EMPIRICAL SUCCESS RATIOS IN USDA AGRICULTURAL UTILIZATION RESEARCH

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In assessing the prospective utility or value of a research program there are three important considerations: (1) potential impact the research will have on the scientific field involved, (2) probable benefits to industry or the public sector and (3) probability of success of projects in achieving these goals. Various studies have been made that emphasize the first and second objectives, i.e., trying to determine both scientific merit and economic value or return on investment in research projects and programs [see 6, 7, 8, 12, 13 and 15]. This paper will be concerned with the latter objective: estimating the probable success of projects which were part of an organized agricultural research program conducted by USDA over a 25 year period.

Success is a relative concept, depending upon the criteria used in evaluating it. Research projects can be evaluated on the scientific or technical merit of the work, the social merit or public welfare implications of results, or some estimate of economic benefits over time. In planning research projects, various types of work sheets and procedural devices are used to try and estimate the probable outcome of certain lines of work — based on certain selected criteria or factors [3, 14 and 19]. However, procedures are complex and subjective, creating considerable uncertainty in trying to estimate the probable success of proposed projects.

Project appraisals on and *ex ante* basis are subject to the best judgement and information available at the time the project is initiated. Consideration is given to types of technical problems involved in the project, logic and clarity of the proposed approach, availability and quality of scientific and technical skills and available manpower, and other factors [3]. The degree of success achieved from previous projects and programs can also be a useful indicator of success. Such indicators can be determined, *ex post,* based on certain standards or defined criteria which empirically reflect the program's performance. Empirical success ratios derived from such a process may be useful in considering new or revised programs of work.

PROCEDURE

Data for this study were obtained from the agricultural utilization research program of the U.S. Department of Agriculture,[1] established in 1939 to create new and improved products and processes for agricultural commodities. It is an organized research program conducted in five regional laboratories in various geographic regions of the U.S. Research emphasis is centered on chemical, physical and biological properties of farm products, but some applied and developmental research is also conducted to help insure the commercial application of results.

In the mid-1960s a comprehensive study of this research program was undertaken to appraise its achievements over a 25 year period. The evaluation was conducted by research teams consisting of senior scientists in specific areas of work, one or more economists associated with the program or the planning and programming staff, and administrative officers of the program. Achievement sheets were prepared for each

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[1]For backgrounds information on this program see [9] and [16].

project believed to have produced a significant innovation.[2] These reports were then subjected to further review by laboratory chiefs and higher level management.

Since the inception of the research program in 1939, a total of 150 projects were considered successful from the standpoint of economic merit. These projects produced 110 different innovations that were commercialized by industry and agriculture. A number of other projects also produced results that were on the verge of being utilized but had not reached the commercial stage by 1966. This was probably a conservative estimate of the number of successful projects, since there were probably some accomplishments that were not reported or were overlooked. In addition, some commercial developments could not be directly attributed to utilization research.

For this study, the number of successful projects was based on results reported in achievement sheets. Selected data on these projects were compiled on an annual basis from 1949 to 1965 [17]. This information was then used to construct empirical success rates along with a probability distribution of successful projects and a control chart showing the proportion of total projects that were successful, with upper and lower limits of success.

RESULTS OF EMPIRICAL ANALYSIS

A project was considered successful if it resulted in an innovation that was adopted commercially by industry or agriculture. The nature of the innovation and the year in which it was commercialized were reported in achievement sheets. The number of successful projects varied from year to year, with at least two and as many as eight innovations per year being produced from the three to four hundred domestic projects currently active (Table 1). This means that successful innovations were derived from less than 2 percent of the projects currently active in any given year.

Table 1. NUMBER OF INNOVATIONS AND OBSERVED SUCCESS RATIOS FOR USDA AGRICULTURAL UTILIZATION RESEARCH AND DEVELOPMENT PROJECTS, UNITED STATES, 1949-1965

