages stopped both "good" and "not good" innovations equally, whereas the innovations frustrated by regulatory factors were overwhelmingly judged to be "good" ones.

The findings present something of a dilemma for public policy. On the one hand, a high rate of failure of industrial innovations is a matter of considerable public interest; it has negative implications for the American economy, particularly when that economy is engaged in international competition. On the other hand, it is not clear that

Beyond stimulating the economy, there is little the government can do about markets that will have more than a symbolic effect. Granted, government could create markets for more innovative new products by itself specifying and purchasing such products for its own use. And indeed, this policy which has often been suggested is currently being expanded. But it can only be expanded so far--if only because such a policy takes a good deal of creative energy, which is always scarce. In any case, while much more effort will surely yield a few more innovative products like quiet lawn mowers and energy-efficient air-conditioners, they will not be enough to make an appreciable difference to the economy as a whole. In short, government purchasing policy is at best a low-leverage one with respect to the economy as a whole.

At worst, a government purchasing policy on behalf of innovation may turn out to be counterproductive. While its thrust is to induce companies to develop innovative new products for later sale to non-government markets, it does little to reduce the risks inherent in those markets. Indeed, it may tend to increase those risks if companies pay insufficient attention to the requirements of the private sector market while they focus on the government's requirements. Whatever the case, given the low leverage of purchasing policies and the high risks of innovating for private sector markets, the federal government should be wary of supporting the development of new products for those markets.

Instead of supporting the development of new products for private markets, the government might risk less and accomplish more by focusing its support on innovations which ordinarily do not encounter to do much good. Innovations generally do not seem to fail because management lacks information about the market--although there is some evidence of that problem. They seem to fail primarily because management does not correctly evaluate the plethora of information that is already available. The chief management problem with respect to marketing is not the lack of market information, but poor organization, staffing, planning and judgment--none of which can be supplied by the federal government.

After respondents had described their specific problems, they were asked to suggest remedial actions which government might take to help overcome the obstacles encountered. Repeatedly, the answer was for the government to keep out of the problem, especially when the problem was market related. Aside from occasional half-hearted suggestions to increase the availability of market-relevant data, the respondent executives generally held to the view that corporate management should be left alone to put its own house in order in its own way. If this is done, many more innovations that now fail will get through the pipeline and most of them will be good ones.

If market, management and organization do not appear to be promising targets for direct government action, neither does technology. As noted earlier, technology was not a major blocking factor, particularly for "good" innovations. Even if it were, government probably couldn't supply the missing technology except at great expense.

Government, however, does have a key role with respect to technology for the future. It must help to prevent future technological obstacles the effect could be to increase the rate of innovation failure. Capital incentives can lead managements to undertake innovative projects with even less careful assessments of markets and production costs and risks.

Further, if public policy addresses capital obstacles, it is moving into a political and administrative minefield. Although government assistance can be given so as not to be a subsidy to business it will be interpreted as such. And, of course, this raises all the old questions about which business and which innovations to subsidize. The difficulty is that although innovation in general is a desirable public goal, it is hard to say that any particular innovation for the private sector is of special interest to the public. Is a quieter lawn mower so important to the public that government should subsidize its development? Is the elimination of ring-round-the-collar more in the public interest than the exorcising of dirty bathtub stains? Such matters have traditionally been left almost exclusively to the private sector decision process. Given scarce resources, the government would have to devise criteria for its capital-assistance program--which criteria, in the nature of things, are likely to be controversial.

The least controversy and most effectiveness might be achieved through tying capital assistance to process innovations which, as noted earlier, aim to improve the firm's productivity. That is indisputably in the national interest. Because productivity innovations, by definition, make good economic sense, a capital assistance program for such purposes could be self-liquidating. A mechanism might be designed to help capital-short firms borrow money specifically to improve their

It is important to understand that a good deal can be accomplished in the short term without having to address the substantive issues of regulation, as desirable as that may be. About half of the innovations affected by the regulatory process were blocked due to uncertainties and interstate variability of the regulations. Uniformity of regulations, comprehensibility, and--above all--timely and flexible decisions respecting their implementation would help enormously.

Stringent standards, tough tests, etc.--all of which may well be in the public interest--were also important blocking factors, but less so. Granted, strict tests and standards may well be necessary to the public interest. Nevertheless, they should be examined periodically to be sure that they do, in fact, contribute enough to the general welfare given their adverse effects on the process of innovation.

The government should adopt a wary policy with respect to product innovations for private sector markets. In the nature of things, these stand a high risk of failing and government intervention in the marketplace could make the situation worse. Rather, the government should avoid market problems and support process innovations to be used by the firm itself by reducing the cost of capital for productivity purposes. Such a policy would both increase the firm's success rate and contribute to an important national goal--greater productivity.

APPENDIX A

TABLE A-I

SUMMARY OF SAMPLE

By Industry and Size of Firm

	Size of Firm									
	Large		Medium		Small		New Venture		Total	
Industry	Intv	Inno	Intv	Inno	Intv	Inno	Intv	Inno	Intv	Inno
Chemicals	6	20	2	6	1	3	1	1	10	30
Plastics	3	10	1	2	-	-	-	-	4	12
Engines	2	4	6	17	3	5	2	3	13	29
Non-agric. Tractors	6	18	3	7	8	14	-	1	17	40
Computers	-	-	3	6	1	3	3	5	7	14
Elec. Power Machinery	1	3	3	5	1	2	-	1	5	11
Electronic Components	-	-	2	6	2	4	2	2	6	12
Other Machine Tools	1	2	1	3	1	1	-	-	3	6
Iron & Steel	2	6	2	8	3	12	-	-	7	26
Aluminum	1	4	1	4	1	3	-	-	3	11
Instruments	1	1	1	2	-	-	4	6	6	9
TOTAL	23	68	25	66	21	47	12	19	81	200
Percent of all companies	28%		31%		26%		15%		100%	
Percent of all innovations studied		34%		33%		23.5%		9.5%		100%

NOTE: "Intv" = number of interviews conducted.
"Inno" = number of innovations described in interviews.

TABLE A-II (Cont.)

INTERVIEW OBJECTIVES

The purpose of this interview is to collect significant information from the experience of managers who have been involved in the generation or adoption of innovations that affect the productivity of their company or its customers.

We are interested in actual cases with new ideas for products or processes that were shelved, significantly delayed, or cancelled after they had been proposed and received some serious attention in the company.

For two or three such cases we would like to know why and how the project began, how far along it was when it stopped, and why it was stopped. We are also interested in your suggestions of management objectives or policy, or changes in government policy which might have overcome the obstacle to completion of introduction or adoption of the new idea.

We will tabulate the results of these interviews so that the particulars of specific instances will not in any way be revealed. Our objective is to determine the specific kinds of obstacles; the relative frequency of their occurrence, and the possibility of governmental policy effects upon them.

TABLE A-IV

PRIMARY OBSTACLES TO INNOVATION
(By Type and Category)

We have established the arbitrary rule that the first obstacle cited in the interview was the primary obstacle we had asked the respondent to identify. The interview records showed the obstacle cited first. Later in the interview some respondents mentioned other obstacles they thought had been important in the decision to block the innovation.

Number of Obstacles Identified	Number of Innovations Blocked		
			Management
6	6	1-01	Company policy not aggressive, reluctant to take risks
1	1	1-02	Management got impatient, sold line
1	1	1-03	Shift in company product objectives
5	4	1-04	Inadequate performance requirements definition
2	1	1-05	Inadequate communication
2	2	1-06	Poor program control - research without economic potential allowed to continue
15	11	1-07	Poor market analysis
5	4	1-08	Poor marketing planning or strategy execution (undersell, poor aim, over-sell)
2	2	1-09	No definite effort to market unused technology
4	3	1-10	Inadequate cost analysis
1	1	1-11	Failure to correctly assess industry-wide changes
1	1	1-12	Failure to make patent search

TABLE A-IV (Cont.)

Number of Obstacles Identified	Number of Innovations Blocked		
			Market (continued)
3	3	3-13	Customer unable to finance acquisition
10	5	3-14	Producer's cost/price ratio unacceptable for market competition
3	2	3-15	Market growth rate too slow
2	2	3-16	Insufficient applications research to generate sufficient demand to develop economies of scale
2	2	3-17	Unable to meet design competition
			Capital/Budgeting/Financing
3	1	4-01	Insufficient capital to develop high-risk markets
5	4	4-02	Insufficient capital to start new product lines (production and marketing costs)
5	4	4-03	Insufficient resources for needed research
1	1	4-04	High cost of entry through completion of pilot plant
5	5	4-05	High cost of pilot program and test program
1	1	4-06	Funding cost of demonstrations too high
5	5	4-07	Installation or change-over costs too high
4	3	4-08	Unfavorable risk analysis
2	2	4-09	Capital unavailable because no market demonstrated
6	4	4-10	Opportunity cost too high
1	0	4-11	Excessive cost of process controls
2	1	4-12	Excessive cost of installation for customer
1	0	4-13	Dollar devaluation

TABLE A-IV (Cont.)

