COST - BENEFIT ANALYSIS OF MASS VACCINATION PROGRAMS EXEMPLIFIED BY MEASLES VACCINATION IN IRAN*

M. A. Faghih**

ABSTRACT

In planning any vaccination program, priority should be given to such programs within the country's overall health plan. This judgement is made on the basis of indices on morbidity, mortality, vulnerability, feasibility and cost-benefit/effectiveness analyses. The application of mathematical/epidemiological models and the use of simulation and goal-seeking techniques and monograms are of great value and will provide information on health benefits which are either quantifiable or excessively difficult to quantify. To illustrate, two examples from Iran's measles vaccination program are cited. In a five-year, country-wide program with 37% coverage and $3,828,136 cost ($1.09/unit), 214,733 cases were prevented and 37,274 lives were saved, resulting in $10,736,650 case-treatment, 1,708,878 life-years and 644,200 school-days saved. The estimated cost of one prevented case is $18.62. A four-year specific campaign covering 55% of the at-risk labor-insured population, costing $59,444 (0.85/unit) resulted in 1,728 cases prevented, 61 lives (2,867 years) and 5,214 school-days and $152.327 case-treatment saved. The cost of one prevented case is estimated at $34.20.

INTRODUCTION

Since its discovery by Jenner in 1796, immunization has gradually become a powerful weapon against communicable diseases. Outstanding achievements have been made over the last fifty years, particularly during the last one or two decades, in immunization

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** School of Public Health and Institute of Public Health Research, University of Teheran; P.O. Box 1310, Teheran, Iran.

against various infectious diseases and hopeful progress is being made toward the development and utilization of this technique for the control of many others.(1)

The efficacy, practicability, low cost, and many other advantages have made this technique of such wide application that the control or even global eradication of some infectious diseases (such as smallpox) has become a tangible wish.

PRINCIPLES

A mass immunization program aims at the control or eradication of a particular communicable disease on a community-wide basis. Because of the nature of their objectives, mass campaigns require a special operating machinery (developed within or aside from general health services but working in close collaboration with these services) in order to ascertain their precise objectives.

A program of this this type is not a universal need in the same way that general health services are; however, it can be indicated or even strongly recommended in certain areas and at certain times. There are still countries and circumstances in which mass campaigns (including mass vaccination programs) against major communicable diseases should be launched. (2)

However, in making a decision as to whether a mass immunization campaign is or is notthe method of choice, as well as in the planning of such a program, priority should be given to such a program within the country's overall health plan. To determine such priority, many factors should be taken into account, such as the following:

a) *Factors related to the disease*

— morbidity and mortality incidence, indicating the magnitude and relative importance of the disease among the total population and particularly among vulnerable groups;
— severity of the disease, its sequelae and other debilitating conditions;
— vulnerability (particularly in respect to the proposed control measures);
— economic implications (direct or indirect economic losses);
— international importance of the disease;
— social awareness, etc.

b) *Factors related to the program*

— potency and efficiency of the vaccine, and risks entailed in its use;
— availability of vaccine in sufficient quantities;
— technical and administrative feasibility;

— economic implications (cost of vaccine, cost of operation, etc.);
— advantages of an immunization program in comparison with other control methods for the specified disease;
— public demand, etc.

In this respect, several priority indices have been developed and introduced into planning practice, such as those suggested and used by :

— Latin American countries; (3)
— U.S. Public Health Service, Division of Indian Health; (4)
— U.S. National Research Council; (5)
— Asian Institute for Economic Development and Planning. (6)

However, in developing countries where resources are limited, the evaluation and analysis of the economic impact of the disease as well as the cost of the campaign should receive particular attention. Under these circumstances, it is imperative to try to attain the best results for the least cost and to obtain the maximum health benefit from the resources available.

In order to make these analyses, various methods are available such as "input-output analysis" and "cost-benefit/cost-effectiveness analysis" and those based on simulation and goal-seeking techniques as well as those based on the use of monograms. The use of mathematical/epidemiological models are also of great value, not only from the econometrics point of view but also to predict an infection over a long period and to serve as a guideline in the planning of control measures such as immunization. (7)

These, on the whole, will provide information on the health benefits that can be obtained from the investment of a given fund on a specific program (such as mass vaccination), which is either quantifiable (such as treatment cost, invalidity expenses, wages that would otherwise be lost, etc.), unquantifiable, or extremely difficult to quantify (such as human lives saved, absenteeism from school, etc.).