Year	Projects Currently Active[a]	Successful Innovations from Projects[b]	Innovations as Percent of Active Projects	Projects Adjusted for Typical Life Span[c]	Proportion of Projects Successful[d]	Annual Costs of Successful Projects[e]	Annual Cost as Proportion of Total Program Costs
	(number)	(number)	(percent)	(number)	(percent)	($000)	(percent)
1949	334	2	0.6	47.7	4.2	315	3.7
1950	329	8	2.4	47.0	17.0	2,850	31.4
1951	329	4	1.2	47.0	8.5	1,045	12.1
1952	352	4	1.1	50.3	7.9	1,512	18.0
1953	365	5	1.4	52.1	9.6	2,455	29.9
1954	345	2	0.6	49.3	4.0	350	4.2
1955	331	8	2.4	47.3	16.9	1,942	21.2
1956	396	3	0.8	56.6	5.3	271	2.8
1957	451	4	0.9	64.4	6.2	318	2.9
1958	416	5	1.2	59.4	8.4	2,933	29.9
1959	406	4	1.0	58.0	6.9	1,102	7.0
1960	324	7	2.2	46.3	15.1	2,461	15.3
1961	299	5	1.7	42.7	11.7	1,626	8.9
1962	306	6	2.0	43.7	13.7	1,134	6.0
1963	368	7	1.9	52.6	13.3	2,209	9.2
1964	419	3	0.7	59.9	5.0	402	1.6
1965	462	3	0.7	66.0	4.5	331	1.1
Total	6,232	80	-	890.3	-	24,256	-
Average	367	4.7	1.3	52.4	9.0	1,427	10.0

[a]Includes only domestic projects active at end of fiscal year. Data from Annual Summary Reports [18].

[b]Includes only products and processes commercially adopted as a result of the research program. Data from [17].

[c]Annual completion rate assuming each project with typical life of 7 years. Based on analysis of successful projects.

[d]Based on number of projects adjusted for typical life span.

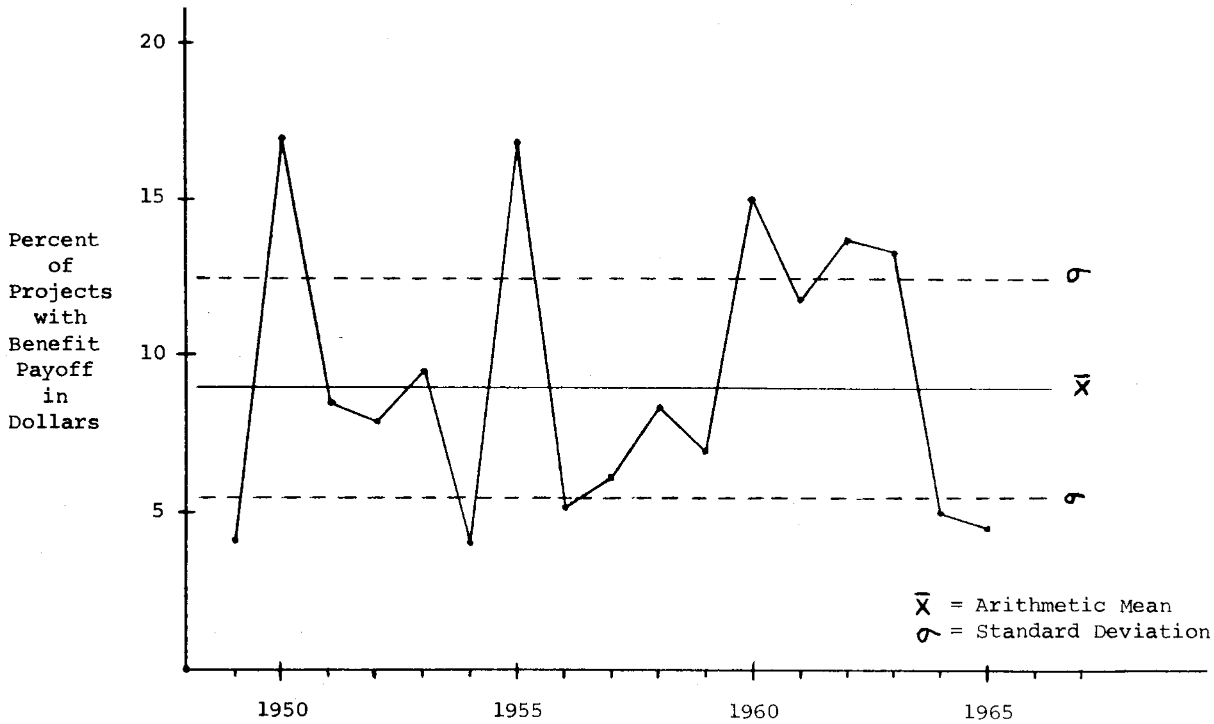
[e]Includes only costs directly attributable to successful projects. Data from Achievement Sheets [17].

[2]Summary sheets listing the achievements of each project were compiled in an internal document [17].

