ECONOMIC ANALYSIS OF FOUR MECHANICAL GRAPE HARVESTING AND HANDLING SYSTEMS

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PAUL LEIGH WILLIAMS

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ABSTRACT

ECONOMIC ANALYSIS OF FOUR MECHANICAL GRAPE HARVESTING AND HANDLING SYSTEMS

by Paul Leigh Williams

The introduction of the mechanical grape harvester in Michigan was thought by many to be long overdue. Stable prices, rising hand harvesting costs and the unavailability of temporary labor hastened the transition to mechanical harvesting. Since 1968, mechanical harvesting has increased from approximately 1 percent of the total grape crop harvested to 87 percent in 1971.

The major question facing grape producers was twofold: what are the breakeven acreages or income possibilities for mechanical harvesting vs. the traditional hand harvesting methods, and how much initial capital investment for mechanization can be justified?

The equipment necessary for mechanical harvesting centers around the ownership of one particular piece of equipment, the harvester. The coordination of other equipment must operate parallel to and concurrently with the harvester.

Five handling methods were designated for analysis and comparison: two existing and two experimental mechanical harvesting and handling systems and the traditional hand harvesting system. Data were accumulated for the five systems under investigation during the 1970 Concord grape harvesting season. Assistance in the analysis and comparison of the systems was accentuated with the aid of a feasibility computer program.

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The results of the study indicated mechanical grape harvesting both existing and experimental was profitable for most conditions, specifically, most conditions above 70 acres per season when mechanized harvesting was used. Income potential increased substantially for growers harvesting more than 250 acres per season. Furthermore, investment for increased mechanization in the "experimental bulk handling system" could be justified by inherent labor reductions. Economically, ownership of the experimental mechanical harvesting systems, when compared to hand harvesting methods, is recommended for growers harvesting 90 acres or more per season.

Approved B. J. Cargill
Major Professor

Approved B A Stout
Department Chairman

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By

PAUL LEIGH WILLIAMS

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DISCLAIMER

References to company names, products, or trademarks do not constitute condemnation or endorsement of these products but are merely convenient designations for selected equipment and materials.

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I. INTRODUCTION

1.1 Historical

Vineyards were among the earliest plantations made by civilized people, those of the Greek, Roman and Biblical eras. "The grape comes to us out of the abyss of antiquity."[1] Viticultural tradition is nearly as old as man; seeds found in remains of the Swiss Lake Dwellings of the Bronze Age and entombed with mummies in Egypt closely resemble cultivated species of today. Details for grape and vine production also figure in the hieroglyphics of the 4th (2400 B.C.), 17th and 18th dynasties of Egypt. Noah, according to the Bible, planted a vineyard. In virtually all of the world today, the technique for harvesting grapes has changed very little since the beginning of viticulture.

1.2 World Production

Land acreage in the world devoted to cultivation of grapes totals more than 25 million acres (10 million hectares). Over 75 percent of the grapes produced are grown in Europe, 11 percent in Asia, 5 percent in South America, 5 percent in Africa, 3 percent in North America, and 1 percent in Oceania. In the United States, California produces 80 percent of the North American total, with a high percentage utilized for table grapes and raisins.[1] Table 1 gives some comparisons between California and the five remaining states producing

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[1] Encyclopaedia Britannica, Inc. Vol. 10, William Benton Publisher, The University of Chicago, 1972, pp 688-693.

TABLE 1--Grape Production Trends for Major States in the United States 1899-1969.(short tons)

Year	U.S. (000)	Calif. (000)	N.Y. (000)	Mich. (000)	Pa. (000)	Ohio (000)	Wash. (000)
1899	650	360	123	21	23	39	
1909	1,285	990	126	60	17	22	
1919	1,258	1,028	76	58	21	21	
1929	1,942	1,691	77	59	22	14	
1936	1,916	1,714	49	39	16	26	5
1940	2,467	2,250	60	38	17	22	10
1945	2,781	2,663	31	13	6	5	19
1950	2,687	2,440	96	43	31	19	23
1955	3,241	3,020	88	23	24	17	49
1960	3,069	2,767	122	65	33	15	38
1965	4,351	3,975	153	75	49	21	37
1966	3,734	3,400	132	49	39	17	64
1967	3,049	2,680	158	39	51	17	73

U.S. Census of Agricultural, 1899-1939; Agricultural Statistics, U.S. Department of Agriculture, 1939-1960.

the other 20 percent. These states of New York, Washington, Michigan, Pennsylvania, and Ohio produce the American Hybrid Concord grape (Vitis labrusca), which is crushed almost exclusively for grape juice and wine. In most years since 1920, Michigan has placed third or fourth among the states in total tonnage of grapes produced and is usually surpassed only by California, New York, and sometimes Washington.[2]

1.3 Michigan Trend

Use of mechanical harvesters to harvest grapes has increased in southwestern Michigan since the introduction of the first harvester

[2]During recent years Washington's production has increased yearly while Michigan's total production has remained relatively constant.

in 1968. In Michigan, mechanical harvesting of grapes has continually increased from 1 percent in 1968 to approximately 87 percent in 1971. The data in Table 2 indicate the dramatic trend that has taken place during the past three seasons. In 1968, approximately 1 percent of the Michigan Concord grape crop was mechanically harvested; however, in 1971, over 87 percent of the grape crop was harvested mechanically.

TABLE 2--The Rapid Trend for Mechanical Harvesting of Concord Grapes in Southwestern Michigan from 1968 to 1971.

Year	Total Concord Grape Crop (tons)	Harvested Mechanically (tons)	Harvested Mechanically (percent)
1968	23,000	400*	1%
1969	38,000	9,500*	25%
1970	62,000	41,500*	67%
1971	72,000*	63,000*	87%

Michigan Crop Reporting Service, Michigan Agricultural Statistics, July, 1971.
*Estimated information supplied by Southwestern Michigan Processors.

Mechanical harvesting of Michigan's 16,700 acres of grapes will eventually approach 100 percent with abandonment and/or replacement of undesirable vineyard sites. Low yields and market requirements may also preclude machine harvesting in certain instances. Thus, capital requirements and personal desires of growers and processors will influence the development of complete grape harvesting and handling systems.

1.4 Michigan Setting and Situation

An era of mechanization has affected nearly every aspect of the food and fiber industries. The fruit and vegetable industry has been more resistant to change particularly due to the delicate nature of the product and the previous availability of abundant temporary farm workers. During recent years, the unavailability of seasonal laborers precipitated by mechanization of other fruit industries has accelerated the pace to design and develop new methods for harvesting grapes. The mechanical grape harvester which was in the developmental stages for a number of years, prior to the scarcity of labor, was introduced in Michigan in 1968. However, the development of the mechanical harvester is only a portion of the solution to the problem. Whittenburger (1970) states, concerning the mechanization of the grape industry: "The invention of a mechanical harvester for Concord grapes is but one step in the development of a complete harvesting system." Many handling systems are currently in operation delivering the grape product to the processor. The existence of many different handling systems and the possibility of new handling methods not yet employed have created uncertainty within the grape industry.

II. STATEMENT OF THE PROBLEM

Many external factors, such as abundant hand labor supply and small family acreages surrounding the grape industry, have combined to allow it to function in essentially the same manner as it has for the past thousands of years. The increased importance of external factors affecting the grape industry--such as the application of engineering techniques, the uncertainty of migrant workers, the changing attitudes of the family enterprise, the availability of research funds, and the changing consumer demand--has brought emphasis to mechanical harvesting. Fortunately, these external factors have played a desirable role in the mechanization of grape harvesting.

2.1 Stable Prices and Rising Costs

The grape industry is inherently stable. Unstable gross return, unavailability of hand labor requirements and long vineyard growth characteristics create a business enterprise demanding care and development best supplied by the family enterprise. Business enterprises are by no means static, but the deletion of external resources normally drawn upon by the enterprise has caused growers to become increasingly concerned for their livelihood. Grape producers, as well as other agricultural researchers, are concerned with economic return affected by increasing costs and stable prices for their product. Stable prices and the consumers' desires for juice, requiring the crushing of grapes, can be reviewed in Table 3.

TABLE 3--Michigan Production, Average Price Per Ton, and Disposition from 1936 to 1971 for Michigan Concord Grapes

Year	Average Price/Ton	Production tons	Home Use	Total Sold	Fresh tons	Juice and Wine	Percent Crushed %
1936	36	34,600	2,610	31,990			
1937	23	55,000	3,660	48,540			
1940	25	38,200	1,900	36,300	23,360		
1945	138	13,000	1,120	12,380	3,780		
1948	98	27,000	960	25,040	7,020		
1949	101	34,000	1,050	30,950	5,860	24,600	77
1952	96	40,000	700	38,300	6,100	21,800	55
1956	80	60,500	500	60,000	8,400	41,600	68
1958	100	50,500	400	50,100	5,500	43,600	88
1960	103	65,000	280	64,620	3,900	60,720	94
1961	101	33,000	250	32,750	2,900	29,850	90
1962	106	68,000	350	67,650	5,100	62,555	93
1963	146	33,500	300	33,200	2,445	30,755	92
1964	126	70,000	300	69,700	3,700	66,000	95
1965	90	71,500	300	71,000	3,350	67,850	95
1966	88	49,000	300	48,700	3,450	45,250	93
1967	119	39,000	300	38,700	3,100	35,600	92
1968	122	23,000	300	22,700	1,900	20,800	88
1969	158	38,000	300	37,700	2,200	35,500	94
1970*	145	60,000					
1971*	100	65,000					

Production and Average price/ton, 1936-1969, from Agricultural Statistics, U. S. Department of Agriculture, 1936-1969.

*Estimated information supplied by southwestern Michigan Processors.

The average price per ton for two 6-year periods, 1958 to 1964 and 1965 to 1971, was $114 and $120 per ton respectively, a 7 percent increase. Hand harvesting costs according to Harsh in (1968) and Kelsey in (1971) were $28.81 and $40.79 per ton respectively, a 41 percent increase in hand harvesting costs.

The major economic question that grape producers face is: how much can I invest in a mechanical harvesting and handling system? The equipment necessary for mechanical harvesting essentially centers around the ownership of one particular piece of equipment, the harvester.

The mechanical grape harvester was introduced for commercial operation in 1968, with initial costs ranging from $22,000 for a Mecca to $28,500 for a Chism-Ryder. The handling system has many alternatives, such as different handling methods, renting or leasing, purchasing new or used components, borrowing or joint ownership, and so on. With all these possible alternatives, the initial decision can be very confusing.

2.2 Unavailability of Labor

Growing pains experienced by grape producers trying to stay competitive over the years increased the dependency of growers to available temporary labor supplies. However, during critical times, unavailability of labor has left the producer vulnerable to this dilemma.

In the past, the migrant labor pool drawn to the state by other fruit and vegetable industries served as a source of labor for grape hand harvesting. Unfortunately, the source of migrant labor has dwindled with the introduction of pallet handling systems and mechanical harvesters for other fruit and vegetable crops. In addition, housing regulations for migrant workers imposed by recent Federal rulings to improve living conditions of migrant workers has caused grape producers to look in other directions for assistance. Finally, unsuccessful wage competition with other nonagricultural industries for local temporary labor has decreased the number of alternatives available. Thus, the uncertainties of obtaining labor during critical periods has created a need for refinement of managerial decisions for purchasing newly developed mechanical harvesting methods.

2.3 Future Predictions

The harvesting of grapes as well as other fruit and vegetable crops has been highly dependent upon an adequate supply of family and seasonal labor. Project 80 (1964), created to study the prospects and potential for rural Michigan by 1980, made the following projections:

> <u>General</u>
> The important factor enabling farmers to increase production while experiencing a decline in farm population and land crop acreage will be more efficient use of fewer farm laborers operating larger and more efficient farm machines.
>
> The ability to handle large volumes of material with minimum labor, to maintain quality, to process mechanically, to feed mechanically, and to measure and weigh automatically, will require careful selection of equipment and considerable investment.
>
> <u>Fruits and Vegetables</u>
> Major changes in the mechanization of fruit crops will occur in harvesting and handling systems.
>
> <u>Grapes</u>
> It is estimated that nearly 90 percent of the grapes harvested in Michigan for processing will be mechanically harvested by 1980.
>
> <u>Labor</u>
> The actual number of workers in the labor force will be reduced by 60 percent from 215,000 in 1963 to . . . 89,000 . . . in 1980.
>
> <u>Seasonal Labor</u>
> Seasonal labor requirements will be reduced by nearly 64 percent from 53,000 to 19,000 workers by 1980.

Cargill (1969) contends in his publication, "Fruit and Vegetable Harvest Mechanization-Technological Implications:"

> As research continues to develop more efficient, lower cost per unit mechanical harvesting techniques, fruit and vegetable growers will continue to substitute capital investment for labor in the reorganization of their enterprises to increase the output per man-hour.

When one reviews the countless volumes of statistical data and records of the agricultural enterprise, mainly confined within the boundaries of many self-supporting farm units, it is easy to realize agriculture is built upon a solid foundation of scientific research, rapid technological development and expanding managerial abilities. Hence, grape producers will have to adopt developments and machines at a faster rate to stave off the cost-price sqeeze in hopes of lowering per unit cost and increasing net returns. Cargill (1969) also goes on to state,

> ...these more efficient, but expensive machines will permit growers more economical operation of larger holdings with less manpower resulting in more timely harvesting of their fruit and vegetable crops. These will include...handling systems.

Unless the grape producer prepares himself knowledgeably to trends and finances, he will find it impossible to salvage his economic existence in the future.

III. REVIEW OF LITERATURE

The groundwork for any type of research rests upon the theories and approved testing and modeling techniques accepted by the Scientific Arts. In the development of comparison studies, the supporting discipline is economics. The purpose of this chapter is to review mechanical harvesting and studies completed by other researchers. The latter part of this chapter includes a concurrent study on the economics of mechanical harvesting at Washington State in 1970. In addition, several different techniques available for analyzing economic costs from a total system approach were reviewed and explored.

3.1 Current Harvesting Cost Knowledge

Not until Shepardson (1957) in New York State was serious consideration given to the possibilities and problems concerned with the development of a feasible machine for grape harvesting. In 1959 Dominick's economic studies indicated that the harvesting costs for handpicked Concord grapes delivered to processors or wineries in the major grape producing areas of New York averaged $30 per ton. Of this total over 75 percent or $23 went for labor in picking, loading and delivering. The remainder consisted of fixed and varied costs for equipment and overhead. Again in 1968, Dominick stated the New York data indicated the harvesting cost for Concord grapes picked by hand and delivered to processors averaged about $35 per ton. The labor portion of this increased to over 85 percent of the total cost, more than offsetting per unit labor and equipment efficiencies that were instituted during this time period.

In Michigan, individual contact with grape growers and processor fieldmen indicated that out-of-pocket costs for hand harvesting ranged from $28 to $35 per ton. This of course did not include the additional overhead cost such as depreciation and use of equipment. Kelsey (1971) indicated in a grape study, "Economics of Grape Production in Southwestern Michigan," that total hand harvesting costs approached $40.79 per ton. Wages paid out to workers represented $32 per ton or approximately 80 percent of the total harvesting costs.

During the period 1957 to 1967, prototype harvesters were being developed and tested by Shepardson (1969) on an experimental basis. During the 1968 season, the mechanical harvesting of grapes on a commercial basis became a reality in New York State with at least ten harvesters operating during the entire length of the harvesting season.

TABLE 4--Mechanical Harvesting Data, 1968 (4 machines Chautauga County, New York)

Days machines were operated		27
Hours machines were operated		323
Acres harvested		255
Tons harvested		939
Yield per acre (tons)		3.7
Cost per ton	fixed	$10
	variable	$11
	TOTAL	$21 per ton

T. Jordan and B. Dominick, Jr. Economic Aspects of Mechanical Harvesting Fruit and Vegetable Harvesting Mechanization, Volume I, p. 593. B. F. Cargill and G. E. Rossmiller, Rural Manpower Center, Michigan State University, East Lansing, Michigan.

Records kept by the operators were summarized in Table 4 by Jordan and Dominick (1969) immediately after the 1968 harvesting season. The machines were used an average of 27 days and operated 323 hours during the harvest season. An average of 939 tons were mechanically harvested from 255 acres for an average of 3.7 tons per acre by each machine.

3.2 A Review of Another Study--Washington

Dailey (1971), an agricultural economist at Washington State and his associates presented a paper to the American Society of Enologists (ASE), Palo Alto, California: "The Economics of Owning and Operating Mechanical Grape Harvester in Washington." Dailey's cost analysis was completed in the traditional agricultural economic technique using methods relying on total capital investments necessary, fixed costs, variable costs, breakeven analysis and straight-line depreciation for their analysis.

In Dailey's study, he and his research associates were concerned with determining the costs of owning and operating mechanical grape harvesters and complementing systems at various harvesting rates. Dailey's major findings indicated an annual mechanical grape harvesting cost of $12.55 per ton or $84.83 per acre for a typical grape harvesting season of 1655 tons harvested on 245 acres. The breakeven point of 136 acres per season paralleled with the initial system cost of $54,055.