Cost-benefit/cost-effectiveness analysis

These techniques yield information on the benefits that can be attained from the investment of given resources on a specific program. These aim to measure and to project all the consequences of a program or policy and entail a comparison between cost and benefits of a series of programs thought of as alternatives or as a competition for funds. Cost-benefit-effectiveness analysis is simply a way of making budget decisions with the goal of maximizing

the delivery of service and minimizing the cost by making the best choice among alternative ways of reaching a planned target. (8)

Cost-benefit analysis was first applied to estimate the utility of public works about the middle of the nineteenth century, and it is still quite popular in that field. More recently, it has been extended to other areas such as health services.

Obviously, before an investment project is chosen, it is essential to forsee the returns and to estimate the actual value of expected future revenue to compare with the present cost of the proposed investment and the present value of future operating costs.

In health programs, similar to other social and welfare plans, the application of cost-benefit-effectiveness analysis is not as easy as in other fields such as industry and agriculture. When the yield on investment in health has to be compared with the alternative benefit from investing the same money in other programs (roads, factories, etc.), it is virtually impossible to arrive at a satisfactory calculation of "opportunity cost" because the outputs of different activities are not commensurable. (7) Moreover, the accurate estimation and projection of the costs and benefits of health programs are not always possible. Some of the factors are measurable, such projected expenditure, usually itemized in the budget (including cost of prevention, detection, treatment, research, training, capital investment, etc.), or benefits from savings in the use of health searvices, gain in economic output, savings in invalidity expenses, wages that would otherwise be lost, etc. (8) However, there are many important items which are either unquantifiable or extremely difficult to quantify or predict, such as : (8,9)

— value of human life and, consequently, the difficulty of estimating mortality losses and gains;
— indirect cost of major chronic diseases, psychic conditions, etc.;
— intangible aspects of human life (happiness, food, health, etc.);
— shift in people's expectations and behaviour;
— absenteeism from school and similar facets.

Therefore, it is desirable that we agree with Fuchs (11) and endorse that :

"The practice of medicine is still more an art than a science. The intimate nature of the relationship between patient and doctor, the vital character of the services rendered, and the heavy responsibilities assumed by medical personnel suggest the dangers inherent in reducing health care to matters of balance sheets, or supply and

demand curves. Economics has something to contribute to health problems, but it should proceed as the servant of health, not its master."

Cost-benefit analysis in immunization programs

Cost-benefit analysis supplies the economic benefits that will be derived from a vaccination program. It is based on the cost of immunization (the aggregate of the cost of vaccine, manpower, transportation, syringes, needles and other material resources) on the one hand and benefits from savings in treatment costs, invalidity expenses, wages that would otherwise be lost, human lives, etc., on the other. (12) As has already been mentioned, some of these factors (such as human lives, invalidity, absenteeism) are very difficult to quantify and cannot easily be taken into the picture.

In the planning of a vaccination program, allowance should be given to the techniques and refined methods through which the cost of vaccination can be materially reduced or its effectiveness increased. The use of a cheaper vaccine (particularly in those cases which are still exceptionally expensive such as measles vaccine), administration in smaller doses and use of large containers, combined vaccine or simultaneous immunization, taking of the oral route rather than the parenteral, faster and more efficient devices (the jet injector), as well as better selection and delimitation of the target group and application of the program at the most suitable time, will contribute to reduction of the cost and increase in the effectiveness of the campaign. (7)

However, in the analysis of the cost and benefits of a vaccination program, the following principal factors should be measured, weighed and compared :

1. *Cost* : the aggregate of various expenditures
2. *Benefits* :
   Measurable : benefits from saving in case treatment saving in wages that would otherwise be lost
   Difficult to quantify : saving in terms of human lives
   saving in terms of absenteeism (from school and jobs)
   saving from invalidity expenses
3. *A few estimates and indices*:
   a. Average cost of unit/vaccination : the cheaper the price of vaccine, the closer and more accessible the target population, the easier the administration of the vaccine needing less manpower and skill, and the more minimum its frequency of administration, the

lower will be this average.

b. Average cost of the prevention of one case: the lower the cost of immunization and higher the number of prevented cases, the lower will be this average cost.
c. Ratio of cost to benefit: the smaller this ratio, the more the campaign is economically justified and should receive priority.
d. Ratio of *b* to *a*: the higher this ratio, the more need there is for higher coverage in order to prevent one case.
e. Comparison and correlation between the following trends may better illuminate the progress of the vaccination campaign :
   — Trend of the increase in vaccination coverage;
   — Trend of the increase in the number of cases prevented;
   — Trend of the decline of the cost of one prevented case;
   — Trend of the decline of the ratio of benefit to cost.