The projects being conducted in any one year, however, are a blend of the old and the new. Some projects are terminated during the year. Others are revised or are just being started. In the years considered in this study, there were 100 or more projects terminated annually, but most of these were replaced with either new or revised projects [18]. The live span of a project will be highly variable depending not only on its degree of success as it moves along, but also on changing priorities and resources of the research program. In order to determine the success ratio of individual projects, then, currently active projects in any given year were adjusted for a typical project life span which, in this study, was 7 years.[3] When allowance was made for project life, the success rate was somewhat higher than before, i.e., approximately 9 percent of the projects were considered successful (Table 1).[4] This ratio varied substantially from year to year, ranging from around 4 to 17 percent of the total number of projects undertaken during the period from 1949 to 1965.

There was a slight upward trend in the number of successful projects between 1949 and 1965. This trend merely reflected the increasing number of projects in the program, however, because the proportion of projects with an economic payoff did not increase during this period (Figure 1). They remained relatively stable from a trend standpoint, even though there were substantial year to year fluctuations.

Figure 1. PROPORTION OF AGRICULTURAL UTILIZATION RESEARCH PROJECTS RESULTING IN SUCCESSFUL INNOVATIONS WITH UPPER AND LOWER LIMITS OF SUCCESS, 80 PROJECTS, 1949-1965



[3] Individual projects varied from a one year life span to several projects that were active for 20 years or more. However, there was a bimodal cluster of project lives with peaks at the second and seventh years with two-thirds of the projects having a life span of 10 years or less.

[4] A success rate of 9 percent is similar to results from other studies: food processing companies had a 5.5 percent success rate for new products from the idea stage and 7.2 percent for all products entering the test stage [4]; industrial companies had a 2.4 percent success rate for new product ideas and 7.7 percent for products entering the development stages [2]. Older Studies indicate at least an 80 percent failure rate for product development by various industries [5].

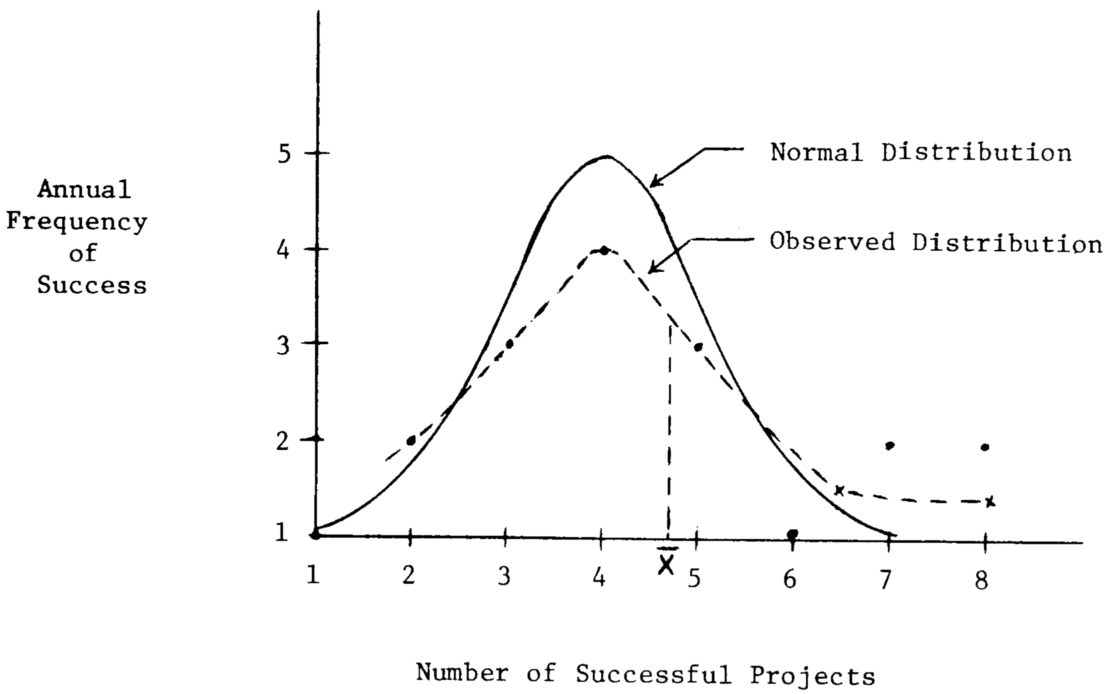
The annual costs of successful projects varied greatly, depending upon the number of projects being conducted, personnel involved and project life span. Costs ranged from a low of $271,000 in 1956 to a high of $2.9 million in 1958 (Table 1). Annual costs for successful projects relative to total program costs were also highly variable, even though on an overall basis the cost of successful projects was only about 10 percent of total program costs. Since 9 percent of the projects were successful and they accounted for only 10 percent of the total program costs, these were no more costly than other projects in the program in the aggregate.