Dailey was explicit in pointing out that not everyone who owns or is thinking of buying mechanical grape harvesting systems would have the same costs. Subcontracts for trucking, previously owned equipment used in the new grape harvesting system, and yield can affect unit cost and capital investment considerably.

The conclusions reached by Dailey are very important; however, the input data is just as important for comparison of averages and ranges used in this study. For this reason, the following information includes data from Dailey's study for comparison purposes throughout the remainder of this thesis.

3.21 Capital Investment

Capital investment costs for a system averaged $54,075 per system with one-half of this investment necessary for the harvester. Salvage value of $5000 and service life of five years was considered average due to the relatively high obsolescence rate of newly developed agricultural mechanics. Table 5 gives an indication of the amount of depreciation that must be justified for each season.

TABLE 5--Estimated Capital Investment and Depreciation Cost Required for Mechanical Grape Harvesting in Washington.

Item	Purchase Price	Salvage Value	Years of Life	Depreciation Total	Depreciation Annual
Harvester	$27,000	$5,000	5	$22,000	$4,400
Tractors (two)	9,000	3,000	5	6,000	1,200
Trailers (two)	3,000	0	7	4,000	430
Trucks (2½ tons)	3,075	1,000	5	2,075	415
Trucks (½ ton)	1,000	150	5	850	170
Straddlebuggy	8,000	2,500	5	4,500	900
Washington Equipment	600	0	5	600	120
Bins	2,400	0	3	2,400	800
Total	$54,075	$12,650		$41,425	$8,435

R. T. Dailey, R.J. Folwell, and R. C. Bevan, The Economics of Owning and Operating Mechanical Grape Harvesters in Washington, Circular 540 Washington Agricultural Experiment Station, 1971.

Dailey also noted the possibility of reducing the capital investment for a system by subcontracting trucking and producer ownership of components such as tractors, washing equipment, bins, trucks, etc.

3.22 Harvester Performance

Harvester owners operated their machines either 8 to 12 hours a day with 1 work shift, or 18 to 24 hours with 2 or 3 work shifts. With the high capital investment and short periods of time the machine could be used, it was important to operate the machine as many hours as possible during the harvesting season. Actual operating time averaged 63 percent of the total time available, which included vineyard equipment relocating, servicing, repairing, labor breaks and washing. Down time averaged 36.5 percent with a range of 20 percent to 46 percent. Acres harvested per hour averaged 0.68 (acres per hour) with harvested yields of 5 to 12 tons per acre.

3.3 Analysis Techniques

Many different methods for system analysis approaches exist depending upon the particular training of the authors. System engineers use dynamic approaches while agricultural economists may employ several methods, such as static modeling, synthetic firm approach, breakeven analysis, and fixed and variable costing. Agricultural engineers may employ feasibility studies and/or optimizing individual equipment or a total system. Regardless of the method employed, the importance of economically analyzing a machine or system cannot be overemphasized.

3.31 Materials Handling

Post harvesting handling systems (materials handling) may be regarded as movement of the product to a new location. Pinches (1958) defined materials handling as any operation which changes the spatial location of the material without changing the form, except incidentally. Cost optimization of the materials handling system may be regarded as manipulation of the operations surrounding the harvester unit to obtain the lowest cost per unit.

The increased interest concerning development of material handling systems has developed not so much because material handling has lagged in an absolute sense, but because it has come to the foreground as the next area needing development. Thus, every phase of handling systems should be regarded as a link in an integrated system involving functional operations. Any individual operation could be a constriction on the efficiency or capacity of the whole system.

Operating efficiency and capital investment costs are normally not in ideal balance in many handling systems. By taking the management viewpoint, we can investigate to understand better how to optimize handling systems and capital investment. Handling systems should be oriented toward operating efficiency by integrating equipment and labor into coordinated systems that reduce output cost per unit.

3.32 Economic Methods

Ricks and Kelsey have authored many reports employing a fixed and variable cost structure analysis on the economics of vegetable and cash crop farming in Michigan. This type of analysis presents an accurate fixed and variable cost per unit of production if the equipment or land is purchased in one lump sum. However, many agricultural engineers question this depreciation method, especially in the grape industry. Grape production is a family speciality handed down from generation to generation and the likelihood of an individual establishing a profitable operation from scratch is prohibitive. Much of the support equipment necessary for the handling system is presently owned or is capable of being loaned or leased, or partnership possibilities exist. Table 6 indicates some of the many possibilities available to grape growers for choosing a system.

The different combinations of mechanical harvesting and handling systems are numerous. With so many possibilities existing for system ownership, leasing, partnership, and renting, assimulating a realistic system becomes impractical. The major fallacy existing with most economic studies is the assumption that all equipment will be purchased new upon initiation of the system, when many times, in actuality, much of the equipment is already possessed by the operator-owner and only a portion must be depreciated toward the harvesting of the crop. The purchase of a new 2-ton truck to haul 400 tons of grapes to the processing plant is not desirable management practice when custom trucking of grapes is available for \$3 to \$5 per ton. Depreciation of fixed costs per unit can be misleading when capital investment is determined by situations not existing in the industry.

3.33 Model Development Review

In general, the system analysis approach requires definition of the boundaries, inputs, outputs, assumptions and the computer model

TABLE 6--Possible Economic Decisions Accompanying Many of the Components of a Mechanical Grape Harvesting and Handling System.

Item	Initial Cost Range Dollars	Rental Cost	Already Own	Lease	Salvage value 10%	Service life
Harvester	22,000 to 27,500	-	-	-	0-3000	3-7
Tractors						
30HP	3,500	possible	possible	possible	300-500	6-10
55HP	6,000	possible	possible	possible	500-700	6-10
Trucks						
1½ ton		\$3-6ton*	10-12¢/mi	possible		
2½ ton		\$3-6ton*	10-12¢/mi	possible		
Trailers	200-600	-	-	-	50	5-10
Containers						
18 cherry tanks	50 ea 720 total	\$10	possible	possible	0	3-6
12 plastic lines	87 ea 1032 total	-	possible	-	0	2-5
Totelift	2700	-	-	-	270	5-10
High Pressure washer	300-1000	possible	possible	possible	30-100	5-10
Service vehicle	2000-3000	possible	possible	possible	200-300	3-6
Forklift						
conventional	3000-5000	350 mo.	possible	possible	300-500	6-10
rotary	4500-7000	500 mo.	possible	possible	450-700	6-10

*hauling cost, vineyard to processor

framework. It is also important to define the interaction and equations. Computer models can be used for many different purposes, with the normal use being tedious calculations, recording payroll, etc. Computer models also can be used for simulation of systems designed to compare the effects of many variables influencing the system.

Two types of simulation--static and dynamic--exist, McMillan and Gonzales (1965). Static simulation is the listing of input parameters for a once only situation and calculating the results. The fallacy associated with static simulation is that all variables remain constant during the analysis without considering conditions of uncertainty which prevail in the real world. Dynamic simulation attempts to deal with these interim period relationships and with the linkage of feedback mechanisms in the model design.

The dynamic simulation technique has the following advantages over other techniques.

1. All possible system designs are evaluated in terms of interface between components.
2. The model is dynamic in structure providing a full impact of time elements and their relationships.
3. The model is sufficiently broad to allow a full interplay of all operational factors.

The disadvantages are:

1. The high cost of seeking perfect information in terms of data collection and analytical structuring.
2. The overall complexity of the study often results in an inevitable communication barrier between technical and general management groups.
3. Extensive time is required to complete the study.

3.34 Machinery Feasibility Study

Stout and Kline (1968) completed a study comparing the feasibility of different machinery systems harvesting tomatoes, asparagus, and cucumbers. In their paper, "Predicting Economic Feasibility of Mechanical Vegetable Harvesting Systems," Stout and Kline considered large numbers of possible hypothetical systems then selected the machine system most favorable from numerical output. Emphasis was placed on high cost items such as labor; capital investment; or manipulation of harvesting rate; and less significant variables such as taxes, shelter, repairs and lubrication lumped into percentages of total capital investment. Grouping of these low cost variables simplified programming. Relatively speaking, less critical variables have very little if any affect upon output data when compared to other more critical variables such as labor and capital investment.

Tennes (1971) modified this feasibility approach in an apple study by incorporating a graphic plot routine developed by Bakker-Arkema (1970) and Lerew. Their plot routine allowed a maximum of 5 output values to be plotted on an X-Y coordinate.

IV. JUSTIFICATION FOR RESEARCH

The grape industry is in a transitional state from hand harvesting to mechanical harvesting. The temporary unskilled labor normally utilized for hand harvesting can no longer be depended upon to harvest grapes in the traditional manner. Rising costs and stable commodity prices have caused grape growers to search for economic relief, particularly toward mechanical harvesting which is sweeping the industry. Efficient use of complex mechanical grape harvester systems depends largely upon the organization and utilization of the various components and labor. Thus, determining the per unit costs (breakeven points) for the various systems would be an asset to harvester operators. This would aid in the acquisition of components to develop a smooth and efficient mechanical grape harvesting and handling system.

Michigan has produced an average of 92,400,000 pounds of grapes annually for the 5-year period 1967-1971. During this time the total annual value of the grape crop produced on 16,700 acres in southwest Michigan averaged $6.5 million. In the same period, the transition from hand harvesting to mechanical harvesting rose from 0 percent to 87 percent and will eventually approach 100 percent.

Neither machinery cost and per unit cost knowledge supplied to the grower has kept pace with the acceptance of mechanical harvesting and handling systems. Equally important, the combining of labor and machinery components by growers into an efficient, lowest cost per unit functioning system implies assistance is needed by application of the systems approach.

The usefulness of the systems approach to machinery analysis can be readily adapted to the individual grower/operator/owner about to select a machinery system. Benjamin in his unpublished thesis (1968) indicated the primary steps required by the farmer to make a decision to select and purchase components for an optimum system as follows: 1) kinds of machinery needed, 2) capabilities of each machine, 3) alternative uses of capital, 4) determining the most important function of the system, and 5) capacities of the system. Based on this knowledge, the final requirements for an efficient machinery system are: a) recommended operation procedures for specific system, b) time limitations that must be imposed upon completion of the job, and c) a and b must be accomplished in the least-cost manner. Fulfillment of these last requirements necessitates the systems approach in order to determine the "most" efficient machinery system for a given enterprise. However, as Conner (1967) points out, changing levels of technology require "...continuous planning in order to maintain an efficient machinery system for any given farm."

Through a study of existing and experimental mechanical grape harvesting systems, a comparative breakdown (income possibilities, profitability) of these systems may be analyzed. Therefore, the following questions regarding mechanical grape harvesting are of interest to grape growers, processors, extension specialists, and researchers:

1. What acreage is necessary to provide a profit comparable to that which the operator might earn by hand harvesting his crop?

2. What are the relative profits of the many alternative systems now available to the developing and expanding mechanical harvesting systems?

3. What are the individual machinery and machine operating costs for different size operations?

4. What is the minimal labor requirement necessary to operate a mechanical harvesting system when substituting for hand harvesting methods?

The grape grower is faced with several alternatives, ranging from system ownership to custom hiring or partnership with another grower. An economic feasibility study requires cognition of these operating costs (direct), ownership costs (indirect), expected years of service, machine capacities, custom rates, interest rates, salvage values, etc. Thus, for comparison to existing mechanical harvesting systems, the development of an experimental system which would maximize recovery, minimize handling costs, reduce labor and result in an economically sound system for the grape industry was explored.

V. OBJECTIVES

5.1 Overall Objectives

The overall objective of this study is to provide to persons in the grape industry pertinent information relative to costs and investments associated with various mechanical grape harvesting systems utilized in southwestern Michigan. Specifically, this study is directed toward determining income possibilities (breakeven points) for the grape operator under different labor usages, harvesting systems, yields, and acreage allotments.

5.2 The Specific Objectives of this Study are:

1. Determine current hand harvesting costs for comparison with mechanical harvesting costs.
2. Define the existing mechanical harvesting systems and determine the current operating costs.
3. Describe the experimental mechanical grape handling system.
4. Determine the factors most critical when acquiring a mechanical grape harvesting system.
5. Determine the breakeven (income possibilities) points for existing mechanical grape harvesting systems vs. the hand harvesting method.
6. Determine the breakeven points (income possibilities)between the experimental and existing mechanical grape harvesting system.

VI. FRAMEWORK AND PROCEDURE

This chapter contains the framework and procedures used to evaluate the relative profitability of alternative mechanical grape harvesting and handling systems in southwestern Michigan. There are three parts to this chapter: 1) the equipment and system development, 2) data procurement, 3) computer program development.

6.1 Equipment and System Development

6.11 Mechanical Harvesting Definition

This study is concerned with the general grape harvesting methods available and their affects on the income producing ability of the different harvesting and handling methods available, both existing and experimental. Specifically, the study is concerned with income variability due to the management of various services, labor, machinery and capital. For the purpose of this study, a mechanical grape harvesting system is characterized by the methods employed to remove the grapes from the vine and to deliver them to the processing plant. This also includes all activities carried out by the harvesting crew such as rinses, washing, repairs, delays, field moves, etc.

6.12 Field System Definitions

6.121 hand harvesting

Figures 1 and 2 on page 25 illustrate the traditional method used to harvest grapes before the introduction of mechanical grape harvesting in Michigan in 1968.

Figure 1. Traditional Hand Harvesting Technique Employed for Grape Harvesting Prior to Mechanical Harvesting.

Figure 2. Conventional Method Employed to Transfer Concord Grapes from Vineyard to Processing Plant Prior to Mechanical Harvesting.

SYSTEM I -- Traditional Hand Harvesting:

The conventional or traditional hand harvesting and handling system utilizes 40-lb. grape lugs, seasonal labor, forklift for lug pickup, and trucks for hauling. Cost evaluation for hand harvesting was obtained from interviews conducted with vineyard owners. These data were compared with data available from other grape producing states. These data are essential to determining breakeven acreages between hand harvesting and mechanical harvesting.

6.122 existing mechanical harvesting systems

A basic mechanical harvesting system consists of the mechanical harvester unit and paralleling vineyard trailer unit operating in the vineyard as a team. Harvested produce was delivered to the processing plant after shaking by various size containers and trucking methods. Current methods consist of handling the grapes in steel or plastic lined pallet containers, approximately 1 ton capacity.

Existing mechanical harvesting methods basically classified as plastic lined pallet and cherry tank containers are represented by a system designation of Systems II and III respectively. Figure 3 on page 27 represents System II with a Chisholm-Ryder self-propelled harvester conveying grapes into plastic lined pallet containers. On the vineyard trailer observe the worker necessary to guide the spout into the containers. Figure 4 illustrates System III and pictures cherry tanks on a flat bed stake truck ready for delivery to the processing plant receiving hopper.

SYSTEM II -- Mechanical Harvesting into Plastic Liners:

The existing bulk pallet container system is filled in the vineyard, transferred from the vineyard wagons by forklift to a truck, hauled to the processing plant, and dumped by rotating forklifts into the processing plant receiving hopper. Equipment required:

Figure 3. Existing Mechanical Grape Harvesting System II in Operation in Southwestern Michigan Utilizing Plastic Lined Pallet Containers to Transport Harvested Grapes to Processing Plants.

Figure 4. Existing Mechanical Grape Harvesting System III in Operation in Southwestern Michigan Utilizing Cherry Tank Containers Instead of Plastic Lined Pallet Containers to Transport Harvested Grapes to Processing Plant.

Harvester	Containers (16)
Tractor(s)	Vineyard trailers
Support unit	Trucks
	Forklift
	a. Conventional - field
	b. Rotating head - plant

SYSTEM III -- Mechanical Harvesting into Cherry Tanks:
Identical to System II except this system utilized 22 cherry tanks instead of 16 plastic lined wood pallet containers. The reason for additional cherry tanks is due to their load capacity of 1500 lbs., approximately 500 lbs. less than plastic lined wooden pallet boxes. Equipment required is essentially the same as for System II except more cherry tank containers are necessary for adequate capacity.

6.123 experimental handling system design

Two experimental mechanical harvesting systems were developed. System V, utilized 3-ton self-dumping vineyard trailers and 8-ton capacity bulk tank trucks. System IV utilized the 8-ton bulk tank trucks but eliminated the self-dumping vineyard trailers and inserted the vineyard trailer, pallet containers and field rotary forklift to dump pallet containers at the field. Figure 5 illustrates System IV, the technique of utilizing a field rotating head forklift to discharge the contents of pallet containers into 8-ton bulk tank trucks. System V is shown in Figure 6 utilizing a 3-ton self-dumping vineyard trailer working with a pull-type Mecca harvester.

SYSTEM IV -- Mechanical Harvesting Utilizing Cherry Tanks and Bulk Tank Trucks:
The same as System III except at the vineyard the cherry tanks are dumped by a rotating head forklift into 8-ton bulk tank transport trucks. Equipment required:

Harvester	Support vehicle
Tractors	Wash unit
Tank trucks	Vineyard trailers
Forklift - rotating head	Containers (6)

Figure 5. Experimental Mechanical Harvesting System IV in Operation in Southwestern Michigan Utilizing the 8-ton Bulk Tank Trucks and Rotary Head Field Forklift to Empty Pallet Containers.