Measles vaccination in Iran

Measles is one of the major communicable diseases of childhood in Iran, having outstanding public health importance. Before the vaccination campaign was begun in this country, the number of recorded cases, varying during epidemic and non-epidemic years, reached figures of nearly 130,000 (an annual incidence of over *15* per thousand among the population-at-risk), with a high case fatality rate exceeding 10 to 15 percent in rural and mountainous areas. With due consideration to the under-reporting of communicable diseases in this country, particularly from rural areas, the real number of measles cases is considered to be much higher than that reported and an estimation of 150,000 to 500,000 during non-epidemic and epidemic years is made by public health authorities. (13, 14)

The highest morbidity incidence occurs in the age group 1-7 years and the highest mortality figures belong to the group of 1-3 years. (14)

Because of the public health importance of measles in Iran (as described above and illustrated in Table 1), receiving high priority within the country's health plan, a mass campaign against this disease was launched in Iran in 1967, covering children up to *10* years of age, predominantly in rural and mountainous areas.

Prior to the establishment of this program, comparative double-blind studies of various vaccines (Edmonston B, Schwarz, Beckenham 31 and locally produced Biken's strain) were conducted by the Institute of Public Health Research, Teheran. (15, 16) As a result, the main vaccine used in the campaign up to 1970 was Schwarz. The cost of the imported vaccine was obviously very high ($0.90 per dose). In 1970, a vaccine using a live attenuated Sugiyamo strain of measles virus was prepared by the Razi Veterinary Institute, Iran, and then assessed in collaboration with the Ministry of Health and found satisfactory. (17) Consequently, from 1970 the vaccine used in mass campaigns in Iran was changed to this new vaccine, which was very effective and reasonably cheaper ($0.30 per dose).

In addition to the main campaign, launched by the Ministry of Health, small-scale programs were also carried out by individual health organizations. The Social Insurance Organization, which is mainly responsible for the provision of medical care for laborers and their families, started a vaccination program in 1967. After an initial but limited program during 1967-68, the campaign has expanded and is still growing. (18)

In the following paragraphs, the public health and economic significance of these two programs are briefly presented and discussed.

Country-wide program (1968-72)

Community-wide measles vaccination was begun in 1967, aimed at covering the population at risk, mostly in rural areas. The first vaccine used was an imported one, resulting in a rather costly program ($1.25 per individual vaccinated), but since 1970 a vaccine prepared in Iran has been used and, as a result, the cost per unit was reduced significantly (0.75).

Some highlights of the results of this program are shown in Tables 1, 2, 3 & 4 and Figures 1 & 2.

Table 1 shows that the number of recorded measles cases during the period of 1963-67 (prior to the vaccination program) ranged from over 50,000 (non-epidemic years) to more than 125,000 (epidemic years). The incidence rate also ranged from 7.5 to 14.9 per thousand of the population-at-risk with an average of 11.6% for that 5-year period. After the establishment of the program, the number of cases has been reduced gradually but continuously (from 94,000 to below 50,000) with an incidence rate ranging from 10.4/1,000 (1968) to 4.8/1,000 (1972) and an average of 7.2/1,000 for the period of 1968-72.

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TABLE 1

Number of reported measles cases, annual measles incidence (per 1000), number of vaccinated and percent coverage in the population-at-risk (children up to 10 years) for the period 1963-1972, Iran

Year	Estimated Population* of children up to 10 years (30% of total population)	Number of Measles Cases	Incidence per/1000	Number of Children Vaccinated		Percent Vaccinated		Case Fatality** Rate
				Annual	Cumulative	Annual	Cumulative	
1963	7,797,038	58,088	7.5	---	---	---	---	14.8
1964	8,038,183	119,908	14.9	---	---	---	---	not available
1965	8,286,787	82,626	10.0	---	---	---	---	12
1966	8,543,079	127,514	14.9	---	---	---	---	11
1967	8,799,371	92,752	10.5	533,984	533,984	6	6	9.7
1968	9,063,353	94,365	10.4	825,821	1,359,805	9	15	7.6
1969	9,335,253	84,486	9.1	945,678	2,305,483	10	24.7	7.8
1970	9,615,312	63,751	6.6	586,573	2,892,056	6	30	4
1971	9,903,771	57,545	5.8	625,491	3,517,547	6	36.5	5.5
1972	10,200,884	49,920	4.8	958,500	4,476,047	7	43	not available

* Estimation based on 1956 and 1966 census and an annual growth rate of 3% (average for Iran).