Number of Obstacles Identified	Number of Innovations Blocked		
			Anti-Trust
3	3	7-01	Anti-trust law bars industry joint effort
1	1	7-02	Inability to assure market with process users
1	1	7-03	Antitrust requirements relicensing
			Technological Barriers
2	2	8-01	Technological barriers: materials
7	4	8-02	Technological barrier: design
1	1	8-03	Technological barrier: scale-up
6	6	8-04	Technological barrier: superior competing technical approach
2	2	8-05	Lack of "key" technical knowledge
1	1	8-06	Technological process unsuited to design parameters
4	3	8-07	Difficulty in controlling process quality
1	0	8-08	Need for technological development of ancillary items
2	2	8-09	Inadequate performance of purchased components
1	1	8-10	Inability to develop adequate research information
1	1	8-11	Inadequate testing prior to installation
			Other
3	2	9-01	Potential labor union opposition (in customer's company)
3	1	9-02	Inadequate government response to proposal
1	1	9-03	Fatigue of the battle

TABLE A-V

NUMBER AND PERCENTAGE OF SPECIFIC OBSTACLES WITHIN EACH MAJOR OBSTACLE CATEGORY

Category and Obstacle	Number of Innovations Blocked	Percent of Category Total	Percent of Innovations Studied
1. MANAGEMENT			
Poor market analysis	11	29.7	5.5
Company policy not aggressive, reluctant to take risks	6	16.2	3.0
Poor marketing planning or strategy execution	4	10.8	2.0
Inadequate performance requirements definition	4	10.8	2.0
Inadequate cost analysis	3	8.1	1.5
All others in category 1	9	24.3	4.5
2. ORGANIZATION AND STAFFING			
Inadequate marketing expertise of distribution organization	3	30.0	1.5
Exceeded staff capabilities	2	20.0	1.0
Inadequate internal responsibility assignments	2	20.0	1.0
All others in category 2	3	30.0	1.5
3. MARKET			
Limited sales potential	9	16.4	4.5
No perceivable market for public interest innovation	6	10.9	3.0
Producer's cost/price ratio unacceptable for market competition	5	9.1	2.5
Customer's cost/benefit/risk analysis unfavorable	5	9.1	2.5
Inability to aggregate market	5	9.0	2.5
Too many competitors	4	7.3	2.0
Superior competing concept extant	3	5.5	1.5
Customer unable to finance acquisition	3	5.5	1.5
Customer resistance to new processes	2	3.6	1.0
Market growth rate too slow	2	3.6	1.0
All others in category 3	11	20.0	5.5

TABLE A-V (Cont.)

Category and Obstacle	Number of Innovations Blocked	Percent of Category Total	Percent of Innovations Studied
8. TECHNOLOGICAL BARRIERS			
Design problems	4	17.4	2.0
Superior competing technical approach	6	26.1	3.0
Difficulty in controlling process quality	3	13.0	1.5
All others in category 8	10	43.5	5.0
9. MISCELLANEOUS			
Potential labor union opposition (in customer's company)	2	22.2	1.0
Inadequate government response to proposal	1	11.1	.5
All others in category 9	6	66.7	3.0
TOTAL	200		100.0

TABLE A-VII

RESPONDENT EVALUATION OF INNOVATIONS BLOCKED BY MARKET-RELATED OBSTACLES

OBSTACLE	"GOOD" C	"GOOD" S	"GOOD" D	"NOT GOOD" C	"NOT GOOD" S	"NOT GOOD" D	TOTAL NUMBER OF INNOVATIONS
Producer cost/price ratio unacceptable for market competition	-	-	-	3	1	1	5
Limited sales potential	-	1	-	6	1	1	9
Customer cost/benefit/risk analysis unfavorable	1	-	-	1	2	1	5
No perceivable market for public interest innovation	1	-	1	-	3	1	6
Inability to aggregate market	1	1	1	2	-	-	5
Too many competitors	-	-	-	3	1	-	4
All other	6	1	3	9	1	1	21
TOTAL	9	3	5	24	9	5	55
PERCENT	16.4	5.4	9.0	43.7	16.4	9.1	100

C: cancelled
S: shelved
D: delayed

TABLE A-IX

RESPONDENT EVALUATION OF INNOVATIONS BLOCKED BY REGULATION-RELATED OBSTACLES

(Combined Category Including Patent and Anti-Trust)

OBSTACLE CATEGORY	"GOOD" C	"GOOD" S	"GOOD" D	"NOT GOOD" C	"NOT GOOD" S	"NOT GOOD" D	TOTAL NUMBER OF INNOVATIONS
Laws, Regulations other than Patent, Anti-trust	4	1	13	-	4	2	24
Patent Regulations	1	-	1	1	2	1	6
Anti-trust Regulations	1	1	1	-	-	2	5
TOTAL	6	2	15	1	6	5	35
PERCENT	17.1	5.7	42.9	2.9	17.1	14.3	100
Percent of all Innovations Studied	3.0	1.0	7.5	0.5	3.0	2.5	17.5

C: cancelled
S: shelved
D: significantly delayed

TABLE A-XI

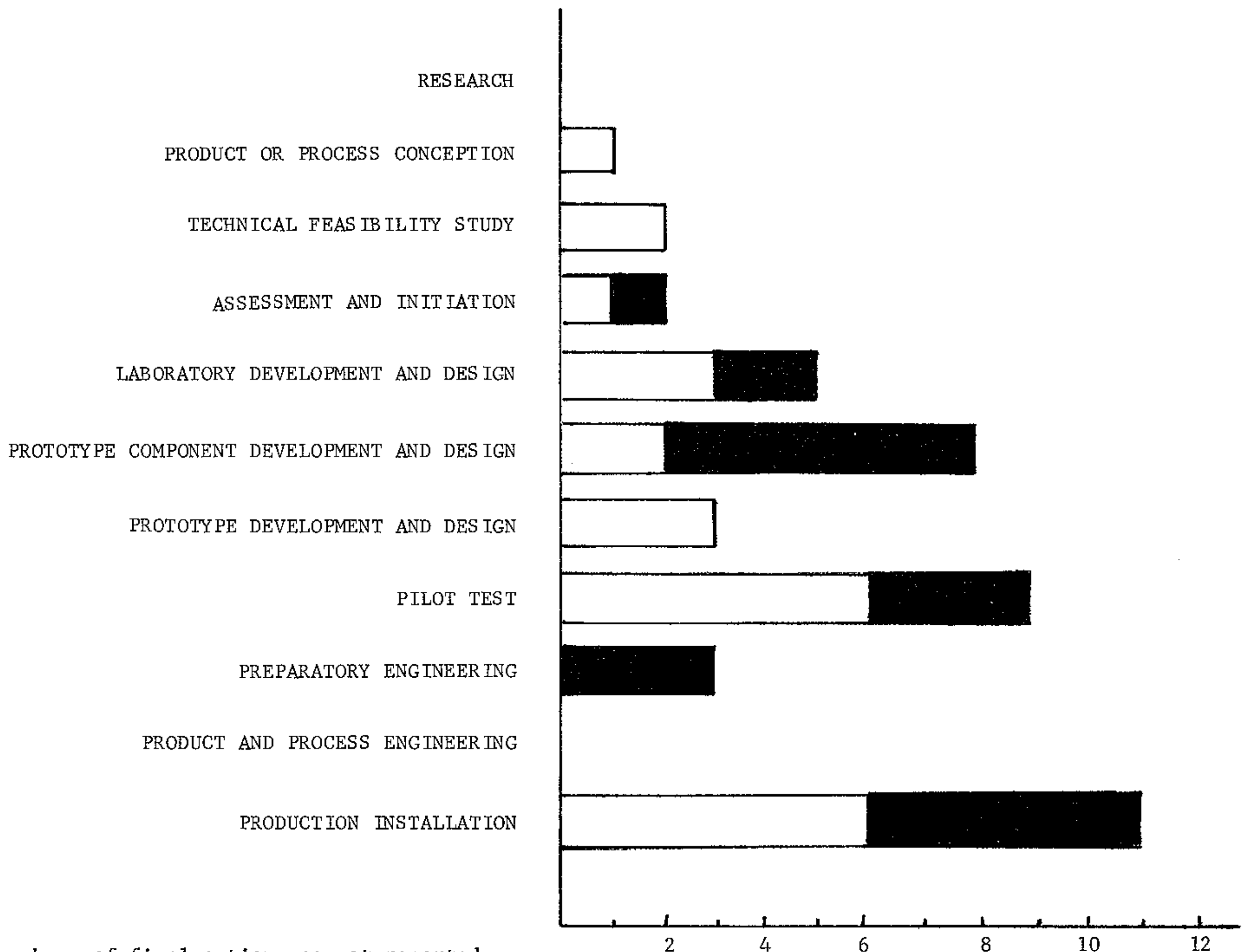
RESPONDENT EVALUATION OF INNOVATIONS BLOCKED BY TECHNOLOGY-RELATED OBSTACLES

	"GOOD"			"NOT GOOD"			TOTAL NUMBER
OBSTACLES	C	S	D	C	S	D	OF INNOVATIONS
Technological barrier: materials	-	-	-	-	1	1	2
Technological barrier: design	-	-	-	3	-	1	4
Technological barrier: superior competing technical approach	-	-	-	4	1	1	6
Lack of "key" technical knowledge	-	-	1	-	1	-	2
Difficulty in controlling process quality	-	1	1	-	1	-	3
Inadequate performance of purchased components	-	-	1	-	-	1	2
All other	1	-	-	2	-	1	4
TOTAL	1	1	3	9	4	5	23
PERCENT	4.3	4.3	13.1	39.1	17.4	21.8	100