Figure 6. Experimental Mechanical Harvesting System V Utilizing Totelifts and 8-ton Bulk Tank Trucks. This New Bulk Handling System Requires a Self-dumping Vineyard Tank Trailer Instead of the Conventional Pallet Containers and Vineyard Trailers.

SYSTEM V -- Mechanical Harvesting Utilizing Hydraulically Operated Dumping Units (totelifts) and 8-ton Bulk Tank Trucks:

A new bulk handling system requiring a self-dumping vineyard trailer (totelift) instead of the bulk boxes and vineyard trailer. The grapes are harvested into the 2- to 4-ton self-dumper and dumped at the vineyard into the bulk tank truck. In this system the forklift and its operator plus the numerous pallet type containers are eliminated. Equipment required:

Harvester	Support vehicle
Tractor(s)	Wash unit
Tank truck(s)	
Totelift(s)	

6.13 Equipment Procurement and Modification for the Experimental System

Two self-dumping vineyard trailer units (hereafter referred to as totelifts) were supplied by the Pixall Manufacturing Company. During preharvest trials, modifications were made to these units and the units were epoxy painted. The modification consisted of shortening the tongue and welding the seams to make the hopper liquid tight. A Farmhand self-dumping trailer was also modified to hold grapes in the vineyard as an emergency reserve unit. Figure 7 shows a totelift discharging into an 8-ton bulk tank truck.

Two 8-ton bulk cherry holding tanks were modified, epoxy painted, and mounted onto 2 hydraulic stake deck trucks. Modification included the design and construction of a tank opening. A tank rear door was designed liquid tight for transportation from the vineyard to the processing plant and to control the flow of product from the tank during dumping. Exterior tank splash shields were added to direct the grapes into the receiving hopper. The tank interior was modified by the insertion of baffles at the 2 rear corners to aid in self-dumping.

Figure 7. Self-dumping 3-ton Vineyard Totelift Discharging into an 8-ton Capacity Bulk Tank Truck (System V).

Figure 8. Bulk Tank Truck Discharging into a Michigan Processing Plant Receiving Hopper (System IV or V).

For sanitary reasons canvas covers were installed for use in the vineyard and during transportation. Figure 8 illustrates the 8-ton bulk tank truck discharging grapes into the processing plant's receiving hopper.

6.2 Data Procurement Technique

Data for the research analysis were collected on data sheets during the 1970 Concord grape harvesting season in southwestern Michigan. The actual data sheets used in southwestern Michigan are in Appendix A. Following is a discussion concerning the technique used to record data.

6.21 Time and Motion Study

Preliminary data gathered prior to the harvesting of the main grape crop, the Concord variety, established a base to develop the coded data sheet for the time and motion study (Bower 1970) and record forms. The coded data sheet standardized terminology for day-to-day recording and aided in the final summary of the time and motion study.

The coded data sheet and record forms were tested during the mechanical harvesting of several small plots of Delaware and Niagara grapes about a week in advance of the main Concord harvest. Data for this study were collected during the harvest of the Concord variety, which normally begins approximately September 15.

The physical spread of system equipment made it impossible for one man to analyze the total system while in operation. However, within each mechanical harvesting system, 3 natural subactivity groups existed: harvesting, field grape transfer, and trucking.

To utilize the time study sheet for the recording of time and rapid recurring events, the code previously developed was memorized. If optimization of daily tonnage is to be achieved, recording operational delays within each hour to harvest grapes from the vine is also important. The delay headings are listed as: breakdown, maintenance, wash, rest period, container change and synchronization of trailer.

6.22 Field Data Sheet

During the preharvest testing of the mechanical harvesting system, a field data sheet was developed for recording additional information, such as weather conditions, cultural practices, condition of the vineyards, and labor utilization.

6.23 Truck Data Sheet

The assistance of the truck drivers to record the movement and delays in the transportation of the grapes to the processing plant was also necessary. The truck data sheet contains records of such major items as trip length in miles and time, container type transported, grape weight, and truck identification.

6.24 Post Harvest Survey

A post harvest questionnaire developed and personally administered due to time limitations which prevented development of a self-administrative type questionnaire, and a personal desire to meet with grape growers to discuss variations with any question was to gather additional information on items such as harvest totals, financial arrangements, leasing or rental arrangements, and important observations and opinions made by operators during the season.

Appointments were arranged for personal visits with the selected owner to complete the post harvest survey form. The questionnaire and summary sheet compiled immediately following the harvesting season are in Appendix B.

6.3 Computer Program Development

The use of a computer to facilitate the analysis of data can simplify the complex problem of comparing the many possible mechanical harvesting systems. To simplify the investigation of the 4 mechanical harvesting systems, the nuclei for the computer program originated from a feasibility study of a mechanical vegetable harvesting system study by Stout and Kline (1968). The advantages of the economic analysis technique utilized by Stout assigned values to many non-varying factors of fixed and variable costs and included them as a percent of initial or total capital investment. Particular data, such as interest, shelter, taxes, etc., is readily available from previous economic studies.

Tennes (1971) modified this feasibility approach in an apple study by incorporating a graphic plot routine capable of graphing output variables on a single graph. This plot routine developed by Bakker-Arkema and Lerew (1970) allows 1 to 5 variables to be chosen from the main program and plotted.

The program and basic equations used in the computer subprogram along with the symbols and description of the function are given in Appendix D and E. The main program consisted basically of the graph routine used for graphing chosen variables. Limited numerical data output was printed--in particular net return machine, net return hand pickers, and breakeven point--to verify the graph function.

6.31 Cost Structure

The costs are divided into 2 groups--variable (operating) and fixed (ownership). Variable costs differ with increased or decreased acreage harvested per year. Fixed costs vary indirectly and are those costs for which the owner must pay whether the equipment operates or not. Such costs are depreciation, taxes, insurance, shelter, etc.

The separation of costs into fixed and variable is important from a management point of view. Variable costs per ton or acre, which normally refer to operating expenses such as gasoline, grease, labor, repairs, etc., remain fairly stable per acre regardless of acreage harvested per season. This is very important to operators in determining cash outflows during the short harvesting season. Machinery fixed costs, on the other hand, are long-term investments and are generally referred to as the depreciation, and storage costs over the number of acres the system is accountable for in a season.

6.32 Source of Data

Much of the data used in this study was drawn from the questionnaire completed after the completion of the Concord grape harvesting season. With the program capable of comparing hand and mechanical harvesting within the same computer run, all initializing values common to either system are listed in Appendix C.

With 36 potential computer input variables to be regulated within a chosen range, grouping of these variables into classes for discussion was appropriate.

Hand harvesting values, such as potential yield, seasonal acreage, preharvest production cost and price of commodity can be located in Appendix C, Table 1. During the season potential mechanical harvesting acreages ranged from 50 to 450 acres per season. With mechanical harvesting costs indirectly related to acreage, acreage is chosen as a variable and utilized for the X axis on the computer output. Hand harvesting costs remain relatively stable per ton regardless of yearly acreage and can be indicated as a horizontal line equal to the current hand harvesting cost on the output graphs.

Potential yield ranges from one-half to 10 tons per acre with reports of 12- and 14-ton yields on several selected plots. The average yield for 1970 was 3.58 tons per acre. Various output graphs were computed, changing potential yield from 2 to 10 tons per acre in 1 and 2 ton increments.

Price of the commodity per ton ranges from approximately $88 to $158 per ton, depending upon the yield. Increased yields normally accompany decreased prices paid for the commodity.

Preharvest production cost per year was established at $150 per acre from a study completed by Harsh in 1967.

The adopted program incorporated comparison of hand and mechanical harvesting costs per acre. Appendix C, Table 2 contains the variables pertinent to cost analysis of hand harvesting. Direct, daily out-of-pocket costs for temporary hand pickers averaged $28 to $33 per ton, depending on the yield. If a large crop was harvested, hand picking costs per ton decreased.

Rental rates for a forklift and trucking rates were introduced for hand harvesting systems when appropriate. Seasonal rental for a conventional forklift cost approximately $350 per month. Trucking costs ranged from $3 to $6 per ton with a chosen value equal to $5 per ton.

The discrete resources, (Appendix C, Table 3) mainly equipment, are purchased in a specific size. Equipment of this type makes up the physical aspects of a mechanical harvesting system and can be under-utilized. Such items as bulk tanks, pallet containers, trucks, and tractors are purchased as a unit to complement the total system. Some of the equipment and values are: totelift, $2700; bulk tank, $800; and plastic lined pallet containers, $87. A range was established for each of the divisible resources with raw data values used for computer computation. Such items as repairs, maintenance, lubrication, fuel cost, interest, taxes, insurance and shelter are calculated as a percent of capital investment for the system and originate from a mechanical harvester feasiblity by Stout (1969). Other mechanical harvesting variables, such as rental leasing, wages, service life, horsepower, and trucking rates, were obtained from data compiled from a post harvest survey conducted during the 1970 grape harvesting season.

Appendix C, Table 4 lists the harvester and handling systems' efficiency factors utilized for determining the effective field capacity analysis. Recording of the individual functions and increments for each machine established the ranges, averages and values utilized in the effective field capacity study. Product loss was observed but not recorded due to a time limitation. Efficiency factors such as trellis length, number of harvesters, wash time, etc. were recorded as divisible values.

VII. DISCUSSION OF RESULTS

This study recognizes the problems plaguing grape growers in selecting a suitable mechanical grape harvesting and handling system. Although the magnitude of investment for the mechanical harvester normally was greater than 75 percent of the total capital investment for a mechanical harvesting and handling system, there are certain unique characteristics associated with management's decisions which rendered difficult the management of available information. Some of these characteristics recognized in this study are:

1. Rapid technological developments in machines without accompanying per unit cost data.

2. Calculation of breakeven points (income possibilities) for different investment levels for mechanization.

3. Economic comparison between different mechanical harvesting and handling systems--both existing and experimental.

4. Determining the economics feasibility of introducing an entirely new and simplified handling system.

This particular chapter is divided into various sections to develop fully the variables indirectly affecting managerial decisions. The development of the concepts behind many of the following sections would have been more difficult without computer assistance. The items discussed in this chapter are as follows: 1) effective field capacity, 2) effects of unequal variables, 3) other variables, 4) discussion of the systems, 5) importance of labor, 6) options, and 7) breakeven points.

7.1 Effective Field Capacity

Determination of the best size and type of equipment to develop a complementing grape harvesting system involves measurement of the factors influencing optimization of a system. Harvester efficiency has a large effect upon per unit cost or breakeven points. Factors which determine system efficiency include total acreage involved, total time available, capacity of the machine, size of machine and compatibility between operating units.

The effective field capacity of an implement is the actual rate of coverage of the field by the machine based upon the total time in the field, Bowers (1970). Certain factors, such as adjustments, lubrication, breakdowns, turning at the ends, plugging, or synchronization of companion equipment, are additive and combine to decrease harvester efficiency.

During the study 3 distinct harvesting time periods were observed in operation--1, 2 and 3 work crew shifts per day, depending upon the acres harvested per season. Little variation in field efficiency was observed between the 3 operating time periods. All 3 working time periods relied upon preventative maintenance techniques to stabilize delay time in the vineyard. One particular harvester operator realized over 99 percent harvester availability, harvesting over 535 acres in 17 days with only 2 hours of downtime forfeited to mechanical breakdown delay.

During the field survey, 4 variables were observed to limit effective field capacity, as follows: 1) delay per hour hopper change or synchronization of harvester and trailers, 2) delay per hour for washing, 3) delay per hour, for mechanical and managerial delays and 4 delay per hour for turning at the end of row. The effective field capacity for the harvester in this particular situation ranged from 19.6 to 63 percent of the possible theoretical harvesting rate. Table 7 illustrates the relationships of these delays to acres per hour. Dailey in his Washington study of the mechanical grape harvester stated that the effective field capacity averaged 63 percent.

With the relative newness of the machines and preventative techniques utilized, minor delays were minimal. The factors included in "mechanical and managerial delay" are as follows: vineyard to vineyard move time, breakdown time necessary to communicate effectively, and other minor incidentals such as the author talking to the harvester operator. This delay normally included all stoppages of the mechanical harvester not appropriate for other delay headings and appeared to be directly related to organization of the operator. The average mechanical and managerial delay was 14 percent with a range of less than 1 percent to greater than 20 percent.

The frequency of washing depended upon several factors, including weather, temperature, sugar content, malfunctioning parts due to stickiness and recommendations by grape processors. Depending upon conditions, harvester operators normally implemented a major wash cycle every 8 hours of operation with a minor wash or rinse every 4 hours. The major wash time ranged from 20 to 60 minutes with an average of 40 minutes for a complete wash. The minor rinse or wash ranged from 10 to 25 minutes with an average of 16.5 minutes, depending upon the washing equipment available. During the wash periods, preventive maintenance was performed by the rest of the crew reducing the necessity for

TABLE 7--Effective Field Capacity for 3 Different Size Mechanical Harvester Operations and 2 Different Row Lengths, 320 Ft. and 2640 Ft.

	9/hr/day 1 crew workshift		18/hr/day 2 crew workshift		24/hr/day 3 crew workshift	
MPH	1.7 mph	1.7mph	1.7mph	1.7mph	1.7mph	1.7mph
Row length	320 ft	2540 ft	320 ft	2640 ft	320 ft	2640 ft
Row width	10 ft	10 ft	10 ft	10 ft	10 ft	10 ft
Wash time	13.8%	13.8%	13.8%	13.8%	16.7%	16.7%
Delay time/hr						
mechanical	11.1%	11.1%	5.6%	4.7%	4.7%	4.7%
management	8.3%	8.3%	8.3%	8.3%	8.3%	9.4%
Hopper change delay/hr*	.8%	4.2%	1.7%	4.6%	1.6%	4.3%
Turn time delay/hr	46.4%	5.6%	46.4%	5.6%	46.4%	5.6%
Total delay percent	80.4%	42.0%	75.8%	37.0%	77.7%	40.7%
Effective field capacity percent (100-TDP)	19.6%	58.0%	24.2%	63.0%	22.3%	5?.3%
If theoretical field capacity equalled 100%	2.1A/h	2.1A/h	2.1A/h	2.1A/h	2.1A/h	2.1A/h
Effective field capacity acre/hour	.41A/h	1.22A/h	.51A/h	1.35A/h	.48A/h	1.28A/h

*Potential yield 4 ton per acre

separate time periods to be set aside for maintanence. The wash delay time to the harvester averaged 13 percent of the time available for harvesting.

Hopper change delay refers to the delay caused to the harvester during changing of vineyard trailers used for operation parallel to the harvester. It is directly related to the potential yield of the vineyard and container size (both in capacity and in the container's opening dimensions). The delay time necessary for hopper change averaged 30 seconds per ton regardless of the system employed and was usually caused by repositioning of the harvester spout from a full container to an empty container. Thus, with an average harvesting rate in 1970 of 3.58 tons per hour, 1.75 minutes per hour were devoted to delays caused by spout change. Therefore, the average delay caused by hopper change approximated 3 percent with a possible range of 0.5 to 6 percent depending upon yield.

Harvesting delays caused to the harvester while turning depend entirely upon two factors: field configuration (row length) and time required for maneuvering and synchronization of the harvester and vineyard trailer for the return row. Since turn delay time is more affected by synchronization delays and not end travel time, effective field capacity will actually decrease if harvester speed is increased for the same field conditions. During the 1970 grape harvesting season, turn time ranged from 30 seconds to 2 minutes per turn with an average turn time of 1 minute per turn (regardless of harvester row speed). Trellis or row lengths ranged from 60 ft. to 3100 ft. with an average 756 ft. per trellis length. Accountability of turn delay time depends largely upon row length and mph of the harvester. Field data indicated delays caused to the harvester for short rows (200 ft. or less) could be greater than 50 percent of available harvesting time. For long rows (3100 ft) with normal harvester operating speeds of 1.7 mph, delays caused to the harvester could be less than 3 percent of available harvesting time. Effective field capacity will increase as improvements to the vineyards and the systems are implemented, such as easier turning, leveler and better headlands, longer rows and better coordination of the work crew.

7.2 Effects of Unequal Variables Incorporated Within the Systems

Accuracy of output results of system analysis, particularly when comparisons are made between four different systems, requires recognition of the variations between systems. System analysis comparison is valid only if the parameters are equal or the effects of the differences are noted in the evaluation. Visualization of the system being analyzed as a matrix or flow chart of activities taking place in a defined time span can help to draw a mental picture of the activities within the system. Not until all the input and output parameters have been recorded and all the internal workings of each system charted can combination analysis of systems commence.

If the definition of grape harvesting is "harvesting and handling" the termination point must be determined for the handling system. Some systems have a natural breaking point such as before unloading of the pallet boxes (as in the case with Systems II and III) at the processing plant. Concurrently in Systems IV and V the natural cost termination existed with the grape juice and pulp unloaded from the truck.