** Based on epidemiological surveys made in rural areas during seasonal outbreaks.

TABLE 2

Cost (operation expenditure) and estimated benefit
(saving in case treatment) of measles vaccination in Iran, 1967-1972

Year	Number of Cases expected(a)	Number of Cases observed(b)	Difference between a & b (no. of cases prevented)		Cost ($ US)***		Estimated Benefits ($ US)**		Ratio of c to d
			Annual	Cumulative	Annual	Cumulative(c)	Annual	Cumulative(d)	
1967	---	---			666,324	666,324			
1968	100,480	94,365	6,115	6,115	1,031,788	1,698,112	305,750	305,750	1/0.45
1969	106,720	84,486	22,234	28,349	1,154,259	2,852,371	1,111,700	1,417,450	1/0.83
1970	112,960	63,751	49,209	77,558	390,000	3,242,371	2,460,450	3,877,900	1/1.36
1971	119,200	57,545	61,655	139,213	585,765	3,828,136	3,082,750	6,960,650	1/2.14
1972	125,440	49,920	75,520	214,733	638,130	4,466,266	3,776,000	10,736,650	1/2.8

* Estimation based on: r (coefficient correlation between cases of measles and Iranian calendar year) = 0.87
and formula: $Y_{\Lambda} = (624x - 19280)(1/10)$

** Estimation based on $ 50 for each case treatment (estimated 10 days of hospitalization at $ 5 daily cost of hospitalization (average for the hospitals of the Ministry of Health).

*** Operational cast of each year regarded as the investment for the following year (i.e. cost in 1971 for benefit in 1972).

TABLE 3

Patterns of coverage, benefits and effectiveness of the community-wide measles vaccination campaign in Iran, 1968-72 (shown by rates and ratios)

Year	Coverage of Vaccination		Number of Cases Prevented		Cost of one Prevented Case		Ratio of Cost to Benefits		Number of Deaths Prevented	
	% Coverage	Pattern (taking 1967 as basis)	Cumulative	Taking 1968 as basis	$ U.S.	Pattern (taking 1968 as basis)	Annual	Cumulative	Number	Cumulative
1967	6	1	---	---	---	---	---	---	---	---
1968	15	2.5	6,115	1	108	1	1:0.45	1:0.45	3680	3,680
1969	24.7	4.1	28,349	4.6	60	0.55	1:1.07	1:0.83	4936	8,616
1970	30	5	77,558	12.6	37	0.34	1:2.1	1:1.36	9545	18,161
1971	35.5	5.9	139,213	22.7	24	0.22	1:7.9	1:2.14	9709	27,870
1972	43	7.1	214,733	35	18.6	0.17	1:6.4	1:2.8	9404	37,274

TABLE 4

Summary statement of saving due to country-wide immunization against measles in Iran (1968-72)

Health and resources	
Cases prevented	214,733 (40% of expected cases)
Lives saved	37,274 (64% of expected deaths)
Years of life saved*	1,708,878
School-days saved**	644,200
Economic	
Cost of unit of vaccination	$ 1.09
Cost of the prevention of one case	$ 18.62 (equivalent to the cost of 17 vacc/unit)
Economic benefits	$ 10,736,650
Cost of the program	$ 3,820,136
Net economic savings	$ 6,908,514***

* Based on 46 years average life-expectancy of children, if they would not have died from measles.

** Based on 10 days absenteeism from school in 30% of the sick children of school age.

*** Equivalent to the daily wages of 3,500,000 unskilled laborers.

TABLE 5

Status of measles and the measles vaccination program among the population-at-risk (children below 10 years) in an insured population group in Teheran, Iran, for the period 1966-1972

Year	Population-at-risk (30% total pop.)	Non-immune* fraction of pop.	Measles Cases		Number Vaccinated (cumulative)	% Vaccinated out of non-immune pop.	% Immune (total)
			Number	Incidence %			
1966-68	258,948 (average 3 years)	155,368 (av. 3 yrs)	992	3.8	12,000	7.7	44.6
1969	328,080	196,848	1023	3.1	24,000	12.2	47.3
1970	340,080	207,648	821	2.4	28,000	13.5	48.0
1971	399,944	236,666	1130	2.8	42,000	17.7	50.5
1972	478,400	287,540	1275	2.45	70,000	24.3	54.6