C: cancelled
S: shelved
D: delayed

TABLE A-XIII

MANAGEMENT- AND ORGANIZATION-RELATED REASONS*

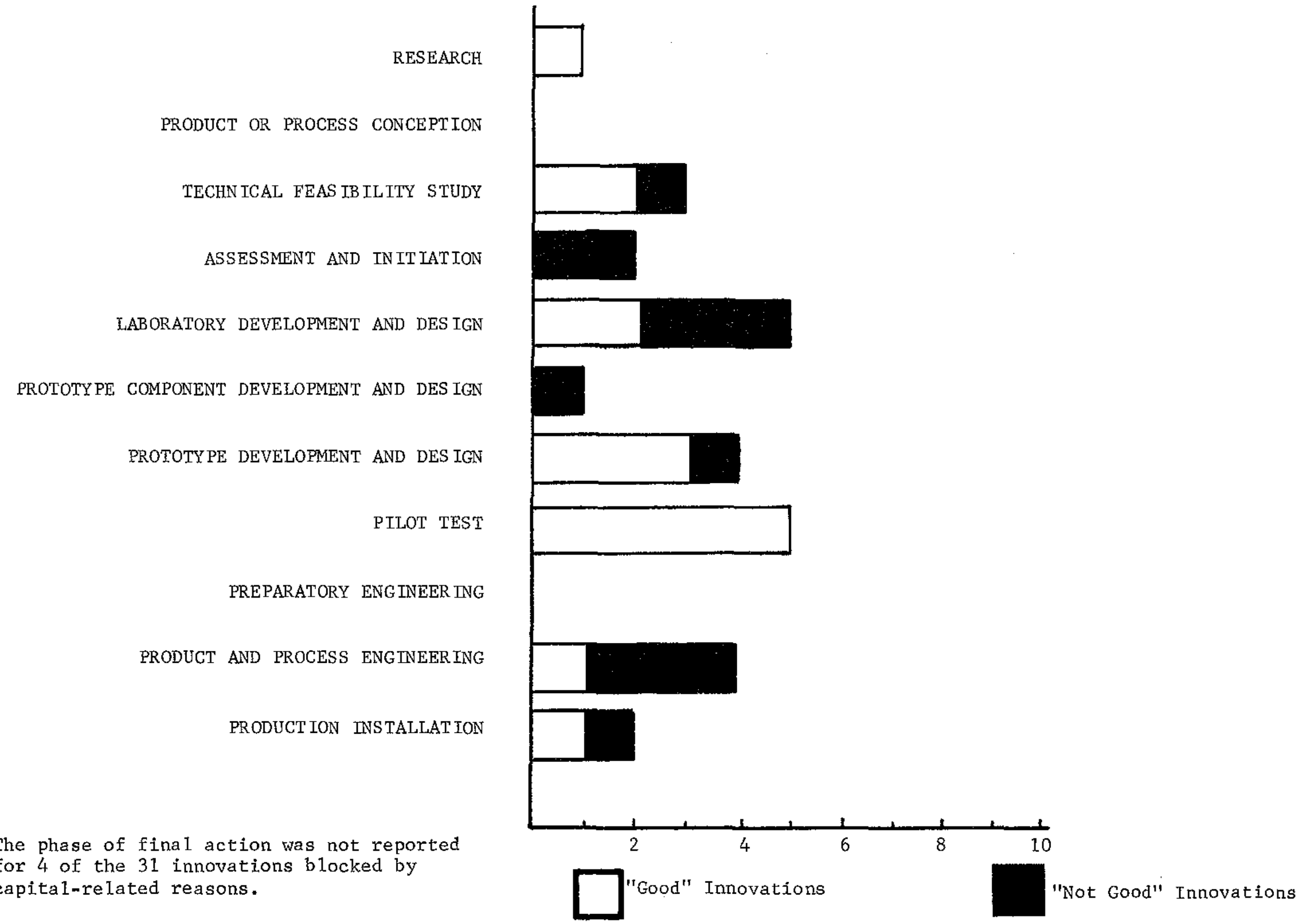


"Good" Innovations "Not Good" Innovations

* The phase of final action was not reported for 3 of the 47 innovations blocked by management- and organization-related reasons.

TABLE A-XV

CAPITAL-RELATED REASONS*



* The phase of final action was not reported for 4 of the 31 innovations blocked by capital-related reasons.

TABLE A-XVII

RESPONDENT RATING OF INNOVATIONS BY OBSTACLE AND SIZE OF FIRM

	"GOOD"					"NOT GOOD"					TOTAL
OBSTACLE	L	M	S	NV	TOTAL	L	M	S	NV	TOTAL	INNOVATIONS
Management	4	8	6	1	19	6	7	3	2	18	37
Organization and Staffing	2	2	1	2	7	-	2	1	-	3	10
Market	5	7	4	1	17	14	14	8	2	38	55
Capital	6	3	3	4	16	4	4	5	2	15	31
Laws and Regulations (excluding anti-trust and patent)	6	4	8	-	18	2	3	-	1	6	24
Patent	1	1	-	-	2	2	1	-	1	4	6
Antitrust	1	2	-	-	3	1	1	-	-	2	5
Technological	1	2	2	-	5	11	3	4	-	18	23
Miscellaneous	2	-	2	1	5	-	2	-	2	4	9
TOTAL	28	29	26	9	92	40	37	21	10	108	200

L: large firm
M: medium firm
S: small firm
NV: new venture

TABLE A-XVIII

CUMULATIVE (DECREASING) PERCENTAGE OF "GOOD" INNOVATIONS SURVIVING SUCCESSIVE PHASES (BY SIZE OF FIRM)

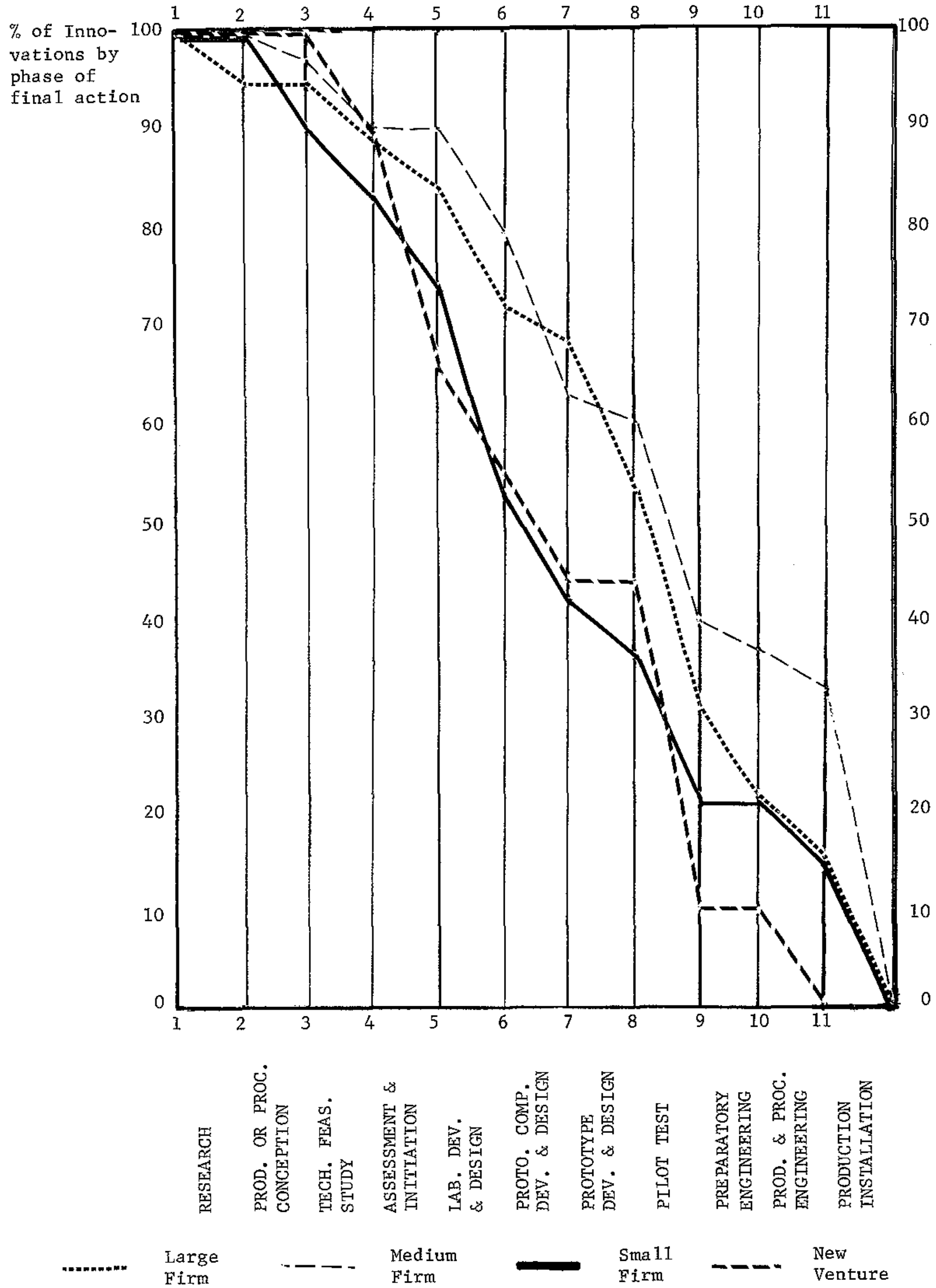
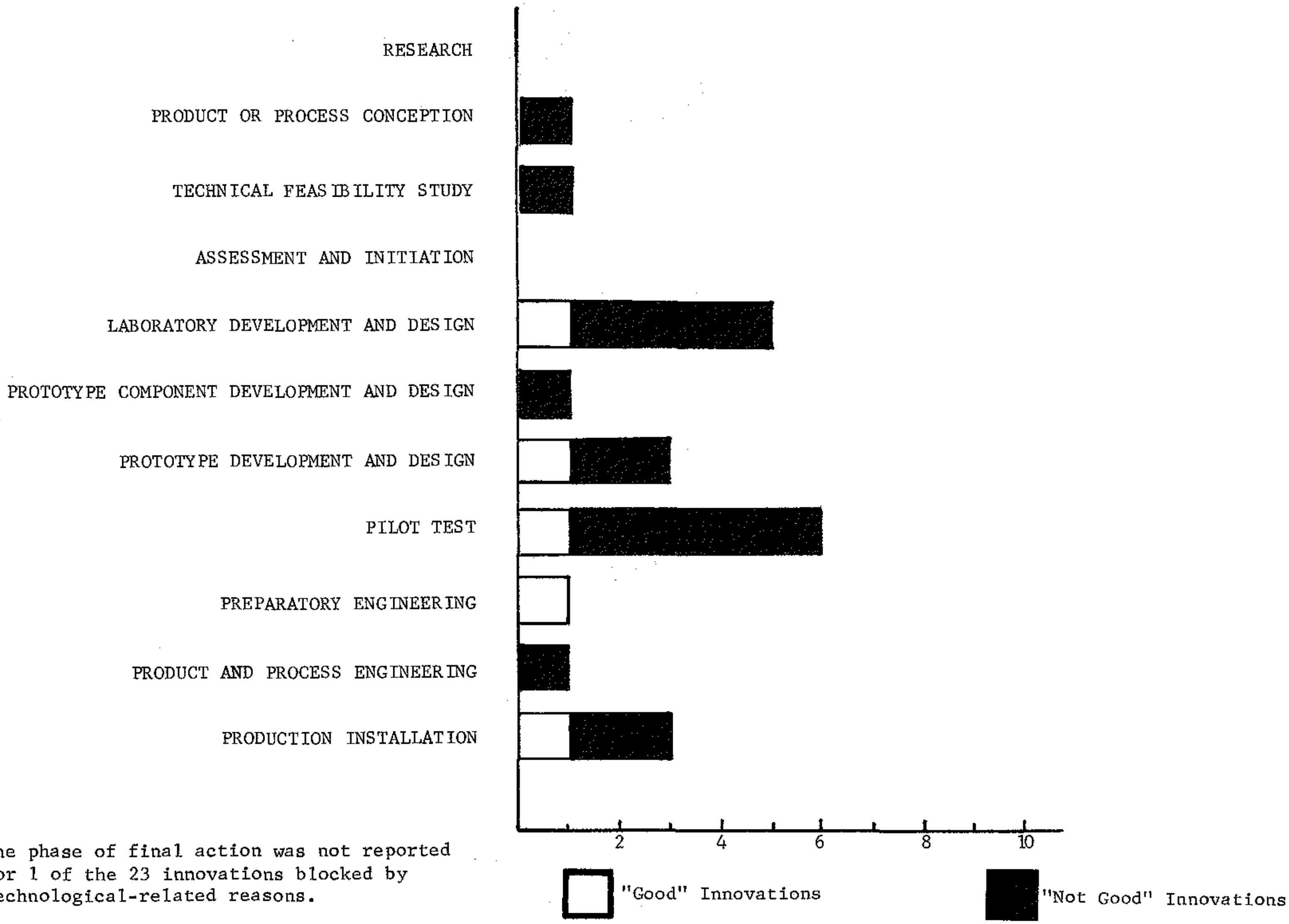