The advantages realized by processing plants when switching to bulk handling basically consist of elimination of plant labor, forklifts and forklift operators. The reduction in plant expenses by elimination of two rotary forklifts and 1 to 3 men per shift represents a substantial amount. Cost reduction in forklift rental of $1000 per forklift per season and labor cost of $1800 (25 days, 24 hours per day,and $3 per hour) are possible by switching to bulk handling. However, for the purpose of this study cost computation will be defined as before the dumping or unloading point. This cost reduction is an additional benefit to plant processors when switching to bulk handling. Equipment necessary for processing plants to switch from pallet boxes to bulk handling essentially consists of rearranging existing equipment and construction of an unloading ramp to receive hydraulic tilt dump boxes.

A second area of concern is centered around the initial harvester cost of $28,500 for the self-propelled Chisholm-Ryder harvester and $22,500 for the pull-type Mecca harvester. The field advantages are well known to the grape producer. However, cost advantages are not; and for economic comparison, ownership and operating costs were calculated for each. Calculation of ownership and operating costs for 300 acres totaled $31.63 per acre for the Chisholm-Ryder machine and $29.13 per acre for a Mecca harvester. The initial capital investment cost for the Mecca can be very important for the small grower; however, for the commercial operator the extra conveniences for the self-propelled unit may be desired. Table 8 gives an ownership and operating cost breakdown for the Chisholm-Ryder and Mecca harvesters.

TABLE 8--Ownership and Operating Costs Per Hour for 2 Different Harvesters. The Self-propelled Chisholm-Ryder and the Pull Type Mecca and Tractor Operated 350 Hours or 301 Acres Per Year.

	Chisholm-Ryder Calculation	Chisholm-Ryder Year cost	Mecca Calculation	Mecca	Tractor Calculation	Tractor
Ownership Costs						
Depr.	$\frac{28500}{20000}$ x 350	4815.00	$\frac{22500}{20000}$ x 350 =	3940.00	$\frac{5000}{12000}$ x 700 =	292.00
Int.	$\frac{28500}{2}$ x .08	1140.00	$\frac{22500}{2000}$ x .08 =	900.00	$\frac{5000}{2}$ x .06 =	150.00
Tax Ins.	28500 x .02	570.00	22500 x .02 =	450.00	5000 x .02 =	100.00
Total fixed cost/year		6525.00		5290.00		542.00
fixed cost per hour		18.64		15.10		1.55
*fixed cost per acre		21.67		17.57		1.81
Operating Costs						
Fuel	45 hp x .75% x .20	0.67	30 hp x .75% x .20	0.52	60 hp x 40% x .20	0.48
Oil and Filter	0.67 x .08	0.09	0.52 x .08	0.09	0.52 x 0.15	0.08
Repairs	$\frac{28500}{100}$ x .04	5.70	$\frac{22500}{100}$ x .04	4.50	$\frac{5000}{100}$ x .012	0.60
						4.00
Labor		4.00				3.50
Operating cost per acre		10.46		5.11		5.14
Total ownership and operating cost/acre		32.13				29.63

* Multiplied by .86, harvesting rate per hour.

7.3 Other Variables

The computer is an invaluable tool for economic analysis when many variables exist. When changed even slightly, the following 3 input variables affect per unit cost: 1) harvesting rate per hour, 2) potential yield, and 3) product recovery. The simulation model developed exclusively for grape harvesting indicated these variables at the present state of the art affected managerial decisions.

7.31 Harvesting Rate Per Hour

Harvesting field efficiency is the ratio of effective field capacity to theoretical or actual time available expressed in percent. By reduction of "lost time" delays to the harvester, effective field capacity will increase due to decreased operating delays per acre.

Increasing harvesting rate per hour depends upon decreasing "lost time" delays to the harvester. Recommended practices of increased row length, smooth and wider headlands, and better coordination of harvester and support trailer will help decrease delays. Analysis of the post harvest survey, Table 9, indicated an actual seasonal harvesting range of 0.68 acres per hour to 1.3 acres per hour. Comparison between the existing and experimental harvesting systems averaged from 0.88 per hour for the existing systems (Systems II and III) to 0.87 acres per hour for the experimental system (System V). Very little difference in harvesting rates existed between the existing and experimental mechanical harvesting systems; however, it should be noted that System V operated almost entirely in "first time" mechanically harvested vineyards where more delays are usually present. A major factor affecting harvesting rate per hour is field configuration; and until vineyard modifications are implemented, harvesting rate per hour will remain in the .8 to 1.3 acre per hour range.

TABLE 9--An Analysis of a Post Harvest Survey of 7 Southwestern Michigan Grape Harvester Operators/Owners Utilizing the Conventional Systems II and III in Comparison to 1 Harvester Operator Using the New Bulk Handling System V.

	Harvester Operator Survey Number For Conventional Systems II and III							Systems II & III Average	System V
	1	2	3	4	5	6	7		8
Days of operation	17	20	23	22	25	25	23	21.8	22
Hours/day	24	9	17	24	14	24	16	16.6	16
Number of workers/shift	6.5	5.5	5.5	5.0	6.0	5.0	5.0	5.4	3.5
Total hours	408	180	391	528	350	600	368	404	352
Breakdown time hours/ season	2	8	16	72	42	63	28	33.0	35
Operating time less break-down	406	172	375	456	308	537	340	371	317
Acres/season	534	175	325	351	300	360	310	337	275
Acres/hour	1.3	.98	.86	.78	.97	.68	.91	.88	.87
Acres/man hour								.16	.25

7.32 Potential Yield

Potential yield has a large effect upon justifying ownership of a harvesting system. The adoption of highly mechanized harvesting techniques and accompanying high capital investment outlays by the growers increases his dependency upon stable yearly outputs of potential yield. Potential yields of grapes are extremely sensitive to temperature, weather, insects, disease, frosts and viticultural practices. Stable potential yields defy reality, and for grape growers to make sound economic decisions requires additional information.

The grape industry's traditional measuring stick regulates movement of the produce by the ton unit.

Agricultural economists normally determine costs on a per acre basis for field equipment. However, in the grape industry, commodity price can fluctuate nearly 50 percent from year to year depending upon the potential yield. If the seasonal production is high, commodity prices are low, and vice versa. A review of Table 3, page 6 , will support this analogy.

With traditional hand harvesting techniques, harvesting costs per ton remain relatively constant regardless of potential yield. Conversely, regardless of yield mechanical harvesting cost per acre remains relatively stable and mechanical harvesting costs per ton fluctuate widely. For mechanical harvesting, potential yield can be utilized as a variable since acres harvested per hour remains relatively constant and is little affected by yield. Per unit costs are presented in both units (acre and ton)to give direction to possible future cost trends and to compare data from existing and current research. Also, per ton costing is utilized for determination of breakeven points (income possibilities) between hand and mechanical harvesting.

Comparison of costs between hand and mechanical harvesting depends upon determination of the current or previous hand harvesting costs. Harsh in 1967 suggested fixed and variable costs totaling $29 per ton for hand harvesting. In 1971 a more recent survey of grape producer costs by Kelsey indicated hand harvesting costs were $40.79 per ton. The post harvest survey by the author in 1970 determined out-of-pocket expenses averaged $29.17 per ton for hand harvesting. This includes no other costs incurred in harvesting, only money paid directly to hand pickers. If this is projected to include these "other costs", hand harvesting approached $38.60 per ton in 1970. Presently, no relief is in sight for reduction in hand harvesting rates.

The grape grower who expects to continue production, provided the decision to sell out is not considered, has 3 choices. One is to continue to harvest grapes in the traditional manner by employing hand harvest laborers with the knowledge that: 1) labor cost will continue to increase, 2) scarcity of labor will increase and 3) the enforcement of more stringent regulations governing migrant housing will push the hand harvesting costs still higher. The grower's second choice would be to purchase a mechanical harvester individually or to form a partnership. If this choice is exploited, the cost per ton for various potential yields is essential for comparison with hand harvesting. The third choice available to the grower is custom hiring a mechanical harvester operator. Of course, many unmeasurable factors, such as timeliness of harvest, frost kill, and unsatisfactory custom harvesting increase growers vulnerability to high crop losses. Presently custom hiring rates vary widely, and are based mostly on harvester ownership intuitive feelings. The current trend indicates custom operators will continue to charge by the ton. Custom hiring rates in 1970 ranged from $27 to $30 per ton with expectation of rate reductions accompanying increased custom hiring competition.

Potential yields, investment levels, and seasonal acreage are 3 important variables used to determine breakeven points between hand and mechanical harvesting systems. Figures 9 to 14 on pages 51 to 57 give mechanical harvesting cost per ton based on potential yields of: 2, 3, 4, 6, 8, 10 tons per acre and a harvesting rate equal to 1 acre per hour. Yearly acreages range from 50 to 450 acres; and system investment levels, from $24,000 to $40,000. The cost per ton can be used as a known or unknown value, depending upon whether it is used for determination of mechanical harvesting cost or for comparison between hand, custom or ownership cost. Figure 15 represents the cost for mechanical harvesting of grapes with calculated values for per acre basis.

7.33 Product Recovery

Evaluation of product recovery was not attempted during the 1970 grape harvesting season. Published data on grape harvesting recovery are non-existent. Plans are being made to evaluate grape recovery in the coming season. In the adopted computer simulation model utilized for the economic analysis, provision for insertion of a product loss factor

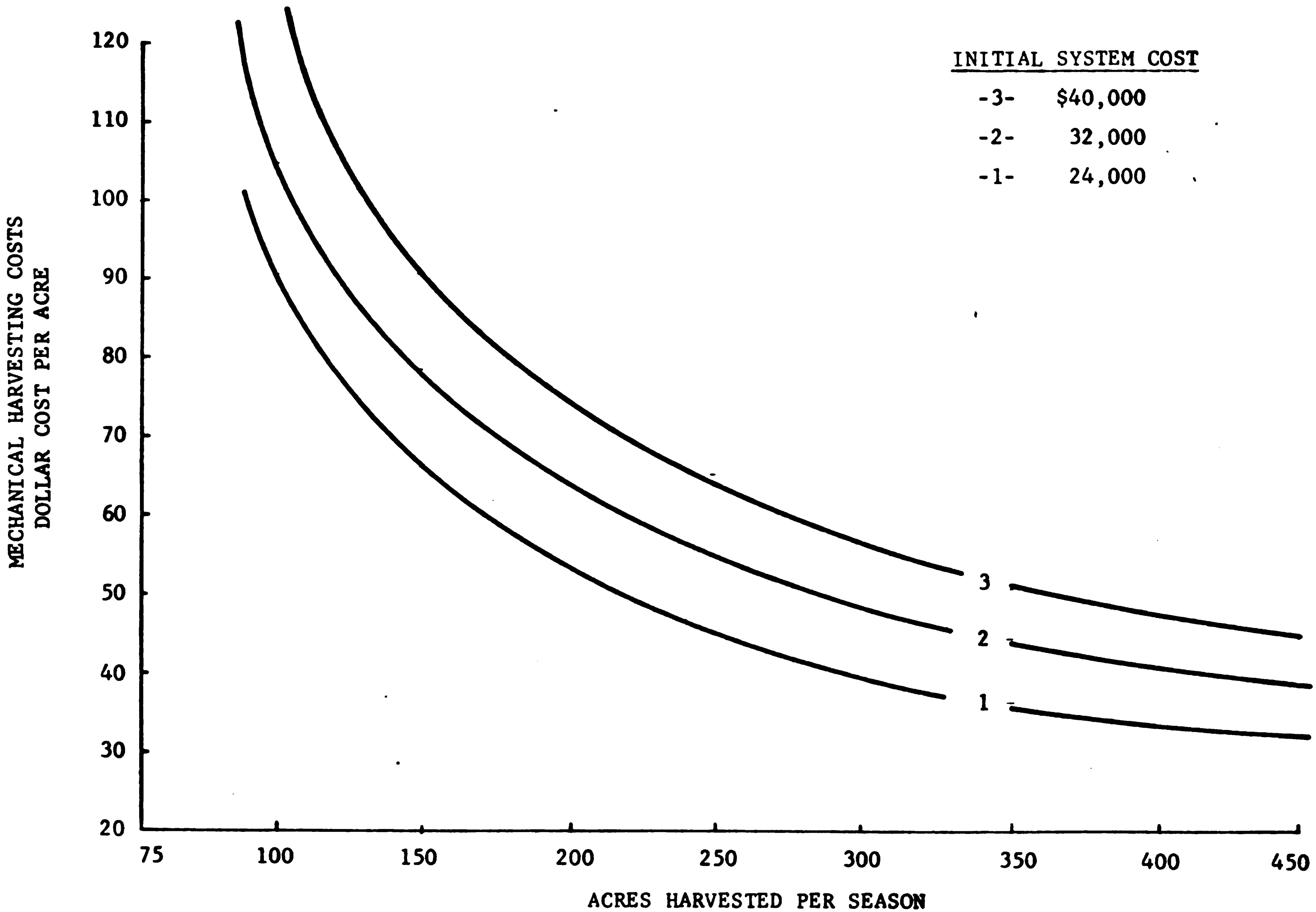

Figure 15. Mechanical Harvesting Cost Per Acre Independent of Yield for Concord Grapes in Southwestern Michigan as Influenced by Initial Harvesting System Cost and Acres Per Season.

or product recovery factor (100 percent - product loss) was possible. During field observation it was apparent product recovery was not 100 percent. Grapes shaken from the vine by the mechanical harvester and not caught by the catching frame were observed on the ground behind the harvester. Also, the axial twisting force imposed upon the individual berry during detachment from the vine frequently split the berry skin and allowed a juice loss in the conveying system prior to reaching a juice tight container. In addition, berry juice was observed on the foliage immediately after harvesting.

From the field observations a value of 10 percent by weight was chosen for product loss and inserted into the simulation model. The computer results indicated that with no other input changes made mechanical harvesting costs increased substantially. As illustrated in Figure 16, based on a theoretical 10 percent loss, the mechanical harvesting costs for 150 acres with a potential yield of 4 tons per acre, increased from approximately $19 per ton to over $33 per ton or a increase of 73 percent for a $32,000 system. For 450 acres and a $40,000 system, mechanical harvesting costs increased from $12 per ton to approximately $22 per ton or an 83 percent increase. These huge increases in mechanical harvesting costs, if they occur, are subtracted directly from profits. These costs or, more appropriately, losses are not out-of-pocket losses and usually are rationalized by the grower as a normal operating expense. However, it was deemed appropriate to inform grape producers of the potential loss for careless or improper grape harvesting operations.

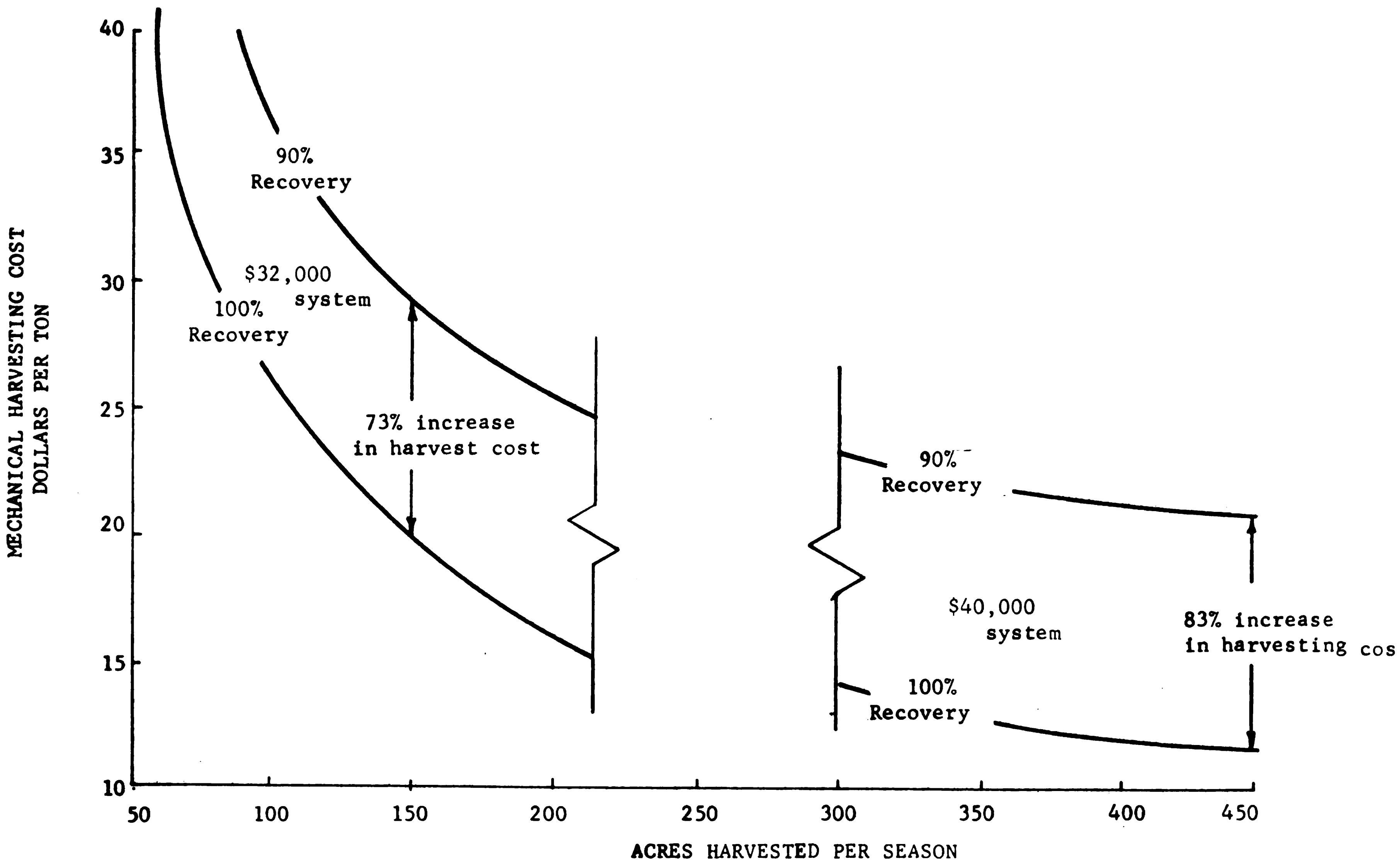

Figure 16. Influence of a 90 Percent Product Recovery Upon Mechanical Harvesting Cost for a $32,000 System on 150 Acres and a $40,000 System on 450 Acres.