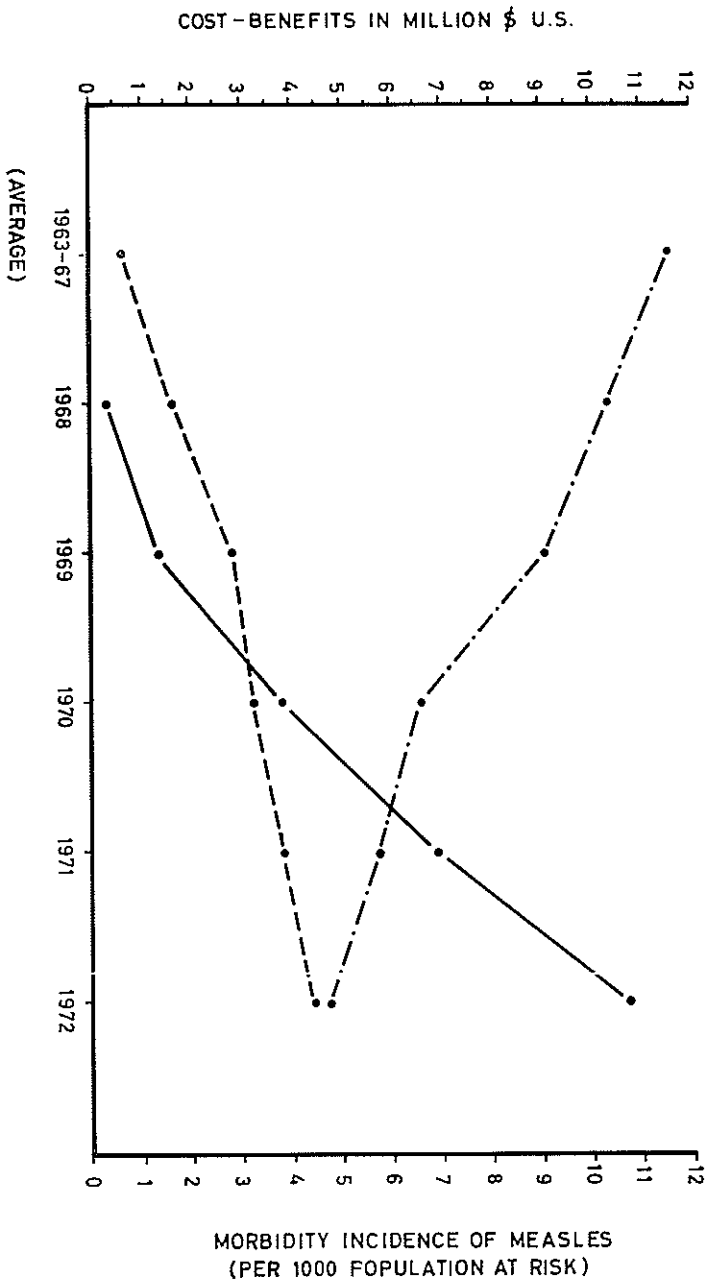
* Children up to 9 months, 10% of children 1-4 and 60% of children 5-9 were considered as non-immune and excluded from vaccination.

TABLE 6

Summary statement of saving due to small-scale vaccination against measles among an insured population group in Teheran, Iran, 1969-1972