TABLE A-XVI

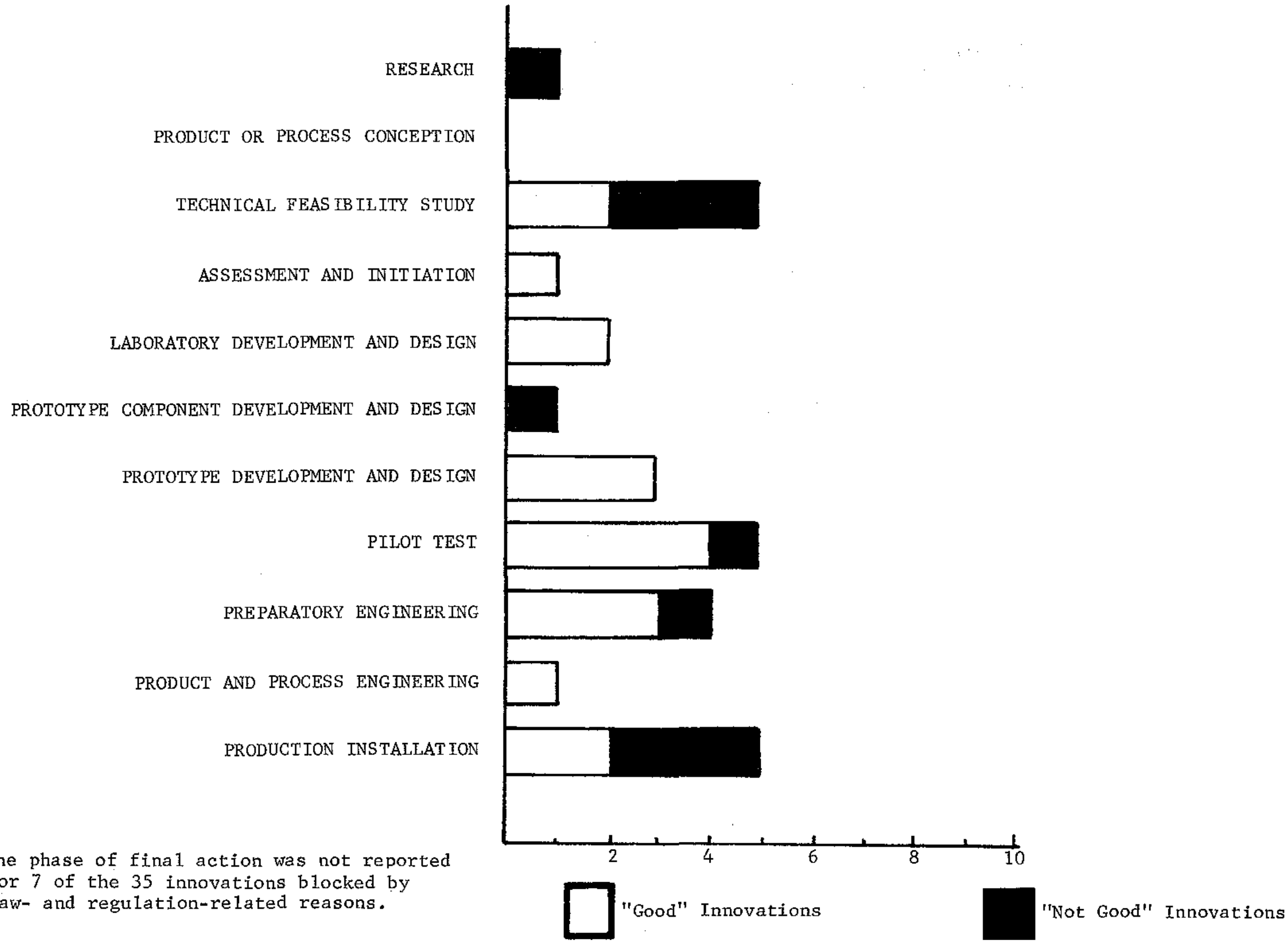
TECHNOLOGY-RELATED REASONS*



* The phase of final action was not reported for 1 of the 23 innovations blocked by technological-related reasons.