7.4 Discussion of the Systems

In the development of a mechanical grape harvesting system, several factors appear to guide decisions made by harvester owners. To develop a system it is important to set goals or to indicate what is to be the optionized cost, acreage per season or harvester efficiency. The concern of the grape industry was to develop and adopt a sound grape harvesting system capable of delivering quality grapes to the processor with costs comparable or less than any system currently in use. The basic philosophy utilized for system comparisons was to maximize net return by minimizing per unit costs through manipulation, addition, or subtraction of men, machinery or capital investment.

7.41 Existing Harvesting and Handling Systems

Determination of per unit cost for the existing mechanical harvesting systems, cherry tanks or plastic lined pallet boxes evolved around the conception that labor requirements differed little between cherry tanks or pallet boxes and harvester efficiency could not be increased noticeably by the addition of more workers. Per unit cost would also increase noticeably if ownership costs increased by the addition of new equipment instead of utilizing existing equipment or leasing unowned equipment. Accurately speaking, per unit costs increased proportionally as total capital investment increased. The figures discussed earlier on potential yield show the relationship between capital investment, yearly acreage harvested and per ton costs.

The major advantage of the existing harvesting system is manipulation of initial capital investment. By the inclusion of existing equipment into the mechanical harvesting and handling system, it is possible to defer capital investment at the expense of additional labor. Hence, it was possible for some multi-diversified operations (harvesting grapes, apples, cherries, etc.) to utilize existing fruit containers and equipment as the handling system, avoiding major additional capital outlays beyond the harvester purchase. Thus, the major advantage to existing mechanical harvesting systems is the deferral of large sums of additional capital investment for the handling system.

The 2 major disadvantages of the existing harvesting and handling system are coordination of labor and the excessive amount of equipment and, secondly, acquisition and night operation of a heavy duty forklift. In the existing systems grape pulp is transferred to the processing plant in 1-ton capacity pallet containers with dust covers. The continual coordination of full and empty pallets, movement of the harvester equipment from vineyard to vineyard and erratic work requirement surges require a larger work force than necessary to operate the harvesting system. To facilitate night transfer of pallets from vineyard trailers to trucks, the vineyard trailers were often transported considerable distance to better lighted farmstead yards for unloading.

Vineyard moves per season averaged 23.8 in 20 days and ranged from 18 to 58 moves for the operators surveyed, moving an average 2 trucks, 2 trailers, harvester, forklift, support vehicle, wash unit, and 16 containers. This moving was accomplished by approximately 4 to 6 men and required frequent looping back of the work crew.

7.42 Experimental Harvesting and Handling System V

With the development and eventual field testing of the experimental bulk handling equipment, it was possible to simplify many of the shortcomings of the existing systems. In particular, the reduction in equipment numbers decreased manpower surges during vineyard relocation. Secondly, the large 3-ton capacity self-dumping vineyard totelift eliminated 16 pallet boxes, 1 field and 1 processing plant forklift, and 2 forklift operators. Thirdly, the self-dumping totelifts eliminated extensive time needed to load a truck ready for return to the processing plant and could be accomplished in any vineyard conditions negotiable by the harvester. Additional advantages not evaluated in economic values are ease of totelift operation in severe weather conditions, large size of receptive opening for harvester spout, and ease of grape transfer.

During the operation of System V (experimental) the dumping time cycle for a loaded totelift to dump in bulk tank truck nearby (same field and headland) averaged 2 to 3 minutes with skilled operators. This time begins at harvester spout discharge termination to harvester spout operation on a new row.

With the elimination of pallet boxes and the maximization of harvester harvesting time, it was thought that 2 totelifts per harvester or at least 3 totelifts to every 2 harvesters in the same field would be necessary to avoid costly delays to available harvesting time.

During the testing of the experimental grape harvesting System V, the author observed that under certain conditions the work crew was actually operating with only 1 totelift without a decrease in effective field capacity. During the conception of the experimental system 2 totelifts were considered essential per harvester. A review of the delay factors revealed the dumping cycle time for a loaded totelift to discharge 4000 to 7000 lbs. of grapes into a stationary bulk tank truck averaged 2 to 3 minutes. With a harvester reposition time of 0.5 to 2 minutes per turn, a possible delay to the harvester of 1.5 to 2.0 minutes existed per dump. Seasonally, this delay would represent 2.8 hrs. or 4.2 hrs. for 600 tons harvested seasonally. The delay to a larger operation would be 5.6 hrs. and 8.4 hrs., harvesting 1200 tons seasonally. This does not take into consideration that every fourth dump would occur during a wash cycle causing no actual delay to the harvester. If such factors as timeliness and long rows are non-applicable, some mechanical harvesting systems could operate satisfactorily with 1 totelift.

With this increased flexibility for matching harvester and handling systems to different size operations, additional possibilities are provided for harvester owners. With this capability it is now possible to operate System V with only a harvester, totelift, wash, support vehicle and 2 trucks depending on the plant dumping delay time and distance to the plant. The original experimental System V was expanded to Option C, and E with a designation of Option D for the experimental System V. The original experimental System IV was expanded to include Option B a derivative of experimental System IV also redesignated as Option B. (See Option 7.6, pg 66).

7.5 Labor

Labor usage normally is a large part of any grape harvesting system. Traditionally, hand harvesting represented 80 percent of the total hand harvesting costs and an average picker could harvest 1200 lbs. daily. Thus, it was essential to hire approximately 26 pickers to hand harvest 100 acres per season.

With the introduction of the mechanical harvester, labor requirements were reduced substantially. However, the workers utilized in mechanical harvesting required more mechanical skill than hand pickers. In 1970 the machine operators utilized in mechanical harvesting consisted mainly of grape growers, their family and year round help.

During the study 3 distinct harvesting periods existed. The labor requirements did vary between the 1, 2 and 3 work shift operations. The labor utilization for the existing mechanical harvesting system consisted of 1 harvester operator, 2 vineyard trailer operators, 1 box tender, 1 forklift operator, and 1 truck driver. In selected cases additional workers such as truck drivers, or maintenance personnel would increase the total number of workers per system. Similarly, jobs could be combined, or a reduction in vineyard tractor operators was possible. In 1970 in southwestern Michigan the existing mechanical harvesting system worker requirement averaged 5.4 workers per shift. The range of workers required in an existing system ranged from 4 to 7 workers.

In the operation of System IV, labor requirements paralleled the existing mechanical harvesting systems in most cases. However, if the elimination of 12 to 16 pallet containers, a one-half reduction in forklift operation time, and reduced labor time for pallet box tie down could be instituted, an advantage to some operations existed. The operation of the forklift by the vineyard trailer operator or truck driver was feasible. This would represent a 1 worker reduction over the existing mechanical harvesting system and could represent a $375 to $1224 per season labor reduction for 100 and 450 acres respectively.

The assignment of labor to each function in the experimental mechanical harvesting System V consisted essentially of 1 harvester operator, 1 totelift operator and 1 truck driver. In some cases a general assistance worker was available to pick up work surges, spell the harvester operator or handle repairs. In 1970, the average number of workers for System V was 3.5 workers per crew shift. The range for the number of workers utilized in System V was 3 and 4 respectively.

During the harvesting season in 1970, variations in labor requirements within each system existed. Labor requirements between systems varied as discussed previously. Some of the factors influencing labor requirements within a system consisted of acres harvested per season, number of work shifts per day and coordination and efficiency of the grower's operation. Between the systems, labor reductions for the experimental systems consisted basically of 1 less worker for System IV and 2 fewer workers for System V.

A strong correlation existed within a system between the number of workers and acres harvested per season. These classifications could be labeled as small, medium and large or commercial size operations. The small operation consisted of a family operation harvesting 75 to 150 acres per season with a reciprocal labor agreement for custom harvesting services rendered to a neighbor. The medium size operation represented the majority of the grower operations in southwestern Michigan in 1970. The yearly acreage ranged from 150 to 300 acres per season and consisted of a 2 shift work crew. The commercial operation consisted of a 24 hr., 3 work crew set-up harvesting over 300 acres per season. In most instances a 1 worker difference existed between classifications. Table 10 shows the differences between different systems and within a given system.

TABLE 10--Comparison of Labor Requirements for Various Sized Operations Using Systems II and III Labor Requirements as the Base for Determining Labor Requirements of the Experimental Systems IV and V.

	*Size Classification of Operation and Number of Workers Per Shift.		
SYSTEM	SMALL	MEDIUM	LARGE
II and III	4 workers	5 workers	6+ workers
IV	3+ workers	4 workers	5 workers
V	3 or less	3+ workers	4 workers

* Assuming effective field capacity between systems is not affected by the worker reduction.

7.6 Options

The number of possible combinations of equipment for system design are infinite. With so many possibilities available to grape growers, breakeven points were developed. These breakeven points between the existing and experimental system are determined by trading off capital investment for labor cost. Hence, the reduction in the forklift operation and labor must economically meet the additional annual cost incurred for the bulk handling system equipment.

Five options (A, B, C, D and E) representing possible experimental systems were developed. The total ownership and operating costs per season for the additional equipment required in the experimental, and eliminated in the existing, systems were calculated for each option. The ownership costs included depreciation, interest, repairs, taxes and insurance; operating costs included gas, oil and maintenance. The physical aspects, labor requirements, investment levels, and annual costs, are listed in Tables 11, 12, and 13 for the 5 options.

Option A. System IV, minimum requirements.

The essential equipment consists of a rotating head forklift, 2 8-ton bulk tank trucks and a vineyard trailer. Option A is used basically for small operations (4 tons per acre or less, short hauls).

Option B. System IV, long distance hauling.

The essential equipment is identical to Option A except for the addition of 1 bulk tank truck and a vineyard trailer. Option B is used basically for operations larger than indicated in Option A (long hauls, long rows, heavy yields, 4 tons per acre or greater).

Option C. System V, minimum requirements.

The essential equipment consists of 2 bulk tank trucks and a totelift. This option is used basically for small operations (short rows, yields 5 tons per acre or less, short hauls, use of vineyard headland for grape transfer to bulk tank truck).

Option D. System V.

The essential equipment is identical to Option C except for the addition of 1 more totelift. This option would function best in vineyards with extremely long trellises, heavy yields 5 tons per acre or greater and in vineyards where grape transfer from totelift to bulk tank truck is not possible in the immediate area.

Option E.

The essential equipment consists of 3 bulk tank trucks and 2 totelifts. This option is best utilized by the 24 hr. or commercial operation. Many alternatives exist for justification: long rows, high yields, long hauling distances, 2 harvesters in average or below average yields, etc.

Table 11 represents the physical similarities and differences among 2 existing systems and 5 options. Costs for the existing systems were calculated at 150 and 300 acres per season for comparison with the different options. Labor was assigned depending upon the acreage harvested per season and for each operation requiring a worker. In some situations 1 man could be assigned two positions. This of course is arbitrary and depends upon the individual grower's operation. The important use of Table 11 is not total number of workers but differences between chosen systems or options.

The physical requirements for equipment were based upon records and observations made during the 1970 Concord grape harvesting season in southwestern Michigan. The number of pallet containers chosen represents actual systems in operation. Determination of bulk tank truck numbers are assigned to situations parallel to existing systems.

The totelifts are a key factor in developing 3 options (C, D, E) parallel to existing systems.

TABLE 11--Physical Aspects for Determining the Breakeven Points Between the Existing (Systems II and III) and Experimental Mechanical Grape Harvesting (Systems IV and V) Expanded to Options A,B,C,D,E

	Existing		Experimental				
	II and III (small or large)		4		5		
	Plastic lined or cherry pallet containers		Rotating fork-lift and bulk tank truck		Totelifts and bulk tank trucks		
			Options				
	Small	Large	A	B	C	D	E
Labor requirements[1]	(8-18 hr)	(24 hr)					
Harvester operator	1	1	1	1	1	1	1
Trailer driver	1	2	1	2	1	2	2
Box tender	1	1	1	1			
Forklift operator[2]	1	1					
Truck driver	1	2	1	2	1	1	2
Equipment							
Forklift							
Conventional	1	1					
Rotating head			1	1			
Pallet container[3]	16	22	6	9			
Bulk tanks (8 ton)			2	3	2	2	3
Truck hoists			2	3	2	2	3
Totelifts (7000 lb cap)					1	2	2

1. Labor requirements vary depending upon the situation; consequently the author's conservative judgement was utilized assigning values to the options. The important concern in assigning workers to a system is noting the difference between existing and experimental and not total workers.

2. For Options A and B it is essential that in some situations a forklift operator may or may not be needed. An analogy would be a half boy to operate the forklift. This decision to pay a forklift operator or combine jobs determines the income potential as negative to positive respectively.

3. Two values were assigned to the number of pallet containers in direct relationship to the number 1½- to 2-ton trucks required per system. The value of the plastic lined pallet containers was $87 each. For the Options A and B, cherry tanks valued at $50 each were assigned.

Table 12 contains the initial investment costs for various options and cost of equipment affected in the analysis of the existing system. Labor costs of $3.00 per hour for all workers, except the harvester operator who received $4.00 per hour, were assigned to the various workers. The various investment for each type of equipment (pallets, etc.) depends upon the number required for each option.

The determination of the annual costs for each of the 5 options and the 2 existing systems are exhibited in Table 13. Labor the major operating expense is utilized as a breakeven variable to compare with additional annual cost for the 5 options. Operating expenses play an insignificant role in determining the breakeven points between the existing and option systems. The various values, labor and annual costs, utilized in determining ownership expenses for the different options are the most important factors in determining income potential.

In all cases except Option E, the breakeven point was less than 150 acres for a 2 worker reduction represented in Table 14. Option E showed the greatest income potential of $1718 per season with Option D showing a negative income potential of $742 per season. It should be noted that in Option D 1 worker was included with the second totelift, but the option still compared to the same 150 acres small operation. If the worker is not included or Option D is compared to the large 300 acre operation, the income potential is minus $137 and plus $1768 respectively.

TABLE 12--Investment or Labor Differences for Determining the Breakeven Points Between the Existing (Systems II and III) and Experimental Mechanical Grape Harvesting (System IV or V) Expanded to Options A, B, C, D and E.

	Existing		Experimental				
	II and III (small or large)		4		5		
	Plastic lined or cherry pallet containers		Rotating head forklift and bulk tank trucks		Totelift and bulk tank trucks		
			Options				
	Small (8 or 18 hr)	Large (24 hrs)	A	B	C	D	E
Labor costs seasonal[1]							
Harvester operator	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Trailer driver	3.00	6.00	3.00	6.00	3.00	6.00	6.00
Box tender	3.00	3.00	3.00	3.00			
Forklift operator	3.00						
Truck driver	3.00	6.00	3.00	6.00	3.00	3.00	6.00
Equipment							
Forklift[2]							
Conventional	350	350					
Rotating head			450	450			
Pallet containers[3] ($86 per plastic container)	1376	1892	300	450			
Bulk tanks (8 ton) ($800 each)			1600	2400	1600	1600	2400
Hoist ($400 each)			800	1200	800	800	1200
Totelifts (2700 each)					2700	5400	8100

1. Labor costs include social security and workmen's compensation.

2. Rental fee for 1 month: conventional $350 and rotating head forklift $450.

3. Initial cost for plastic lined pallet container $87 a piece and service life of 4 or 7 years depending upon use (small or large operation). If cherry tanks are utilized, investment costs of $1100 and $1650 would be substituted for the plastic liners. (22 x $50 and 33 x $50).

TABLE 13--Annual Costs for Determining the Income Potential (Breakeven Points) Between the Existing (Systems II and III) and Experimental Mechanical Harvesting (System IV or V) and Extended Options A, B, C, D, E.