PROBABILITY OF SUCCESS

In a broad perspective, the world can be considered a complex structure where the outcome of any given event is a combination of causal factors and elements of chance. Research is a unique and complex process. The specific factors producing successful results are not well known [11, 15 and 20]. Uncertainty and serendipity are well-known components of the research process. The success ratios observed in this study could be expressed in probability terms even if little were known about the causal factors contributing to successful research. Therefore, without *a priori* knowledge about what may happen for a given project, the likelihood of success can be estimated based on the laws of chance.

The application of probability concepts to events based on human behavior patterns is difficult, and subject to considerable variability due to shifts in social and cultural factors over time. These social forces upon which economic and business decisions are based are neither independent nor evenly balanced in terms of the normal distribution upon which probability theory is based [1, 10]. Data from the social sciences are usually more complex and skewed than in the physical and biological sciences. These characteristics are illustrated by results of this study where the frequency distribution of the number of successful projects on an annual basis is compared to the normal distribution (Figure 2). The observed distribution is skewed slightly to the right, giving a modal value of four successful projects a year — as compared to the arithmetic mean of 4.7 projects per year.

Figure 2. COMPARISON OF EMPIRICAL SUCCESS RATIOS OBSERVED IN THIS STUDY WITH THE HYPOTHETICAL NORMAL DISTRIBUTION



Despite the slight skewed effect, the observed distribution does conform reasonably well to the normal distribution. Thus, application of probability measures to empirical success ratios could be useful if other information were lacking. With a large number of cases and a normal distribution, the most likely estimate of an event occurring at any given point in time would be its arithmetic mean. However, in the normal course of events there is usally a variation of individual items about the mean. This variation can be measured by the standard deviation, which provides probable limits to the occurrence of a specific event.

Application of these measures to the data in this study are illustrated in Figure 1. The arithmetic mean was 4.7 successful projects per year and the standard deviation about the mean was 1.866. In a normal distribution one standard deviation (plus and minus) about the mean will include 68 percent of the observations and two standard deviations will include 95 percent. Thus, if successful research results were governed by the laws of chance alone, there would be a 68 percent probability that between 5.5 and 12.5 percent of the projects would produce commercially adoptable results in any given year of the study period. There would also be a 95 percent probability that between 2 and 16 percent of the total number of projects would be successful in any given year.

When considering the probability of success of agricultural utilization research projects from a statistical standpoint, then, there could be somewhere between 2 and 16 percent of the projects in the program likely to have an economic payoff in any given year. Of course, this provides only a rough estimate of the probable success of such projects based on past experience. Future success ratios are likely to be highly dependent on the causal human elements in research rather than chance [11]. Success will be a function of the scientists involved, characteristics of a research program in terms of its responsiveness to human and commercial needs, and the ability of personnel to formulate and carry out a viable and workable program of research.

CONCLUSIONS

This study presents historical data on the degree of success achieved from research projects based on the number of products and processes eventually adopted by agriculture and industry. Since there are many discoveries and innovations that take decades before being appreciated and adopted, success ratios are highly subjective. Also, much of the basic research preceding certain innovations cannot be accounted for in this type of analysis. Thus, the use of probability concepts in trying to estimate success ratios for research projects should be undertaken with considerable caution. There is undoubtably an element of chance in the research and development process because there is a great deal of uncertainty about occurrences in natural and human events. However, subjective elements and creativity in the research process are likely to dominate the degree of success achieved, particularly for individual projects.

Certain projects dealing with new types of products and capital equipment, including new varieties, improved feeds and chemicals, etc., are more easily evaluated empirically than many economic and social problems. Other broader criteria would produce success rates considerably higher than indicated in this study. Since the primary objective of research is new knowledge, most projects will achieve at least some degree of success. Also, success rates are only one element in the evaluation process. The economic benefits from only a few outstanding projects from a program with a relatively low success rate may be substantially greater than a program with many successful projects with low rates of return per project. Over a period of time, the significance of a research program in the aggregate will be judged primarily in terms of its performance and contribution to society rather than on statistical probability — even though some empirical measure of success would be a useful indicator to consider in the planning process.

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