TABLE A-XIV

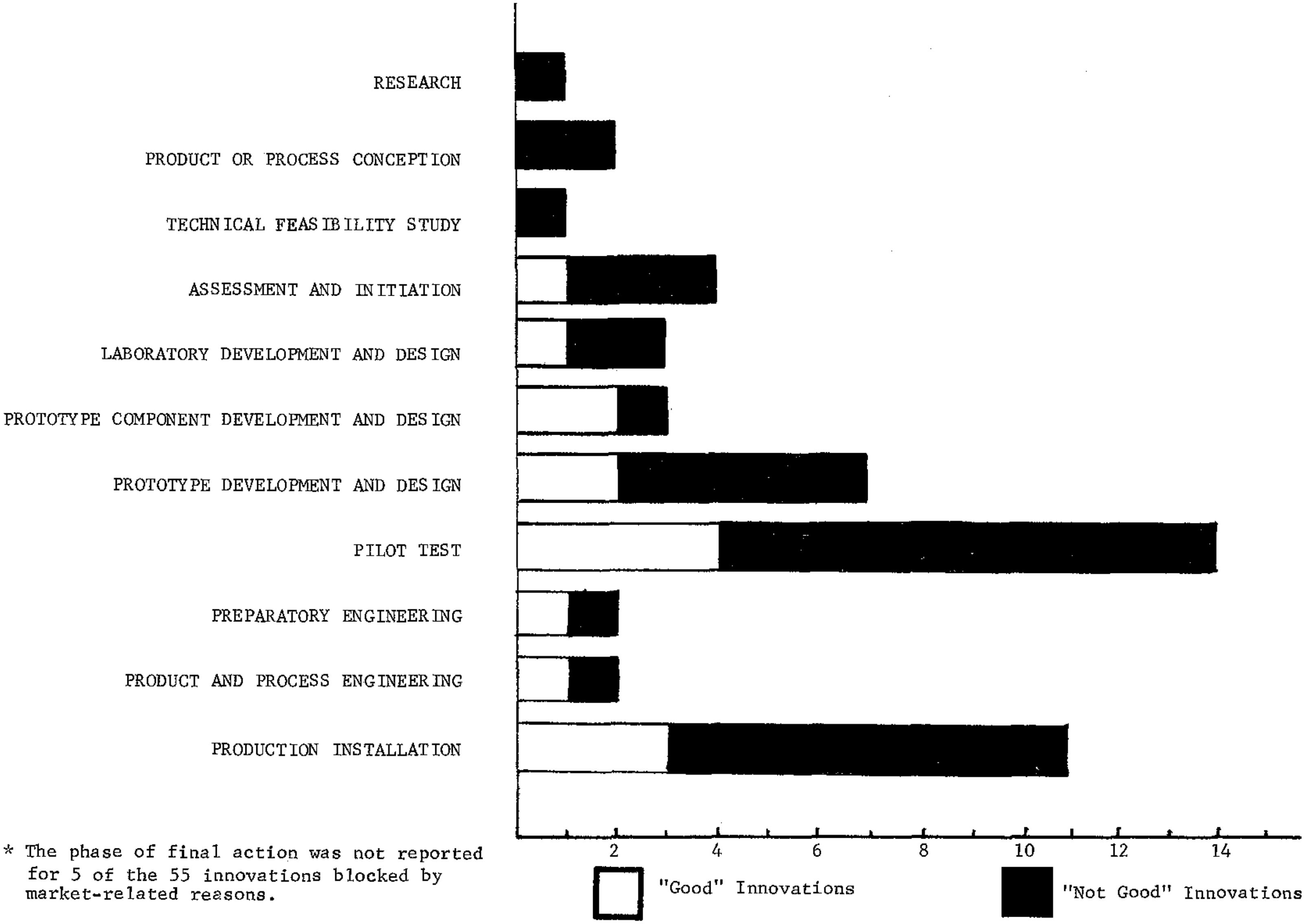
LAW- AND REGULATION-RELATED REASONS*



* The phase of final action was not reported for 7 of the 35 innovations blocked by law- and regulation-related reasons.

TABLE A-XII

MARKET-RELATED REASONS*



* The phase of final action was not reported for 5 of the 55 innovations blocked by market-related reasons.

TABLE A-X

RESPONDENT EVALUATION OF INNOVATIONS BLOCKED BY
CAPITAL-RELATED OBSTACLES

OBSTACLE CATEGORY	"GOOD" C	"GOOD" S	"GOOD" D	"NOT GOOD" C	"NOT GOOD" S	"NOT GOOD" D	TOTAL NUMBER OF INNOVATIONS
High cost of pilot and test program	-	2	1	2	-	-	5
Installation or changeover costs too high	-	1	1	1	2	-	5
Opportunity cost too high	-	2	-	-	2	-	4
Insufficient resources for needed research	4	-	-	-	-	-	4
Insufficient capital to start new product lines	-	1	1	1	-	1	4
Unfavorable risk analysis	-	-	1	2	-	-	3
All other	-	1	1	1	3	-	6
TOTAL	4	7	5	7	7	1	31
PERCENT	12.9	22.6	16.1	22.6	22.6	3.2	100
Percent of all Innovations Studied	2.0	3.5	2.5	3.5	3.5	0.5	15.5

C: cancelled
S: shelved
D: significantly delayed

TABLE A-VIII

RESPONDENT EVALUATION OF INNOVATIONS BLOCKED BY MANAGEMENT-RELATED OBSTACLES

OBSTACLE	"GOOD" C	"GOOD" S	"GOOD" D	"NOT GOOD" C	"NOT GOOD" S	"NOT GOOD" D	TOTAL NUMBER OF INNOVATIONS
Poor market analysis	2	-	-	5	1	3	11
Company policy not aggressive, reluctant to take risks	1	1	3	-	-	1	6
Inadequate performance requirements definition	1	-	1	2	-	-	4
Poor marketing planning or strategy execution (undersell, poor aim, oversell)	1	2	-	1	-	-	4
Inadequate cost analysis	-	1	1	1	-	-	3
All other	4	1	-	3	1	-	9
TOTAL	9	5	5	12	2	4	37
PERCENT	24.3	13.5	13.5	32.5	5.4	10.8	100

C: cancelled
S: shelved
D: significantly delayed

TABLE A-VI

RESPONDENT EVALUATION OF SECONDARY OBSTACLES*

PRIMARY OBSTACLES	Number of Innovations by Primary Obstacle	SECONDARY OBSTACLES								
		Manage-ment	Organiza-tion and Staffing	Market	Capital	Laws and Regula-tions	Patent	Anti-trust	Technology	Miscellaneous
Management	37		1	3	1	1				
Organization and Staffing	10	1								
Market	55	1			5	2	1		1	1
Capital	31		1	2			1			
Laws and Regulations	24				1				1	
Patent	6			1						
Antitrust	5					1				
Technology	23			2	1		1			
Miscellaneous	9									
TOTAL	200	2	2	8	8	4	3	0	2	1

*Those obstacles listed by the executives as secondary, when different from primary obstacle category

TABLE A-V (Cont.)

Category and Obstacle	Number of Innovations Blocked	Percent of Category Total	Percent of Innovations Studied
4. CAPITAL			
High cost of pilot production and test program	5	16.1	2.5
Installation or changeover costs too high	5	16.1	2.5
Insufficient resources for needed research	4	12.9	2.0
Opportunity cost too high	4	12.9	2.0
Insufficient capital to start new product lines	4	12.9	2.0
Unfavorable risk analysis	3	9.7	1.5
Insufficient capital to develop high risk markets	1	3.2	.5
All others in category 4	5	16.1	2.5
5. LAWS AND REGULATIONS (excluding patent and antitrust			
Federal requirements uncertain	7	29.2	3.5
variability	4	16.7	2.0
Federal standards too stringent	3	12.5	1.5
Inadequate technology base for government decisions	3	12.5	1.5
Excessive length/cost of federal test	1	4.2	.5
All others in category 5	6	25.0	3.0
6. PATENT			
Government's patent rights policy too restrictive	2	33.3	1.0
Inconsistency of court protection	1	16.7	.5
Competition has cross-licensed patents	1	16.7	.5
All others in category 6	2	33.3	1.0
7. ANTI-TRUST			
Antitrust law bars industry joint effort	3	60.0	1.5
All others in category 7	2	40.0	1.0

TABLE A-IV (Cont.)

Number of Obstacles Identified	Number of Innovations Blocked		
			Other (continued)
1	0	9-04	Restricted access (social) to test arena
1	1	9-05	No way to transfer from university to producer
			No Obstacles
-	4	9-99	No obstacles reported
256 OBSTACLES	200 BLOCKED INNOVATIONS		

TABLE A-IV (Cont.)

Number of Obstacles Identified	Number of Innovations Blocked		
			Laws and Regulations
8	7	5-01	Federal requirements uncertain
5	3	5-02	Federal standards too stringent
2	2	5-03	Inadequate knowledge of regulations
5	1	5-04	Excessive length/cost of federal tests
5	4	5-05	Interstate variability
1	1	5-06	EPA requirements preempted capital
1	0	5-07	Customer won't accept EPA standards
1	0	5-08	Concern over pollution potential
1	1	5-09	IRS investment rules
1	1	5-10	Product liability suits
3	3	5-11	Inadequate technology base for government decisions
1	1	5-12	OSHA regulations
			Patent
1	1	6-01	Competitor's patent preempted field
4	2	6-02	Government's patent rights policy too restrictive
2	1	6-03	Inconsistency of court protection
1	1	6-04	Technologically incompetent government patent staff
1	0	6-05	Government procurement violates patent law
1	0	6-06	Time delays in patent system slow capital funding
2	1	6-07	Competition has cross-licensed patents

TABLE A-IV (Cont.)

Number of Obstacles Identified	Number of Innovations Blocked		
			Organization and Staffing
4	3	2-01	Inadequate marketing expertise or distribution organization
2	1	2-02	Change of personnel
3	2	2-03	Inadequate internal responsibility assignments
5	2	2-04	Exceeded staff capabilities
1	1	2-05	Headquarters - Branch office organizational conflict
1	1	2-06	No sponsor for idea
			Market
1	1	3-01	Market instability
9	9	3-02	Limited sales potential
5	5	3-03	Inability to aggregate market
3	3	3-04	Superior competing concept extant
4	4	3-05	Too many competitors
2	2	3-06	Customer dropped or changed requirements
2	2	3-07	Market tightened - technology obsoleted
3	2	3-08	Customer resistance to new processes
1	1	3-09	Disagreement on joint venture marketing strategy
8	5	3-10	Customer's cost/benefit/risk analysis unfavorable
1	1	3-11	Marketing introduction would compete with customers
7	6	3-12	No perceivable market for public interest innovation

TABLE A-III

A-4

PHASES OF TECHNOLOGICAL INNOVATION

1. RESEARCH:
   Includes research definition, experimentation, analysis and evaluation.

2. PRODUCT OR PROCESS CONCEPTION:
   Completion of description of both the technical concept and the potential uses of the outcome of the project. Does not include experiments or analyses to demonstrate technical feasibility.

3. TECHNICAL FEASIBILITY STUDY:
   Completion of project proposal based on preliminary theoretical or experimental evidence of feasibility of the technical approach proposed. Includes determination of project costs and evaluation of potential value of results sought.

4. ASSESSMENT AND INITIATION:
   Concludes with decision of approval or rejection of project proposal. This decision may or may not include the assignment of manpower and funds to the project.