	II and III(small or large)		4		5		
	Plastic lined or cherry pallet containers		Rotating head forklift and bulk tank truck		Totelift and bulk tank trucks		
	Small (8-18 hrs)	Large (24 hrs)	Options A	B	C	D	E
Hours	175	350	175	350	175	175	350
Acres[1]							
Acres	150	300+	150	300	150	150	300
Labor Costs[2]							
Harvester operator	700	1400	700	1400	700	700	1400
Trailer driver	525	2100	525	2100	525	2100	2100
Box tender	525	1050	525	1050			
Forklift operator[3]	525	1050					
Truck driver	525	2100	525	2100	525	525	2100
Total Annual Labor Cost	2800	7700	2275	6650	1740	3325	5600
Equipment[4]							
Forklift[5]							
Conventional	350	350					
Rotating head			450	450			
Pallet containers	379	558	64	95			
Bulk tanks(8 ton) and hoists			688	1032	688	688	1032
Totelifts(7000 lb capacity)					583	1166	1166
Total Annual Equipment Cost	729	908	1192	1577	1271	1854	2198

1. Two acreages chosen for the existing systems, 150 and 300 acres. This corresponds to 175 hrs or 350 hrs per season (175 x .87 acres per hour etc.).

2. Labor costs represent total wages paid to each worker for his responsibility in the system.

3. The operation of the forklift in Option A can normally be carried out by either the truckdriver or the vineyard trailer operator depending upon the situation.

4. Annual equipment costs were calculated with the following values and method:

RMLH (repairs, etc.) = 4% R(interest) = 8%
TIS (taxes,insur.shelter) = 1.5%

	CIH initial cost	SVH salvage value	SLH service life
Totelift	$2700	10%	8 yrs
Bulk tanks	800	10%	5 yrs
Hoists	400	10%	5 yrs
Plastic lined pallets	87	0%	5 yrs
Cherry tanks	50	10%	8 yrs

$$COH = \frac{CIH - (\frac{SVH}{100})}{SLH} + \frac{R}{100}\ \frac{(CIH + (\frac{SVH}{100})(CIH))}{2}$$

$$+(\frac{TIS}{100})\ (CIH) \quad + \quad (\frac{RMLH}{100})\ (CIH)$$

5. Forklift values are assigned on a one month leasing basis. The conventional forklift leases for $350 per month and the rotating head forklift for $450 per month.

TABLE 14--Income Potential for the Five Options

	Existing		Experimental				
	II and III(small or large)		4			5	
	Plastic lined or cherry pallet containers		Rotating head forklift and bulk tank trucks			Totelift and bulk tank trucks	
			Options				
	Small (8 or 18 hr)	Large (24 hrs)	A	B	C	D	E
Labor	2800	7700	2275	6650	1740	3325	5600
Equipment	729	908					
Option			1192	1577	2171	1854	2198
Equipment eliminated			(729)	(908)	(729)	(908)	(908)
Total Annual Cost	3529	8608	2738	7319	2282	4271	6890
Income potential when switching to a particular option			+$791	+1289	+247	-$742	+$1718

7.7 Breakeven Points

The determination of breakeven points between the existing and experimental mechanical grape harvesting and handling systems depends upon depreciating of additional equipment against labor reductions inherited in the options (System IV or V). The annual costs for the various affected components are listed in Table 13 along with annual labor costs. Breakeven points between existing systems and the 5 options fluctuated widely depending upon 1 factor, number of workers eliminated (1 or 2). This factor, when adopting any option, would double or halve the acreage breakeven point. This factor was influenced strongly by classification or sizing of an operation as small, medium and large or job double up.

The normal worker reduction as discussed in labor was 1 less worker for System IV and a 2 worker reduction for System V. If no worker reduction existed, the additional yearly cost for any option would be equal to the annual cost for option equipment and equipment eliminated (System II or III). This condition normally would not exist, but the cost data is available in Table 13.

To determine the breakeven points for 1 or 2 worker reduction, Figure 17 represents the seasonal acreage necessary. Option A_2 and E_1 have the lowest and highest breakeven acreage. As more harvesters are introduced into the grape industry, Option C with breakeven points at 79 and 158 acres will be preferred by the family or partnership grower. Option D will be preferred by growers having unusual factors such as long rows, heavy yields or remote vineyards. Option E will be preferred by the commercial grower.

OPTION	ONE WORKER REDUCTION	EVEN ACRES	TWO WORKER REDUCTION	EVEN ACRES
A	A_1	134	A_2	67
B	B_1	194	B_2	98
C	C_1	158	C_2	79
D	D_1	274	D_2	137
E	E_1	374	E_2	187

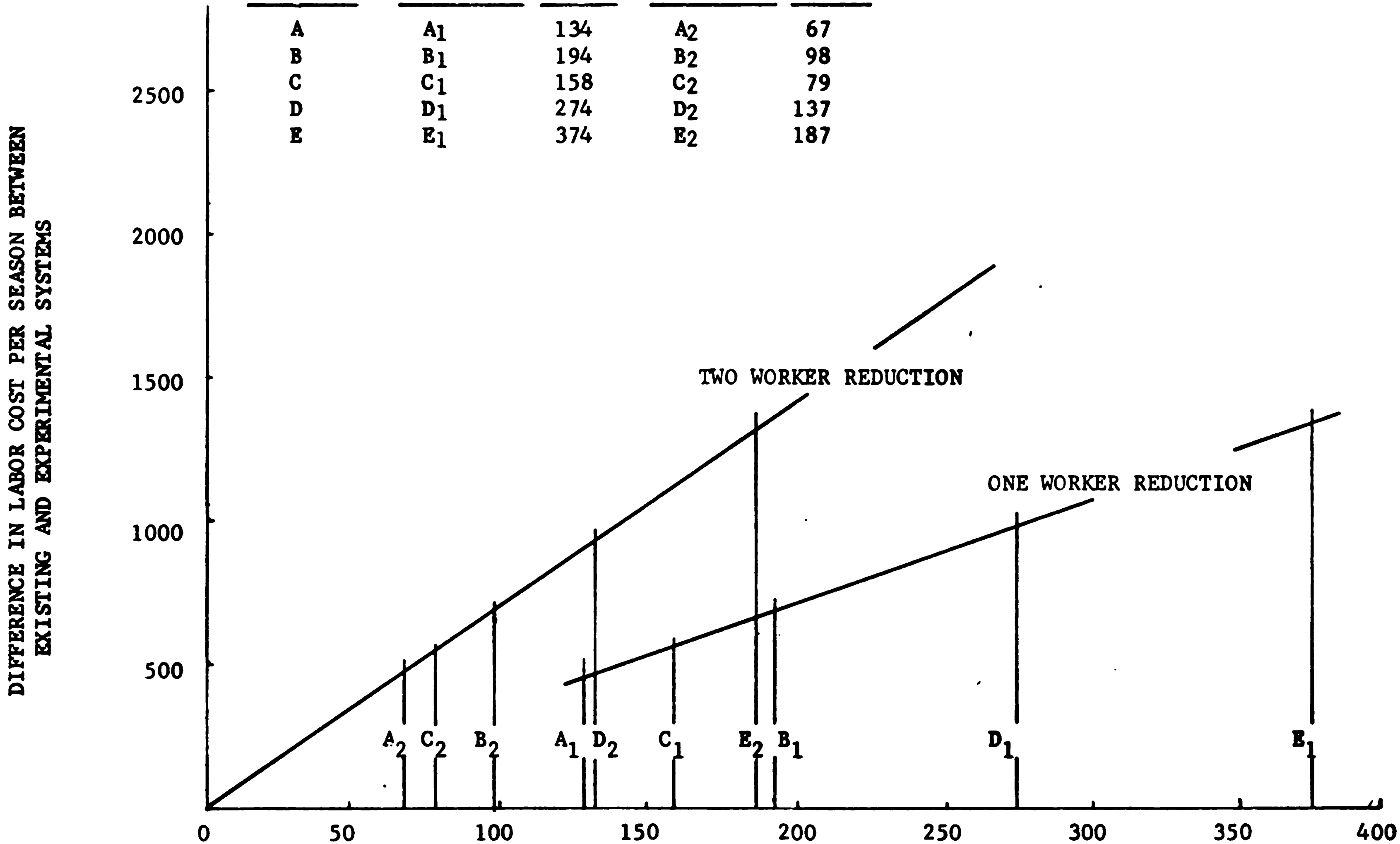

Figure 17. Breakeven Points (for the Options) Between the Existing and Experimental Mechanical Grape Harvest System Based on a Reduction of 1 or 2 Workers Per Shift.

It is assumed every situation where decisions by the grower are made concerning selection of a method for harvesting grapes, variations in value of important input values exist. A selected situation representative of the grape industry, with the following important variables, indicated a cost per ton for mechanical harvesting to approach $30 per ton for 100 acres, $32,000 investment in new equipment, and expected 4-ton yield. If yield, investment or acreage increased or decreased, harvesting costs would vary appropriately.

Acreage breakeven points between hand and mechanical harvesting varied depending upon the local hand harvesting costs per ton and projected total investment in new equipment for a mechanical grape harvesting and handling system. For a selected situation with hand harvesting costs equalling $32 per ton and initial capital investment of about $32,000, the projected breakeven point would be approximately 80 acres. This breakeven point would be for vineyards yielding 4 tons recovery per acre. If local conditions increase or decrease average yearly yields, the breakeven point between hand and mechanical harvesting varies inversely. For 10-ton yields the breakeven point is substantially less than 50 acres. For 3-ton yields the breakeven point increases to approximately 125 acres.

Acreage breakeven points between existing and experimental mechanical harvesting varied depending upon the levels of labor reduction possible vs. increased capital investment for more mechanization. If the seasonal work crew for the experimental system was reduced by 1, the breakeven point for no increase in the cost to the producer for Option C (1 totelift) was approximately 158 acres. However, if 2 seasonal workers could be eliminated by adoption of the experimental system, the breakeven acreage approximated 79 acres.

VIII. SUMMARY

This research study evolved from the introduction of an experimental mechanical Concord grape harvesting and handling system and included an economic comparison of hand and existing and experimental mechanical harvesting and handling systems.

The following objectives were cited:

1. Determine current hand harvesting costs for comparison with mechanical harvesting.
2. Define the existing mechanical harvesting systems and determine the current operating costs.
3. Determine the factors most critical when acquiring a mechanical grape harvesting system.
4. Determine the breakeven (income possibilities) points for existing mechanical grape harvesting systems vs. the hand harvesting method.
5. Describe the experimental mechanical grape harvesting system.
6. Determine the breakeven (income possibilities) points between the experimental and existing mechanical grape harvesting systems.

In 1970 an economic analysis was made of Michigan Concord grape harvesting and handling systems (including 4 mechanical and 1 hand harvesting system). The mechanical systems included 2 conventional systems of semi-bulk handling and 2 totally new bulk handling systems. A computer assimilation was made of field and survey data. Three economic variables (harvesting rate per hour, percent recovery, and potential yield) were determined to have the greatest economic effect on the cost of mechainical harvesting and handling.

Ricks indicated that in 1970 hand harvesting costs in Michigan ranged from $28 to $32 per ton excluding ownership and operating costs; Kelsey reported that total costs for hand harvesting in 1970 were $38.60 per ton. Hand harvesting costs are expressed on a per ton unit basis and costs are not influenced by potential yield as is the case with mechanical harvesting.

Mechanical harvesting and handling involves a substitution of capital for labor, therefore owners and/or operators of mechanical harvesting systems are interested in the economic breakeven acreages and income potentials in comparison to hand harvesting.

The results of this study indicated mechanical grape harvesting was profitable for most conditions above 70 acres per season. The experimental handling system employing a hydraulically dumped vineyard wagon could be justified due to inherent labor reductions. The study indicated the experimental system could be recommended for growers harvesting 90 acres or more per season.

IX. CONCLUSIONS

1. In 1970 the hand harvesting costs averaged $38.60 per ton. The average for 1970 and 1971 was $39.70 per ton.

2. The existing mechanical harvesting and handling system consists of a mechanical harvester, field forklift, pallet containers, trucks, tractors, trailers, washing, support vehicle and labor in varying numbers.

The current mechanical harvesting costs varies from more than $100 per ton to less than $12 per ton. For example, a particular system with initial investment of $32,000 for a harvesting and handling system, harvesting a potential yield of 4 tons per acre and 100 acres per season, the cost is $26 per ton.

3. Three factors influenced the per unit cost extensively; they are harvesting rate per hour, potential yield and product recovery.

4. Breakeven points between hand and mechanical harvesting vary depending upon potential yield. However for a particular mechanical harvesting system investment of $32,000 the breakeven point is 65 acres when harvesting a potential yield of 3 tons.

5. The experimental mechanical harvesting and handling system consists of 1 harvester, totelift(s), 8-ton bulk tank truck(s), tractor(s), labor, combination wash and support vehicle.

6. The breakeven points between the existing mechanical harvesting system (System II or III) and experimental (System IV) options A and B are 134 and 194 acres respectively with a 1 worker reduction. The breakeven points for experimental (System V) Options C, D and E are 79, 139 and 187 acres per season with 2 worker reduction.

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APPENDIX A

TIME STUDY

Machine____________________ Time Start __________ Date________ Pg.__ of __ pages
____________________ Time Finish _______________ Weather______________
____________________ Recorder Sig.______________________
____

TIME	CODE	DESCRIPTION	TIME	CODE	DESCRIPTION

FIELD DATA SHEET

Process Murch Welch Mich Winery Weather Sunny Warm Cold Drizzle Rainy

Date__________ Plot Ident.___________ Size of Plot ___________________

Variety Concord Row Width ______________ Row Length ________________

Vine Spacing ____________________ Mileage to Plant __________________
(One Way)

What system is being analyzed? 1 2 3 4 5

Type of harvester: Mecca, CR?

Are trellises in good, fair, or poor condition?

Type of terrian? Level Rolling Hilly

Number of trellis wires? 1 2 3 Height min _ ____ " Max ________".

Field conditions: Dry, wet, odd rows, triangle shaped field, short turning area, small loading area, etc., _______________________

____

List equipment used: (Boxes included)

1 _________________ 3___________________ 5 _____________ 7_____________

2 _________________ 4___________________ 6 _____________ 8_____________

How many people involved?____________
What is the duty of each? Wage?

1 ____________________ $ _______ 7 ___________________ $ __________

2 ____________________ $ _______ 8 ___________________ $ __________

3 ____________________ $ _______ 9 ___________________ $ __________

4 ____________________ $ _______ 10 ___________________ $ __________

5 ____________________ $ _______ 11 ___________________ $ __________

6 ____________________ $ _______ 12 ___________________ $ __________

Comments ____

____

____

____

____

Score Card

Number of boxes loaded 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

Pix-All Dumps 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Truck Loads 1 2 3 4 5 6 7 8 9 10

DATA SHEET - TRUCK

Name ________________ Truck Number __________ Date ________
(Your Name)

Plot or Ident. Name ________________ Mileage to Plant __________

Goods delivered to Murch, Welch, Mich. Wineries?

What type of container? Plastic lined, Cherry, Tank truck

Time : Load departed for plant, and

Time	Weigh in	Weigh out
:		
:		
:		
:		
:		
:		

Time Study for the

MICHIGAN CONCORD GRAPE
RESEARCH FUND

CODE SHEET

Date: September 18, 1970

H = harvester

P = Pixall unit one

Q = Pixall unit two

T = Truck one

U = Truck two

F = Forklift field

G = Forklift Plant

C = Cart (wagon and trail) unit one

D = Cart (wagon and trail) unit two

THE CODE

HARVESTER

HO harvester operate
HH harvester harvest
HT harvester turn
HS harvester stop
HD _ _ 1 = E-essential
1 2 N-nonessential

2. B breakdown
F full container
J jockey
M maintenance
P plug
R rest-cig
-
-

PIXALL

PO Pixall operate
PDD Pixall dump
PT Pixall travel
PD _ _ 1 E
1 2 N

2. _
_
_
_
_
_

Note: Stop=Shutdown for the day!

TRUCK

TO truck operate
TT truck travel
TW truck weight
TWW truck wash
TD _ _ 1 E
1 2 N

2. B bolts
L line wait

TS

Notes to identify one of two trucks the make or some other number and call truck one T, and truck two the next letter in the alphabet U.U, this necessary for computor differiation likewise with the Pixalls and carts and forklifts. Vehicle number two,will the next letter in the alphabet

Pixall one P
Pixall two Q
Cart one C
Cart two D
Forklift one F
Forlift two G

FORLIFT FIELD

CART(wagon or trailer)

FO forklift operate

FL empty/full lift

FR empty/full return box

FD 1 2 — 1 E N — 2. B breakdown

FJ jockey

FS stop

R rest delay

CO cart operate

CP cart park for loading and un

CE cart empty

CD 1 2 — 1 E N — 2.