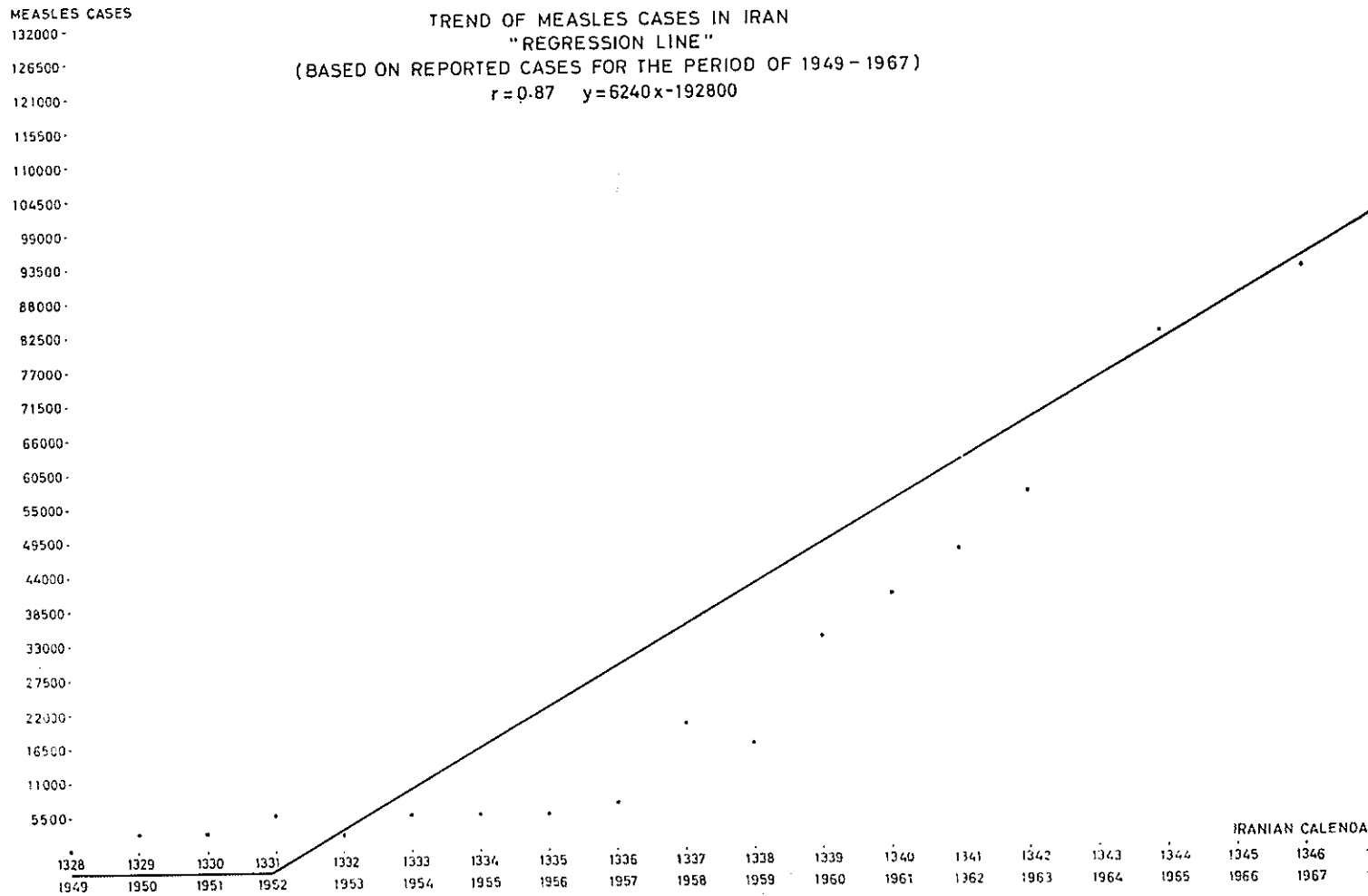
Health and Resources	
Cases prevented (1)	1,738 (29% of expected cases)
Lives saved (2)	61 (34% of expected deaths)
Years of life saved (3)	2,067
School-days saved (4)	5,214
Economic	
Cost of unit of vaccination	$ 0.85
Cost of the prevention of one case	$ 34.20 (equivalent to 40 vacc/unit)
Economic benefits (5)	$ 1,52,327
Cost of the program	$ 59,444
Ratio of cost to benefits	1:2.56
Net economic savings	$ 92,883

(1) Expected number is calculated on the basis of 3.8% (average incidence for the years 1966-68).
(2) Based on 3.5% case fatality rate (average for the last ten years).
(3) Based on 47 years average life-expectancy of children, if they would not have died from measles.
(4) Based on 10 days absenteeism from school in 30% of the sick children of school age.
(5) Based on average period of hospitalization (10 days) and daily hospital cost of $ 8.76 (average for Social Insurance hospitals).



CUMULATIVE COST AND BENEFITS OF
MEASLES VACCINATION PROGRAMME IN IRAN
1968-1972

MORBIDITY INCIDENCE
CUMULATIVE BENEFITS
ON CASE TREATMENT
CUMULATIVE COST
OF VACCINATION


TREND OF MEASLES CASES IN IRAN
"REGRESSION LINE"
(BASED ON REPORTED CASES FOR THE PERIOD OF 1949 - 1967)
r = 0.87 y = 6240 x - 192800
MEASLES CASES
132000
126500
121000
115500
110000
104500
99000
93500
88000
82500
77000
71500
66000
60500
55000
49500
44000
38500
33000
27500
22000
16500
11000
5500
IRANIAN CALENDA
1328 1329 1330 1331 1332 1333 1334 1335 1336 1337 1338 1339 1340 1341 1342 1343 1344 1345 1346
1949 1950 1951 1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967