5. LABORATORY DEVELOPMENT AND DESIGN:
   Concludes with the first successful laboratory demonstration of the concept or of the crucial parts of the process. This phase produces what is typically described as the "breadboard" or "bench" models of the product or process desired.

6. PROTOTYPE COMPONENT DEVELOPMENT AND DESIGN:
   Concludes with completion of design or development of each component equipment or material to the level of performance believed necessary to achieve total product or process desired performance. Does not include the experimentation to solve component interaction problems.

7. PROTOTYPE DEVELOPMENT AND DESIGN:
   Concludes with the successful operation of the process or product incorporating all components and materials. Includes the resolution of component interaction problems.

8. PILOT TEST:
   Concludes with achievement of desired product or process characteristics on pilot plant equipment.

9. PREPARATORY ENGINEERING:
   Completed when all data and specifications needed for installation in production facilities have been determined and compiled.

10. PRODUCT AND PROCESS ENGINEERING:
    Completed with the first achievement of the acceptable rate and quality of production using the project results under plant conditions with plant personnel.

11. PRODUCTION INSTALLATION:
    Includes the continuation of the introduction of new processes or products into additional plants. Completed when all planned installations have been completed. (Note: Where installation requires significant additional laboratory work to adjust a process to the special requirements of a product line, that work would normally come within phases 2 through 10.)

INSTITUTE OF PUBLIC ADMINISTRATION

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LYLE C. FITCH, PRESIDENT

SUMNER MYERS, DIRECTOR
URBAN SYSTEMS STUDIES

July 17, 1973

Dear Mr.

The Institute of Public Administration has been asked to assist in the National Science Foundation's Experimental R&D Incentive Program. The Foundation's objective is to determine, by experiment, the actual effects of various incentive mechanisms which the federal government might use to increase the effective introduction and implementation of innovation. For your background information, a copy of the Foundation's description of the Program is enclosed.

Before designing experiments, the most important barriers to technological innovation must be more clearly understood and their relative importance established so that limited resources can be applied to the more promising experiments. One of our projects is to develop a prototype scheme for evaluating the relative priority of these barriers as objects of experimentation. If it is to be valid, such a scheme must be based upon the experience of those who have directly participated in decisions concerning innovation in American industry.

We will greatly appreciate an opportunity to learn from you something of the problems you have encountered in this area, and to discuss with you some of your ideas concerning the ways these obstacles can be overcome. We plan to collect our data by discussing a limited set of questions by telephone sometime during your normal work day, at a time convenient to you. We expect that no more than 20 to 30 minutes will be needed although any added comments you want to make will be welcomed. I am enclosing a brief description of the kind of information that will be of value. The data will be used in a way that will protect the anonymity of firms and individuals who have contributed information.

A member of our project staff will contact your office within the next week to work out a specific date that is convenient to you for a telephone conference. Thank you, in advance, for your assistance through the sharing of your experience with us.

Sincerely yours,

Sumner Myers

Sumner Myers, Director
Urban Systems Studies

SM:lg

productivity. One simple and direct way of doing this might be to guarantee loans intended for the acquisition of productivity. One simple and direct way of doing this might be to guarantee loans intended for the acquisition of productivity-improving technology. The loans themselves might be backed up by equipment trust certificates, such as those used for years in the capital-short railroad industry. More ambitiously, the government might consider forming a Productivity Bank through which productivity loans could be expeditiously made against performance criteria.

Finally, the government might improve its regulatory processes. This is an excellent target for direct government intervention on behalf of innovation: most of the innovations blocked were good ones. The form--if not the substance--of regulation, is an area in which government administrators can exercise considerable control; and efforts directed to this area do offer promising opportunities for improving the rate of innovative success in industry. For example, it would be most helpful if the government could provide advisory guidance concerning the applicability of a regulation and means by which the potential product or process could be adapted to meet regulatory requirements. Firms are often required to launch projects in the absence of such advice and discover--too late--that their new products or processes have to be expensively adapted to meet regulatory requirements which they had "incorrectly" interpreted. This type of governmental assistance is surely well within the existing capabilities of regulatory bodies.

that might otherwise occur by continuing to fund R&D. Past funding has had a beneficial effect; another study of 567 commercially successful innovations showed that government-sponsored technology was an important basis for a large percentage of innovations--10 percent.[2] That percentage is put into perspective when compared with the single most important outside source of technology: vendors. Vendors supplied the technology base for 12 percent of the 567 innovations studied. Thus, it would appear that the results of government R&D have successfully permeated the nation's technological system and are, in fact, used extensively. And this, of course, argues for continued expenditure of government monies for R&D in the future.

Capital factors and government regulations remain as the most promising targets of direct government policy. Firms of all sizes appear to need capital for innovations; and half the innovations blocked by capital shortages were found to be good ones. The government could, through such measures as guaranteed loans, tax credits, depreciation allowances, etc., help to make more capital available. There is little doubt that more available capital would expedite the development of more innovations. There is a danger, however, unless this capital is made available for carefully circumscribed objectives

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[2]Ibid., 50. This is a surprisingly high figure in view of the notable failure of direct government efforts to develop useful civilian technologies. One might ask why government technology is not more visible than it is. The answer is that it has found its way into innovations that are important to the firm but not big enough for an historian to write about.

marketing obstacles at all--that is, process innovations. Such innovations avoid largely marketing obstacles when they are used within the firm itself to increase quality and/or decrease costs. In stimulating firms to undertake process innovations for their own use, the federal government would not only improve the success rates of those firms; it would also get them to accomplish innovations that improved firms' productivity--something that is in the national interest.

Management and organization factors are also poor targets for direct government help. Here too, the most effective role that government can play is an indirect one: it can assure the widest communication of results of studies such as this to the many specialized institutions concerned with the improvement of managerial performance capabilities. More direct intervention in the education of managers--for example by sponsoring university programs--would necessarily be of such limited scale and effect that the resources would be largely wasted. Whatever the case, the problem is not so much to train managers how to manage, it is to remind them to ask the right questions: Does the innovation have a product champion? Are internal responsibilities for the innovation clearly assigned? Are staff capabilities matched to the innovation tasks involved? Is the cost analysis of the innovation adequate? And so on.

Other studies of innovation have suggested that the government can help management function better by providing timely market information that could be the basis for correct innovative decisions. This can do little, if any, harm but the data at hand suggest it is unlikely public policy directed solely at helping technological innovations at the firm level can do much to improve industries' success rates. This may come as something of a shock to those who have grown accustomed to attempted governmental intervention in a wide range of problems. Nevertheless, this may well be the case regarding most of the factors that block industrial innovations.

If government policy is to help improve the rate of success of those innovative ideas which enter the R&D pipeline, it must be able to (1) identify the major blocking obstacles; and (2) affect those obstacles in a significant way. The first condition has been met--at least in part. This study has identified important factors blocking innovation.

In terms of affecting those obstacles in a significant way, this study showed that limited sales potential is the single biggest market factor blocking innovation. Similarly, an earlier study showed that anticipated sales potential was the single largest factor stimulating innovation.[1] In a sagging economy, it is hard for innovations to get started, let alone succeed--even if there is a benign regulatory policy, shrewd management and all the technology in the world. A booming economy, on the other hand, spurs innovation more than anything else because it generates the demand to which innovation responds.

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[1]Sumner Myers and Donald C. Marquis, <u>Successful Industrial Innovations: A Study of Factors Underlying Innovation in Selected Firms</u>, National Science Foundation, NSF 69-17 (Washington, D.C.: Government Printing Office, 1969), p. 32.

TABLE VIII

FACTORS BLOCKING INNOVATIONS
BY SIZE OF FIRM

(Percent of Innovations)

OBSTACLE	LARGE	MEDIUM	SMALL	NEW VENTURE	TOTALS
Management and Organization	17.7	28.8	23.4	26.3	23.5
Market	27.9	31.8	25.5	15.8	27.5
Capital	14.7	10.6	17.0	31.6	15.5
Laws and Regulations	19.1	18.2	17.0	10.5	17.5
Technology	17.7	7.6	12.8	-	11.5
Miscellaneous	2.9	3.0	4.3	15.8	4.5
TOTAL NUMBER	68	66	47	19	200
PERCENT	100.0	100.0	100.0	100.0	100.0

more heavily at terminal phases; but "not good" innovations were blocked much earlier, prior to the pilot test.

Technology blocked few innovations in the early stages of development, where it is often cited as a factor, but did appear as a problem in the middle stages where the classic problems of subsystem interaction and producibility become salient.

Size and Type of Firm

Since the sample was not intended to represent a microcosm of American industry, and was not a sample in a statistical sense, no attempt was made to analyze the data in terms of firm types, i.e., the products they produced. However, every attempt was made to give attention to a cross-section of major industries. Eleven types of industries were interviewed, but four industries, chemicals, engines, nonagricultural tractors, and iron and steel, accounted for 58 percent of the interviews and 62.5 percent of the innovations. Generally, for all types of industries, the number of innovations reported was proportional to the number of firms interviewed. An exception was iron and steel firms, which made up 8.7 percent of the firms interviewed but reported 13 percent of the innovations.

Since the size of firms is often pointed to as a factor in innovation some analysis of this was included in the present study. Included with the large, medium, and small firms were a number of "new ventures," firms built around the product whose commercialization was being attempted. The number of unsuccessful innovations reported in each category of firm was roughly proportional to the number of such firms included in the sample, although large firms reported somewhat may be necessary before flaws are uncovered, but remember that technology was cited less than any other factor as a primary blocking agent.