CS cart stop

FO fork operate

FL empty/full lift

FJ fork jockey

FD fork dump

FWW fork wash

FR empty/full return box

FD 1 2 — 1 E N — 2. B breakdown

F full plant capacity

no trucks to empty

HO operate E essential
HD$_{\overline{1}}$$_{\overline{2}}$ delay 1 N nonessential 2. B breakdown
F full container
J jockey
HH harvest
HT travel M maintenance
HS stop P plug
R rest cig
_
_
_
_

Note:
Time study starts at predetermined time.

PD$_{\overline{1}}$$_{\overline{2}}$ 1 E essential / N nonessential

PDD dump
PT travel
PS stop

2 Complete dump cycle
HT to PDEJ-travel
PDEJ to FDD-jockey
PDD to PDNH-dump
PDNH to PT-wait
PT to HH-travel

Note: It is not necessary to time Pixall or cart when it is part of the harvester operation, only from full load condition to empty rest condition. Any delay by Pixall will be listed as a (HDNJ,HDNF,etc.) harvester delay

---

TE empty
TT travel
TD$_{\overline{1}}$$_{\overline{2}}$ 1 E / N 2. B bolts / L line
TW weight
TWW wash

TE to T TE	fill time
TT to TDN	travel time
TDNL to TW	delay time
TW to TDNL	weight time
TDNL to TD	delay time
TD to TWW	dump time
TWW to TDEB	wash time
TDEB to TW	door bolts time
TW to TT	weight time
TT to TE	travel
TE to TT	fill time

FO operate
FL lift
FT travel
FR place on truck
FS stop
FD_ _ 1 E/N 2
1 2
J jockey
R rest
_
_
_

FO
FL
FT
FP
FS
FD_ _ 1 E/N 2
1 2
J jockey
R rest
_
_
_

CO operate
CP part for unloading
CE empty
CD _ _ Delay 1 E/N 2.
1 2
___
___
___
___

HT to CP travel
CP to CE unloading
CE to CDNW wait
CANW to HH travel

FO operate
FL lift
FT travel
FD dump
FWW wash
FR return box
FS stop
FD_ _
1 2
L
R rest
P plant delay
W wait for trucks

APPENDIX B

GRAPE MECHANIZATION SURVEY QUESTIONNAIRE

FOR THE

MICHIGAN CONCORD GRAPE RESEARCH FUND

MICHIGAN STATE UNIVERSITY/U.S.D.A.

RESEARCH TEAM

THE SURVEY

Harvest Operation

Personnel Requirements

Breakdown & Delays

Vineyard Data

Problems Encountered

Future Plans for Operators

This questionnaire directed to grape harvester operators will be used to obtain labor and cost variables in conjunction with time study data collected during the 1970 Concord grape season.

October, 1970

I

Personnel Requirements

1. How may work shifts? (1, 2, 3)
2. Manpower per shift?

   Shift 1 (1, 2, 3, 4, 5, 6, 7, 8) hrs. per shift (4, 6, 8, 10, 12).

   Shift 2 (1, 2, 3, 4, 5, 6, 7, 8) hrs. per shift (4, 6, 8, 10, 12).

   Shift 3 (1, 2, 3, 4, 5, 6, 7, 8) hrs. per shift (4, 6, 8, 10, 12).
3. Number of part-time workers? (_____).
4. List assignment

   How many hours per day did you plan to operate the harvester? (_______hrs.)

   How many hours did you actually work per day? (_______hrs.)
5. How many people working are?

   family (__________) permanent hired help (__________)

   relatives (__________) local help (__________)

   other farmers (__________) migrants (__________)
6. Do you see a future decrease in the availability of qualified labor? (Yes, No)
7. Do you have this qualified help available when needed? (Yes, No)
8. Do you see a need for someone to initiate training programs for skilled operators? (Yes, No)
9. Labor Cost Analysis:

	Shift I		Shift II		Shift III	
	No.	Salary	No.	Salary	No.	Salary
1. Harv Operator						
2. Cart Operator						
3. Box Tender						
4. Forklift Operator						
5. Truck Driver						
6. Maintenance						
7. Other						
8.						
9.						
10.						

II

Equipment List and Costs of Operations

1. **Harvester**
   1. Make and Year: (C R, Mecca 68, 69, 70)
   2. Power Unit (__________________) (Gas, Diesel)
   3. Tachometer hours (________________)

   Cost: Do you (own, lease) your harvester?
   What is the approximate cost or value? ($_________)

2. **Harvest Container** (Plastic Liners or Cherry Tanks) Did you use covers? (Yes, No)

   No. of Containers: Plastic Liners (2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 ______)

   Cherry Tanks (2, 4, 6, 8, 10, 12, 14, 16 18, 20, 22, 24, 26, 28, 30 ______)

   Cost: Do you (own, rent, borrow) your containers?
   What is the cost or value of these containers? ($__________)

3. **Forklift** Did you (own, rent, or lease) your field forklift?

   size (______________) 4 wheel or tricycle (2 or 4)

   make (______________) front or rear (front, rear)

   wt (______________)

   pds cap (______________)

   year (______________)

   Cost: Own (_______), Leased (____________)

4. **Trucks** How many trucks per harvester? (1, 2, 3, 4, 5) Cost (________)/ton

   How many trucks do you own? (0, 1, 2, 3, 4, 5) Cost (________)/ton

   How many trucks do you lease? (0, 1, 2, 3, 4, 5) Cost (________)/ton

   Independent trucker? (0, 1, 2, 3, 4, 5) Cost (________)/ton

   How many boxes to each truck?

   Truck No. 1 (2, 4, 6, 8, 10, 12, 14, 16, ________)

   Truck No, 2 (2, 4, 6, 8, 10, 12, 14, 16, ________)

   Truck No. 3 (2, 4, 6, 8, 10, 12, 14, 16, ________)

   Truck No. 4 (2, 4, 6, 8, 10, 12, 14, 16, ________)

5. <u>Trailer</u>

2 wheel or 4 wheel trailer? (2,4 both)

How many 2-wheel trailers (1, 2, 3)

How many 4-wheel trailers (1, 2, 3)

How many boxes do you place on each unit?

Unit 1 (1, 2, 3)

Unit 2 (1, 2, 3)

Unit 3 (1, 2, 3)

Cost: Did you (make or buy) these units? Value (1) $______________
(2) $______________
(3) $______________

6. <u>Support Vehicle</u>

What type of support vehicle? (Pick-up, Truck, Car)

Is it adequate to carry all the equipment? (Yes, No)

What do we have on this vehicle?

Welder (yes, no, would like, not required)

Tools (yes, no, would like, not required)

Parts (yes, no, would like, not required)

Clean Up (yes, no, would like, not required)

_____ ______________________________

_____ ______________________________

_____ ______________________________

_____ ______________________________

Cost: Do you (own, rent, borrow) this support vehicle?
What is the value or cost? ($__________)

7. <u>Cleaning Equipment</u>

Cleaning Equipment Use?

1. Garden hose & brush (Yes, No)
2. Roller pump (Yes, No)
3. High pressure sprayer (Yes, No)

PSI water pressure (__________psi)

Spray heads/gun (1,2,3). No. of guns? (1,2,3)

Approximate gals. of water consumed per clean-up?
(25, 50, 75, 100, 125, 150, 175, 200)

Do you use detergents to assist clean up? (Yes, No)

How many times per day did you clean up?
Warm day (1, 2, 3, 4, 5)
Cold day (1, 2, 3, 4, 5)

5. Trailer

2 wheel or 4 wheel trailer? (2,4 both)

How many 2-wheel trailers (1, 2, 3)

How many 4-wheel trailers (1, 2, 3)

How many boxes do you place on each unit?

Unit 1 (1, 2, 3)

Unit 2 (1, 2, 3)

Unit 3 (1, 2, 3)

Cost: Did you (make or buy) these units? Value (1) $__________ (2) $__________ (3) $__________

6. Support Vehicle

What type of support vehicle? (Pick-up, Truck, Car)

Is it adequate to carry all the equipment? (Yes, No)

What do we have on this vehicle?

Welder (yes, no, would like, not required)

Tools (yes, no, would like, not required)

Parts (yes, no, would like, not required)

Clean Up (yes, no, would like, not required)

____ ____________________

____ ____________________

____ ____________________

____ ____________________

Cost: Do you (own, rent, borrow) this support vehicle?
What is the value or cost? ($________)

7. Cleaning Equipment

Cleaning Equipment Use?

1. Garden hose & brush (Yes, No)
2. Roller pump (Yes, No)
3. High pressure sprayer (Yes, No)

PSI water pressure (________psi)

Spray heads/gun (1,2,3). No. of guns? (1,2,3)

Approximate gals. of water consumed per clean-up?
(25, 50, 75, 100, 125, 150, 175, 200)

Do you use detergents to assist clean up? (Yes, No)

How many times per day did you clean up?
Warm day (1, 2, 3, 4, 5)
Cold day (1, 2, 3, 4, 5)

The **average** time required for clean-up?

1 Minor (5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60)
Max _____) Min (________)

1 Major (5, 10. 15. 20, 25, 30, 35, 40, 45, 50, 55, 60)
Max (______) Min (_________

Cost: Do you (own, lease, borrow) your clean-up unit?
What is the cost or value of this unit? (_______)

Grower Cost

How did you determine grower cost?

ton ________

acre ________

both ________

max ________

mix ________

Fuel Cost

Fuel Costs (Total) _______________

Harvester _______________

Other Vehicles _______________

III

Breakdown & Delays

How many major breakdowns (1 hr. or more) did you encounter? (_____)

Cause of breakdown? Operator Error ___________

Vineyard Fault ___________

Machine Fault ___________

List a few and time required to repair and cost?

1. ____

2. ____

3. ____

4. ____

How may minor delays (of 1 minute to 1 hour) encountered?

Cause of breakdown? Machine Fault ____________

Vineyard Fault ____________

Operator Error ____________

List a few: time lost, correction:

1. ____________________

____

2. ____________________

____

3. ____________________

____

4. ____________________

____

5. ____________________

____ ____________________

What do you estimate total time lost to <u>breakdowns</u> for the season? ________ hrs.

What do you estimate total time lost to delays accounted for? _________hrs./day

Do you normally set aside a maintenance period for each day? (Yes, No)

If yes, hrs. (1, 2, 3, 4)

IV

Harvest Data

How many days did your harvester operate this season?(_______) days

How many acres did you harvest this fall? (______) acres

First time mechanically harvested? (_____)

What was the average yield /acre (______tons)

Lowest (______tons)

Best (______tons)

How many times did you move this fall? (_______)

Longest distance moved (______mi), Ave. (__________).

How long was the time delay for the harvester during field to field moving?

Ave. _________ Min. __________ Max. __________

To move the complete system? Ave. _________ Min. ___________ Max. __________

How did you move your equipment from vineyard to vineyard?

1. Car crew ______________
2. Tow extra equipment ______________
3. Best way possible ______________

Was ample turning room available? (Yes, No)

How much distance do you need?(_________ft.)

How much distance do you want?(_________ft.)

Was an adequate loading area provided nearby? (Yes, No)

If no, how large an area do you need? ______________________

Did terraces cause you any problems? (Yes, No)

Will you harvest terraces next year?(Yes, No)

If no, what do you recommend? ______________________________

____

____

How long was the Average trellis? (______________)

Shortest trellis? (______________)

Longest trellis? (______________)

Check the requirements you like to see in a vineyard.

Type of floor practices:

Sod & mowed __________

Not hilled __________

Weeds cut in row __________

No terraces __________

Ample turn __________

Row width 5,6,7,8,9,10' __________

Headlands 30' __________

Load Area:

Sod __________

Mowed __________

Level __________

,Road access __________

____

____

____

____

____

Trellis conditions:

Wires: Max. ________"

Min. ________"

Post. dia. ________

Knees removed ________

P Q hedged ________

Problems Encountered

What problems did you encounter this year?

Expected ____

____

____

____

____

Unexpected ____________________

____

____

____

____

What problems did you eliminate before harvest started this year?

____

____

____

____

During the harvest season?

____

____

____

____

____

Plans for next year?

____

____

____

____

____

____

____

____

APPENDIX C

TABLE 1-- Initializing Values Ulilized Both for Hand and Mechanical Harvesting where Appropriate.

SYMBOL	DESCRIPTION	RANGE	VALUE
A*	Acres per season	50-450, 4	variable
PA**	Price of commodity/ton	88 to 158	150
CP***	Preharvest production cost		150
PY*	Potential yield	0 - 10	4

* Unpublished data gathered from a post harvest survey in southwestern Michigan, Nov., 1970.

** Source, Agricultural Statistics, U.S. Department of Agriculture. 1939-1970.

*** Ricks, D., Agricultural Economics Report Number 95, 1968, Grape Production Costs in Southwestern Michigan, Michigan State University, East Lansing, Michigan.

TABLE 2--Values Assigned to Major Factors Used in the Analysis of Hand Harvesting of Grapes.

SYMBOL	DESCRIPTION	RANGE	VALUE
HPCT*	Cost per ton for hand pickers only, does not include forklift or trucking	28-33	28.00
XFORK*	Seasonal rental cost for forklift	0-550	3.50
TRCT*	Trucking rate per ton	3.00-6.00 .10 to .25¢ /mile	5.00 .12

* Same as Table 1

TABLE 3--Values Assigned to Major Non-Varying Factors Used in the Analysis of Mechanical Harvesting of Grapes.

SYMBOL	DESCRIPTION	RANGE	VALUE
RMLH#	Repairs, maintenance, lubrication on harvester system,percent of initial system cost.	2-5	4%
FC*	Cost of fuel, dollars/gal.	0.20-.30	0.24
I*	Interest rate percent	5-10	8
TIS#	Taxes, insurance, shelter, percent		1.5
TTANK*	Value of one 6- to 8-ton bulk truck tank	500-1500	800
TOTE*	Value of one totelift	1500-3000	2750
TAINER*	Value of cherry or plastic pallet container	40-90	87
XFORK*	Seasonal rental cost for forklift	0-550	450
TRCT*	Truck rate per ton dollars, ton or dollars/mile	3.00-6.00 .10 to 25¢/mi	5.00 .12
WAGE*	Average wage per hour	1.75 to 5.00	3.00
CIH*	Cost of harvest system capital investment for SystemsII and III	24,000 to 40,000	4000
HP*	Horsepower of the system	100-200	140
SFC%	Specific fueld consumption rate, hp-hrs/gal	7-16	8.5
NOHC*	No. of harvest containers	0-30	12
SLH*	Service life of harvester years	3-7	5
XMILE*	Miles to plant one way	1-60	13.5

* same as Table 1

\# Stout, B. A., Predicting Economic Feasibility of Mechanical Vegetable Systems, Transactions, ASAE (vol. 11, no. 3 pp 353-4-5-9)

% Specific fuel consumption, assuming a varying load, taken from the Agricultural Engineering Yearbook as equal to 8.5 horsepower per hours

TABLE 4--Harvester and System Efficiency Factors Used in the Analysis of Mechanical Harvesting of Grapes

SYMBOL	DESCRIPTION	RANGE	VALUE
A%%	Acres per season	50-450	
HN%%	No. of harvesters	1-3	1
PL%%	Product loss	0-10%	0 and 10%
HOURS%%	Total working hours per day	8-24	8-18-24
DAYS%%	Total working days per season	15-30	21
TRELL%%	Length of vine row, ft.	60-2640	633
TRWIDE%%	Trellis spacing, ft.	7-12	9
XMPH%%	Miles per hour of harvester	0.5-2.5	
TWT%%	Total wash time/day in hours	0.5-4.0	2.0
MGMTH%%	Management time in one 9-hour shift,hrs.	.5-1.5	.75
HPCMIN%%	No. of minutes delay to switch pallet boxes	.5-2.0	1.0
AMDS%%	Average mechanical delay 2-100 hrs. per season, hrs.	2-100	40
TT%%	Turn time delay,minutes	.5-3.0	1.0

%% Unpublished data from a time and motion study conducted in southwestern Michigan, Oct., 1970.