Looking at the entire sample, there is little difference between "good" and "not good" innovations in terms of the phase at which they are blocked, as Table VII indicates. Seventeen percent of the good ones make it to the "final cut" of production installation, but the same is true for 20 percent of those judged "not good."

Although there is little correlation between phase of development and the "goodness" of an innovation, some patterns are discernible when the innovations are examined in terms of primary blocking factors. (Graphs for each factor are presented as Tables A XII-XVI.)

In particular, market-related factors tend to block innovations later in the development process, about a quarter of them falling at the pilot-test stage. Respondents judged a preponderance of these innovations to be "not good" ones with higher mortality observed during early phases. The judgment of the market is not debated, it is conclusive.

Management-blocked innovations exhibited a similar pattern, including the large numbers dropped at the pilot-test and product-installation stages.

Capital factors tended to show their effects pretty much across the board, although capital is a more important cause of "good" innovation mortality at the pilot-test and product-engineering phases than at the beginning, where little or no capital is ordinarily needed, and at the end, where it is presumably available. Regulations blocked "good" innovations process or "pipeline," was divided into 11 segments and a determination was made, based on the management interviews, at which segment each innovation was blocked.

The hypothesis was that a pronounced number of failures at particular stages would point to certain factors producing the failure. Thus, if most innovations wash out at the early research and planning stages, it would indicate a lack of technology, or possibly capital. If most innovations survived until the production installation stage, it would suggest that the market was the all-important variable. There are cost implications for management, of course, should large numbers of innovations get past the relatively inexpensive laboratory and prototype development phase only to fail later. Figure 3 shows the percentage of the total number of innovations that had failed by the time each development phase was reached.

The graph indicates that the middle phases of development, especially the pilot test, along with the phase of production installation, are the peak times for weeding out innovations. Nearly 90 percent survive the technical feasibility study and go into some phase of design and development, but only 29 percent pass through the pilot test successfully. If they do, they have a good chance to make it to the production installation stage, where the last 19 percent or so of the innovations in this study were wiped out. It is noteworthy that almost three out of four innovations entering the pipeline made it all the way into pilot test before management decided to call a halt. Where tricky technical matters are involved, of course, extensive development work accounted for about equal numbers of blocked good innovations, with technology a minor factor. With regard to "not good" innovations, the market far outweighed other blocking factors. Management performance was a distant second with the other three major factors vying for third, as indicated in Table VI.

To sum up, we have seen that the primary factors blocking innovation are, in order, market, management, regulations, capital, and technology. The relative impacts of management performance and capital remain about the same with respect to both "good" and "not good" innovations. In absolute terms, however, management emerges as the leading factor blocking "good" innovations. Market factors display a Darwinian tendency to frustrate many more "not good" than "good" innovations. Technology has the same relative effect, although its overall impact is much smaller, in any case. Regulations work in the opposite direction; they killed off twice as many "good" as "not good" innovations.

Certainly, for policy decisions, primary attention should be given to obstacles blocking "good" innovations. An important point illustrated by Table V is that if a good item is going to be blocked, it will be due to something other than technology.

Phases of Development in Innovation

Before an innovation actually reaches the market, it goes through a series of phases--initial research and feasibility determination; laboratory and prototype design and development; a pilot test and the engineering work leading to product installation. In this study, the

It might be delayed or it might be shelved pending some change that could make the product commercially successful. Or it might be cancelled if it appeared that the unanticipated blocking factor would be too difficult to dislodge. It was still a "good" innovation. In a way then, management officials, in assessing innovations as "still good" or "not good," were really critiquing both the wisdom of the firm in proceeding with the innovation and the market worth of the innovation itself.

More information on the wisdom of innovation decisions should shed more light on the factors blocking innovation, at least in a general way. If a preponderance of blocked innovations are judged "good," for example, it may mean that the market is hard to anticipate or government regulations are difficult to interpret.

The data do not yield such a clear-cut conclusion. Of the 200 innovations studied, about equal numbers were judged to be "good" and "not good." The "not good" innovations were as likely to be cancelled as shelved or delayed. "Good" innovations were cancelled much less frequently than "not good." Table V gives the complete results.

When "good" and "not good" innovations are related to the various factors blocking them, the results are also a little surprising. The expectation might be that "good" innovations would be affected more often by factors external to the firm and thus more difficult to predict and control. Not so. Management performance and organization factors block more good innovations than any other category--nearly 30 percent of the total. Laws and regulations is a close second. Marketing and capital

As noted earlier, in about one-fourth of the cases, the respondents cited a secondary reason for an innovation blockage in addition to the primary reason. (The results are summarized in Table A-VI.) In general, no particular pattern emerges in the linkage of primary and secondary factors. The market and capital were the two most frequently cited secondary reasons for innovative failure, but the numbers involved are too small for any real conclusions to be drawn. The remaining findings in the study are accordingly based on an analysis of primary factors alone.

It is apparent that a large share of the obstacles to industrial innovation are less susceptible to direct government action--just about two-thirds of them, to be exact. Of course, the categories are very broad, so that government action might be able to affect specific aspects of a field generally beyond its reach.

The point should be kept in mind because, within the major obstacle categories (including organization, patents and antitrust as major), specific obstacles often stand out as particularly important. (Table A-IV in the Appendix lists the primary obstacles to innovation mentioned; Table A-V groups these into general and specific obstacle categories.)

The chief market problem for the producer's goods industrial segment was limited sales potential for proposed innovations, including public interest innovations; this accounted for over one-quarter of the market obstacles cited. Only five of the 55 innovations blocked by the market fell victim to the company's inability to aggregate a fragmented market for them. This figure seems remarkably low. However, it probably understates the negative influence of fragmented markets; innovations are not funded at all and never enter the pipeline if it is obvious at the outset that a market cannot be aggregated for them. Similarly, the effects of competition also may be understated; only four innovations were blocked because there were too many competitors in the market. Here, too, the obvious problem of entering an already crowded field would block innovation at the outset. The effects of competition manifested themselves with respect to technology: in fully one-quarter of the innovations blocked for technological reasons, the innovation. If the problems are mostly internal, the responsibility for innovative success or failure devolves primarily on management in the private sector of the economy. On the other hand, if the chief offenders are external, industrial firms may well need outside assistance in grappling with innovation. Figure 1 presents one way of classifying the blocking factors in this light, excluding the miscellaneous category.

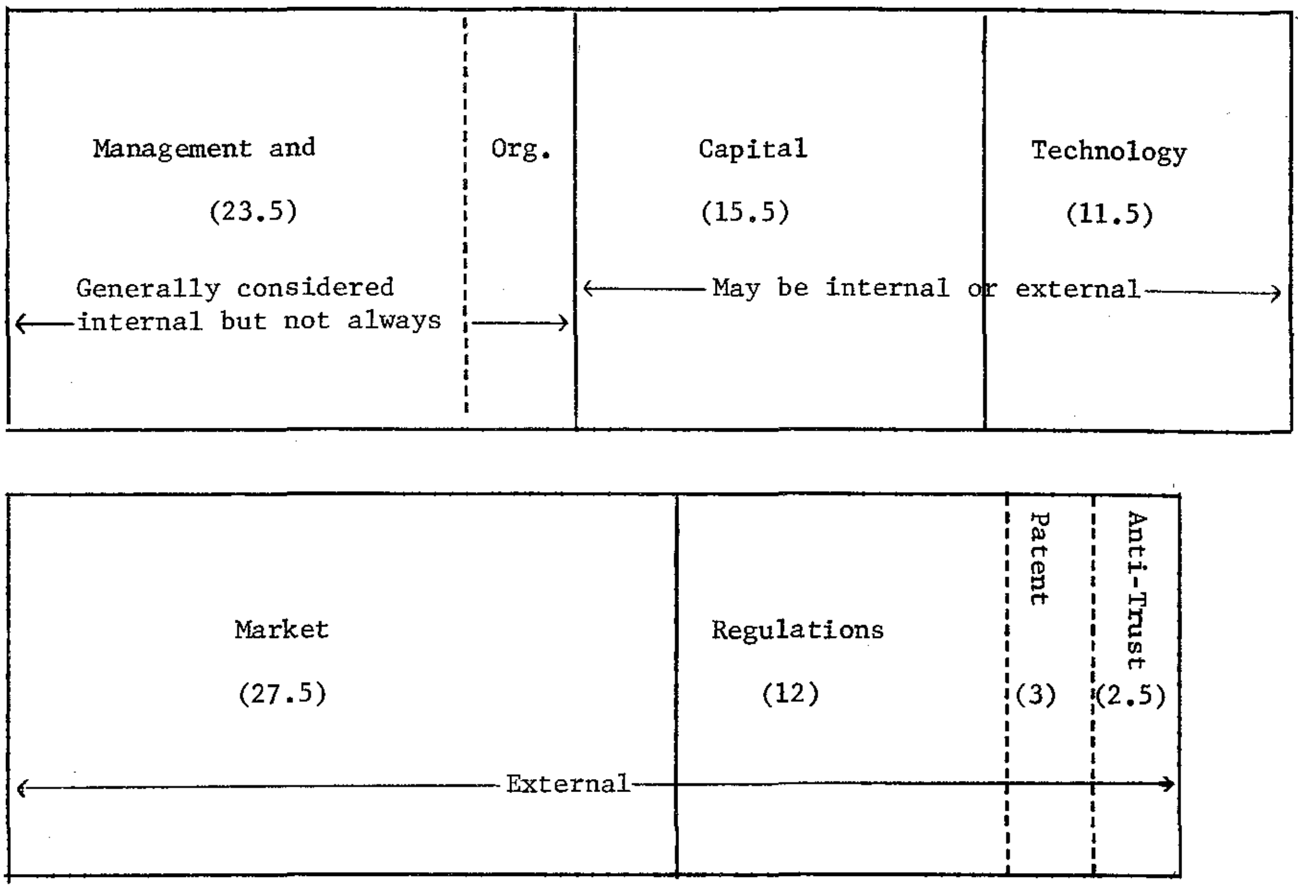

Figure 1

PERCENTAGE OF INNOVATIONS BLOCKED BY
INTERNAL AND EXTERNAL FACTORS

were unresponsive because marketability had not been demonstrated by available data (which could only be obtained through field tests!). (The barrier in this case was classified as capital.)

Case 2: A superior competing technological approach can cancel the development of a new product or process. A major metals company undertook the development of vacuum deposition of aluminum as a substitute for tin plate in cans and other containers. The process was developed through completion of a full-scale, high-speed production line--which never went into full production because the firm discovered that chrome plate was much cheaper and just as good. The entire production line for aluminum production remains mothballed by the firm. (The barrier in this case was classified as technological.)

Case 3: The assumption that an innovation will be in violation of antitrust regulations can prevent development of the innovation. A medium-sized steel company developed a process for reclaiming zinc and iron by processing pelletized dust reclaimed from scubbers of exhaust gases. The quality of the zinc by-product made the process look economically promising at the pilot-plant stage, if sufficient tonnage of reclaimed dust could be obtained. More than one plant was required if this tonnage was to be obtained. When a joint venture with other steel companies was explored as a feasible basis for full-scale operation, however, the objection was raised that such a venture would violate antitrust laws. The process has not been developed further in spite of its economic and ecological advantages--although the requisite joint venture might or might not violate antitrust laws: the Department of

TABLE IV

PERCENTAGE OF INNOVATIONS BLOCKED BY PRIMARY FACTOR

Primary Factor Blocking Innovation	Number of Innovations Blocked	Percent of Total
Market	55	27.5
Management (including organization)	47	23.5
Laws and Regulations (including patent and antitrust)	35	17.5
Capital	31	15.5
Technology	23	11.5
Miscellaneous	9	4.5
TOTAL	200	100.00

production and changeover, insufficient resources and opportunity costs. However, the incidence of capital as a barrier, blocking approximately 15 percent of the innovations coupled with its susceptability to government action, suggests that it is a factor that should be addressed in considering policy options.

The findings of the study suggest that the role of government in encouraging innovation is necessarily both limited and indirect. Increased support for R&D is unlikely to solve the problem because technology is not the major reason for the failure of innovations. In fact, for "good" innovations, it is the least important of the categories. Market and management are generally beyond the scope of direct governmental intervention, although some actions can be taken in these areas, such as providing an initial market or supporting management training. Government can play an important role in some areas, however, particularly in reconsideration of laws and regulatory requirements that may impede innovation and in supporting accumulation of business capital.

Consideration of Some Factors Underlying the Obstacles

Phase of development. Data gathered included information on phase of development at which the innovation was blocked. An eleven-stage model of the innovation process was used, ranging from research to product installation. Two phases of development--pilot test (stage 8) and production installation (stage 11)--are the peak times for weeding out innovations. These stages generally require major capital investment so the results are not surprising, with the capital investment requirements forcing a "hard look" at the other factors such as market, management and technology.

TABLE III

OBSTACLES TO INNOVATION

OBSTACLE		TOTAL	"GOOD"	"NOT GOOD"
Capital	%	15.5	17.4	13.9
	(n)	(31)	(16)	(15)
Laws and Regulations	%	17.5	25.0	11.1
	(n)	(35)	(23)	(12)
Management	%	23.5	28.3	19.4
	(n)	(47)	(26)	(21)
Market	%	27.5	18.5	35.2
	(n)	(55)	(17)	(38)
Technology	%	11.5	5.4	16.7
	(n)	(23)	(5)	(18)
Miscellaneous	%	4.5	5.4	3.7
	(n)	(9)	(5)	(4)
	%	100	100	100
	(n)	(200)	(92)	(108)

Within this framework, respondents were asked to indicate the phase in the development process in which a decision was made to drop an innovation and to discuss the factors inducing that decision. The respondents had no difficulty in identifying the phases--research, technical feasibility study, laboratory development and design, pilot test, etc.--but they did so in their own words, which were then converted to a standard classification. (See Table A-III.)

In most cases, the innovation was acted upon for one primary reason which the respondent clearly stated. In 56 of the 200 cases, other reasons were also provided. But the primary reasons were considered so compelling that it seemed appropriate to analyze the data only in terms of the primary causes of innovative failure, although some discussion of linked reasons is also included.

Finally, the study probed the attitudes of the management officials concerning the innovations that had failed. Based on the respondents' judgments obtained in the interviews, the innovations were classified, in broad economic terms, as either innovations that the respondents still considered to be "good" or as innovations that they now believed were "not good," in view of the events that led to blocking. Obviously, these were subjective judgments made by respondents, but there did not seem to be much hesitancy in making them. Indeed, when there were multiple respondents commenting on the same innovation, there was almost invariably agreement as to whether the innovation was good or not good. However, an interviewee who was closely associated with an innovation, possibly as the innovation's

TABLE II

SIZE OF FIRMS INTERVIEWED

Industry Size	Number Interviewed	Number of Innovations
Large	23	68
Medium	25	66
Small	21	47
New Ventures	12	19
TOTALS	81	200

Table I

TYPES OF FIRMS IN SAMPLE

Type Industry	Number Interviewed	Number of Innovations
Nonagricultural Tractors	17	40
Engines	13	29
Chemicals	10	30
Iron and Steel	7	26
Computers	7	14
Electric Components	6	12
Instruments	6	9
Electric Power Machinery	5	11
Plastics	4	12
Aluminum	3	11
Other Machine Tools	3	6
TOTAL	81	200

learnedly on innovation in general but to describe and evaluate what actually happened in particular cases.

The man on the scene may also have his biases, of course. Blaming one's mistakes on others is a common enough human failing. Would not management officials, asked to explain an innovative failure, tend to point to scapegoats--petty government bureaucrats, greedy union officials, ignorant engineers, etc.? Surprisingly enough, in no interview was there evidence of such scapegoating. On the contrary, management talked freely and openly--and not without humor--about errors of judgment of which they had been guilty. Perhaps because innovation is so risky, there is no particular stigma attached to the corporate officials who "blow one." The attitude of "you can't win them all, even though you try " was prevalent.

If scapegoating was not a problem, neither was faulty memory. Can people really recall why an innovation was blocked, when the decision was made, what they thought about the decision, etc., given the many corporate decisions that have to be made? The answer, in this case, is an unequivocal "yes." Respondents without exception remembered the innovations and the circumstances surrounding them, even down to fine points. Again, the reasons for this can only be the subject of speculation at this point. For example, all respondents were alerted by letter before being interviewed and had some time to reflect on past events or even consult files. A factor of likely greater importance is that once an innovation has been funded, even to a small degree, the decision to drop it is a wrenching experience that everyone remembers.

innovations are not the mirror images of factors that block innovation. Nor will the presence of factors associated with success necessarily result in success; new products or processes can be blocked even though all of the success factors are present. Thus, remedial policies designed to increase the number of innovation successes must both ensure that the conditions for success are maximized and that the chances of blockage are minimized.

The study considered only innovations that were blocked after they had been selected for funding and were in the pipeline; it does not address issues related to the conception of ideas for innovations prior to the initial funding of technical work. Therefore, relative importance of factors affecting innovation identified in this study might shift significantly if blockage of ideas for innovations also was considered.

Firms. Prepared for NSF under Contracts NSF C-321 and C-556, NSF 69-17, 1969.

Project Hindsight (First Interim Report and Final Report). Prepared by the Office of the Director of Defense Research and Engineering, Department of Defense, 1966 and 1969, respectively. AD-642400 and AD-495905 (available from NTIS, Springfield, Virginia).

Science, Technology and Innovation (Preliminary Report) and Interactions of Science and Technology in the Innovative Process: Some Case Studies (Final Report). Prepared for NSF by Battelle Institute, Columbus, Ohio, under Contract NSF-C667, 1973.

Technology in Retrospect and Critical Events in Science. Prepared for NSF by the Illinois Institute of Technology Research Institute, under Contract NSF-C535, December 15, 1968.

Industrial "innovation" is a progressive activity beginning with the conception of a new idea and culminating in a new item of economic or social value--a new product, a new component of an existing product, or a new production process. In a world in which technological advance and economic growth are standard measures of success in industrial competition, innovation is essential to survival, both for business firms and for nations. Thus, the high rate of failure which seems characteristic of industrial innovation in the United States must be a cause of concern for public policy-makers as well as for corporate management.

The problem can be attacked from both ends of the innovative process. Given the high mortality rate of innovations entering the pipeline, the assumption is sometimes made that the number emerging successfully can be increased by increasing the number that begin the journey. This requires that more be done to stimulate creativity, to spur inventions, and to increase research and development (R&D). The correctness of such a policy has long been an article of faith among many in the R&D field. Put more money into research and development, many say, and there will be more successful industrial innovations.

A corollary policy is to attack the barriers to innovation, to find out why innovations fail and make appropriate changes so they are not necessarily blocked. Many in business and government, concerned with spiralling R&D costs, tend to favor this approach. The policy option is something like that which an impoverished underdeveloped country faces trying to maintain an adequate work force in the face of