APPENDIX D

APPENDIX D

PROGRAM NUMBER 2

```
••PNC 066634  070171  11  WILLIAMS                          JJ JJ)JJJJ N *•)JJJ•
WILLIAMS•CM43000•T30•L100•
      REAL NRM•NRHP
      READ 800•  A•AH•CIH•CP•HN•PA•PY•SLH•PL
C  A IS ACREAGE  AH IS HARVEST RATE  CIH IS INITIAL COST OF HARVESTER
C  COMMODITY   PYIS POTENTIAL YIELD   TMY IS TOTAL MARKETABLE YIELD
C  CP IS PREHARVEST PRODUCTION COST   HN IS NUMBER OF HARVESTS   PA=PRICE OF
      READ800•CLH•FC•HP•R•RMLH•SFC•SVH•TIS•CPAHP
C  SLH IS SERVICE LIFE OF HARVESTER IN YEARS   PL IS PERCENT PRODUCT LOSS
C CLH IS COST OF LABOR OPERATIONS/HR)   FC IS COST OF FUEL/GAL)
C  HP IS HORSEPOWER OF SYSTEM   R IS INTEREST RATE  RMLH IS REPAIRS AND
C  MAINTENANCE•LUB• ON HARVESTER SYSTEM•ETC•   SFC IS SPECIFIC FUEL
C   CONSUMPTION   SVH IS SALVAGE VALUE OF HARVESTER   TIS IS TAXES•
C  INSURANCES•SHELTER•PER CENT OF I•C•/YEAR
C  CPAHP ISCOST PER ACRE FOR HANDPICKERS
      READ 800•WAGE•HOURS•DAYS•TRCT•XFORK•XMILE•PROC•TRELL
C   WAGE = AVE OF TOTAL WAGES/HOUR   HOURS = IS TOTAL WORKING HOURS PER DAY
C  DAYS= TOTAL WORKING DAYS / SEASON  TRCT = CURRENT VALUE OF TRUCKING RATE/TON
C    XFORK = SEASON COST FOR  FOR RENTAL•HARVEST OPERATOR FORK CONTINUE
C   XMILE IS AVE MILAGE TO PROCESS PLANT  PROC TRUCK TURN AROUND TIME AT PLANT
C   TRELL =  EQUAL LENGTH OF VINE ROW IN FT
      READ 800•TAINER•NOHC•HPCT•TOTE•TTANK•TRWIDE
C     TAINER = THE VALUE OF A CHERRY OR PLASTIC TANK  NOHC =  NO• OF CONTAINERS
C    TOTE = VALUE OF ONE TOTE LIFT  TTANK = EXPECTED COST OF ONE SIX TON TANK
C      TRWIDE =  THE TRELLIS WIDTH BETWEEN ROWS
 800  FORMAT(9F8•0)
      PRINT 81•  A•AH•CIH•CP•HN•PA•PY•SLH•PL
   81 FORMAT (1H1•*A=*F5•1* AH=*F5•2* CIH=*F6•0* CP=*F6•2* HN=*F5•2* PA
     1=*F6•2* PY=*F5•2* SLH=*F3•1* PL=*F5•2 /)
      PRINT82•CLH•FC•HP•R•RMLH•SFC•SVH•TIS•CPAHP
   82 FORMAT(2X*CLH=*F5•2* FC=*F3•2* HP=*F5•1* R=*F4•1* RMLH=*F4•1* SFC=
     1*F4•1* SVH=*F6•2* TIS=*F3•1* CPAHP=*F5•2 /)
      PRINT 83•WAGE•HOURS•DAYS•TRCT•XFORK•XMILE•PROC•TRELL
   83 FORMAT (2X*WAGE=*F5•2* HOURS=*F5•2* DAYS=*F4•1* TRCT=*F5•2* XFORK=
     1*F6•2* XMILE=*F5•2* PROC*F5•2* TRELL=*F5•1 /)
      PRINT 84•TAINER•NOHC•HPCT•TOTE•TTANK•TRWIDE
   84 FORMAT (2X*TAINER=*F5•2* NOHC=*F5•2* HPCT=*F5•2* TOTE=*F7•2* TTANK
     1=*F7•2* TRWIDE=*F5•1 /)
```

APPENDIX D

PROGRAM NUMBER 2

```
••PNC 066634  070171  11  WILLIAMS                        JJ JJ)JJJJ N *•)JJJ.
WILLIAMS.CM43000.T30.L100.
      REAL NRM.NRHP
      READ 800.  A.AH.CIH.CP.HN.PA.PY.SLH.PL
C  A IS ACREAGE  AH IS HARVEST RATE  CIH IS INITIAL COST OF HARVESTER
C  COMMODITY  PYIS POTENTIAL YIELD   TMY IS TOTAL MARKETABLE YIELD
C  CP IS PREHARVEST PRODUCTION COST   HN IS NUMBER OF HARVESTS   PA=PRICE OF
      READ800.CLH.FC.HP.R.RMLH.SFC.SVH.TIS.CPAHP
C  SLH IS SERVICE LIFE OF HARVESTER IN YEARS   PL IS PERCENT PRODUCT LOSS
C CLH IS COST OF LABOR OPERATIONS/HR)   FC IS COST OF FUEL/GAL)
C  HP IS HORSEPOWER OF SYSTEM   R IS INTEREST RATE  RMLH IS REPAIRS AND
C  MAINTENANCE.LUB. ON HARVESTER SYSTEM.ETC.   SFC IS SPECIFIC FUEL
C   CONSUMPTION   SVH IS SALVAGE VALUE OF HARVESTER   TIS IS TAXES.
C  INSURANCES.SHELTER.PER CENT OF I.C./YEAR
C  CPAHP ISCOST PER ACRE FOR HANDPICKERS
      READ 800.WAGE.HOURS.DAYS.TRCT.XFORK.XMILE.PROC.TRELL
C   WAGE = AVE OF TOTAL WAGES/HOUR   HOURS = IS TOTAL WORKING HOURS PER DAY
C  DAYS= TOTAL WORKING DAYS / SEASON  TRCT = CURRENT VALUE OF TRUCKING RATE/TON
C    XFORK = SEASON COST FOR  FOR RENTAL.HARVEST OPERATOR FORK CONTINUE
C   XMILE IS AVE MILAGE TO PROCESS PLANT  PROC TRUCK TURN AROUND TIME AT PLANT
C   TRELL =  EQUAL LENGTH OF VINE ROW IN FT
      READ 800.TAINER.NOHC.HPCT.TOTE.TTANK.TRWIDE
C     TAINER = THE VALUE OF A CHERRY OR PLASTIC TANK  NOHC =  NO. OF CONTAINERS
C    TOTE = VALUE OF ONE TOTE LIFT  TTANK = EXPECTED COST OF ONE SIX TON TANK
C      TRWIDE =  THE TRELLIS WIDTH BETWEEN ROWS
 800  FORMAT(9F8.0)
      PRINT 81.  A.AH.CIH.CP.HN.PA.PY.SLH.PL
   81 FORMAT (1H1.*A=*F5.1* AH=*F5.2* CIH=*F6.0* CP=*F6.2* HN=*F5.2* PA
     1=*F6.2* PY=*F5.2* SLH=*F3.1* PL=*F5.2 /)
      PRINT82.CLH.FC.HP.R.RMLH.SFC.SVH.TIS.CPAHP
   82 FORMAT(2X*CLH=*F5.2* FC=*F3.2* HP=*F5.1* R=*F4.1* RMLH=*F4.1* SFC=
     1*F4.1* SVH=*F6.2* TIS=*F3.1* CPAHP=*F5.2 /)
      PRINT 83.WAGE.HOURS.DAYS.TRCT.XFORK.XMILE.PROC.TRELL
   83 FORMAT (2X*WAGE=*F5.2* HOURS=*F5.2* DAYS=*F4.1* TRCT=*F5.2* XFORK=
     1*F6.2* XMILE=*F5.2* PROC*F5.2* TRELL=*F5.1 /)
      PRINT 84.TAINER.NOHC.HPCT.TOTE.TTANK.TRWIDE
   84 FORMAT (2X*TAINER=*F5.2* NOHC=*F5.2* HPCT=*F5.2* TOTE=*F7.2* TTANK
     1=*F7.2* TRWIDE=*F5.1 /)
```

```
      N=0
      DO 11 I1=1,100,1
      A = I1*4 + 50
      N=N+1
      DO 10 I2=1,5,1
      CIH = 20000+ I2*4000
C
C          NEEDED EQUASIONS AND CALCULATED VALUES
C
      CPA=CP*A
C   CPA = COST OF PRODUCTION  (DOLLARS / YEAR)
      AVETON  =PY*A/DAYS
C    AVETON   = IS THE AVE TONNAGE PER DAY HARVESTORED BY THE HARVESTOR
C
C                       COST OF LABOR FOR EACH SYSTEM
C
      GO TO(12,21,31,41,15)I2
   12 COL = HPCT* PY*A+12.16 $ GO TO 61
C              LABOR COSTS FOR HAND PICKING
   21 COL=6.0*WAGE*HOURS*DAYS    $ GO TO 61
C            LABOR COSTS FOR SYSTEM TWO ( PLASTIC LINERS )
   31 COL=6.0*WAGE*HOURS*DAYS   $ GO TO 61
C        LABOR COSTS FOR SYSTEM THREE   ( CHERRY TANKS )
   41 COL=5.0*WAGE*HOURS*DAYS    $ GO TO 61
C     LABOR COSTS FOR SYSTEM FOUR ( TANK TRUCK PLUS CHERRY TANKS ROTOR )
   15 COL=4.0*WAGE*HOURS*DAYS   $ GO TO 61
C     COST OF LABOR FOR SYSTEM FIVE ( TANK TRUCK PLUS TOTE LIFT )
   61 CONTINUE
C
C                                        TRUCKING COSTS
C
   25 IF(XMILE.GE.10.)      GO TO 26
  255 COT=TRCT*A*PY      $ GO TO 27
   26 IF(TRCT.GE.4.80)      GO TO 255
      COT=TRCT*A*PY+.12*(XMILE-10.)   $ GO TO 27
C   IF XMILE IS GEARTER THAN TEN MILESS, ADDITIONAL COST IS ADDED AD THE RATE OF
C    .12 CENTS/MILE IF TRUCKING COSTS ARE LESS THAN 4.80/TON
   27 CONTINUE
C
```

```
C        FIXED COSTS             FIXED COSTS             FIXED COSTS
C
C
C                                HARVESTOR OVER HEAD COST
C
      IF(I2.EQ.1)  GO TO 33
      CFL=1.03*FC*HP*A*HN/(AH*SFC)
C      COST OF FUEL AND LUBRICANTS     ( DOLLAR / YEAR)
      COH= (CIH-SVH)/SLH + (R/100.)*CIH/2. + CIH*RMLH/100. + CIH*TIS/
     1100.
C    COH = COST OF HARVESTOR OVERHEAD    ( DOLLARS/YEAR)
   33 CONTINUE
C
C                                FORKLIFT COSTS (DOLLARS/SEASON )
C
      GO TO(36,36,36,37,39)I2
   36 IF(XFORK.EQ.0.) GO TO 38
C  IF THE FARMER ASSUMES XFORK EQUAL TO ZERO OR IS LEFT BLANK IT WILL BE CALCULA
C  TED AT THE RATE OF.30*PY*A
      FORK=XFORK           $ GO TO 39
   37 FORK=.40*PY*A  $ GO TO 39
   38 FORK=.30*PY*A      $ GO TO 39
   39 CONTINUE
C
C                               HARVEST CONTAINER COST
C
      GO TO(499,43,46,465,47)I2
   43 IF(TAINER - 64.)444,444,45
C  IF TAINER COST IS LESS THAN 64.00 /TAINER WE ASSUME A ORGINAL COST FOR
C   PLASTIC LINERS OF 86.00/TAINER
  444 CONTAIN = NOHC*(77.40/SLH + R/100.*86./2. + RMLH/100.*86. + TIS
     1/100.*86.)*.8   $ GO TO 49
C   THE DATA CARD VALUE IS TO SMALL THEREFORE IT IS ASSUMEDS 86 FOR THE TAINER
   46 IF(TAINER - 64.)45,45,447
C    IF CONTAINER COST IS GREATER THAN 64.00 /TAINER FOR THE CHERRY TANK SYSTEM
C    WE ASSUME A N ORGINAL COST OF 45.00/ TAINER
  447 CONTAIN= NOHC*(40.5/SLH + R/100.*45./2. + RMLH/100.*45. + TIS/100.
     1*45.)*1.25 $ GO TO 49
C   THE DATA VALUE IS TO LARGE THEREFOR IT ASSUMES 45 FOR TAINER
   45 CONTAIN= NOHC*(TAINER-.1*TAINER)/SLH + R/100.*TAINER/2. + RMLH/
```

```
      1100.*TAINER + TIS/100.*TAINER     $ GO TO 49
C     THE DATA CARD TAINER IS OK AND CALCULATES FIXED COST AS GIVEN BY THE OPERAT
  465 NOHC= 6    $ GO TO 447
C
C
C                                              TOTE LIFT CALCULATIONS
C
   47 BC=PY*6.*(2.*TRELL)/TRWIDE
C   BC = PY*A*CORRECTION FACTOR WITH A DIRECT RELATIONSHIP BETWEEN TRELLIS
C LENGTH AND ROW LENGTH WHICH DETERMINES NUMBER OF TOTES NEEDED/OPERATION
C     AT 5000 LB CAPACITY PER TOTE.  WITH A 30 PERCENT SAFETY CAPACITY
      IF(BC.GT.5000.)         GO TO 482
C   IF AVE TONNAGE/DAY IS GREATER THAN 50TONS, NUMBER OF XTOTES = 2
      IF(HN.GT.2.)            GO TO 488
      XTOTE = 1    $ GO TO  48
C    BC LT 5000(LESS 50 TON/DAY) NO. OF TOTES = 1
  482 IF(HN.GE.2)       GO TO 488
      XTOTE=2
     1100.)*XTOTE
   48 COTO=(TOTE-.1*TOTE)*SLH*2 +((R*TOTE/2.)+(RMLH*TOTE)+(TIS*TOTE)/
      CONTAIN = COTO    $  GO TO 49
C   COTO=  COST OF TOTE LIFT OVERHEAD WITH SLHOF TOTE =  2 TIMES HARV. LIFE.
C    HN = I AND, AND TONNAGE PER HARVESTOR IS GREATER THAT 50 TONS/DAY
  488 IF(HN.GT.2.AND.BC.GT.5000.)      GO TO 4888
      XTOTE=3       $   GO TO 48
 4888 XTOTE=4. $ GO TO 48
C    HN = 2 AND TONNAGE PER HARVESTOR IS GREATER THAN 50 TONS/DAY
  499 CONTAIN=0
   49 CONTINUE
C
C                         TANK FOR TRUCK  IN TOTE AND ROTOR SYSTEM
C
C
      GO TO (59,59,59,50,50)I2
   50 NOTT=BC/2500.
      IF(NOTT.LE.1.0)    GO TO 51
      IF (NOTT.LE.2.0)       GO TO 52
      IF(NOTT.LE.3.0)         GO TO 53
      IF (NOTT.GT.3.0)     GO TO 54
   51 NOTT = 1  $GO TO 56
```

```
   52 NOTT = 2   $ GO TO 56
   53 NOTT = 3   $ GO TO 56
   54 NOTT = 4   $ GO TO 56
   56 CTTANK=NOTT*((TTANK-.1*TTANK)/SLH*2. + R/100.*TTANK/2. + RMLH/100.
     1*TTANK + TIS/100.*TTANK)     $ GO TO 599
   59 CONTINUE
      CTTANK=0
  599 CONTINUE
C
C
C             SYSTEM SUM CALCULATION   (GROUPING OF CALCULATED VARIABLES)
C
      TMY=((PY*(100-PL))/100)
C  TMY = TOTAL MARKETABLE YIELD
      TMY=PY
      IF(I2.GT.1)  GO TO 333
      CHHP=A*PY*CPAHP
C  CHHP = COST OF HANDPICKING  (DOLLARS / YEAR)
      GRHP=TMY*PA*A
C  GRHP = GROSS RETURN FOR HANDPICKING  (DOLLARS / YEAR)
      NRHP=GRHP-(CHHP+CPA)
C  NRHP = NETRETURN FOR HANDPICKERS  (DOLLARS / YEAR)
      CHA=COL+COT+FORK+CONTAIN
C        CHA IS COST OF HAND HARVESTING/SEASON
      Y(I1,I2)=((PY*PA*A*PL/100.)+CHA)/(PY*A)
      IF(N.LT.5)  GO TO 10
      PRINT877,Y(I1,I2),PY,PA,A,PL,CHA,COL,COT,FORK,CONTAIN,I1,I2
  877 FORMAT  (  5E20.10 /  5E20.10 /  2I10  )
      PRINT 803,A,AH,CIH,CP,HN,PA,PY,SLH,PL
  803 FORMAT(* A=*F4.0* AH=*F5.3* CIH=*F6.0* CP=*F4.0* HN=*F2.0* PA=*F5.
     12* PY=*F4.0* SLH=*F2.0* PL=*F4.0)
      PRINT 804,CPA,XMILE,HOURS,CHHP,GRHP,NRHP,AVETON,COL
  804 FORMAT(7X*CPA*7X*XMILE*7X*HOURS*7X*CHHP*6X*GRHP*6X*NRHP*4X*AVET
     1ON*7X*COL*/8F10.2///)
      GO TO 10
  333 CHA=CFL+COH+COL+COT+FORK+CONTAIN+CTTANK
C  CHA = COST OF MECHANIZED HARVESTING  (DOLLARS / YEAR)
      GRM=TMY*PA*A
C  GRM = GROSS RETURN MACHINE  (DOLLARS / YEAR)
      NRM=GRM-(CHA+CPA)
```

```
   52 NOTT = 2  $ GO TO 56
   53 NOTT = 3  $ GO TO 56
   54 NOTT = 4  $ GO TO 56
   56 CTTANK=NOTT*((TTANK-.1*TTANK)/SLH*2. + R/100.*TTANK/2. + RMLH/100.
     1*TTANK + TIS/100.*TTANK)    $ GO TO 500
   50 CONTINUE
      CTTANK=0
  500 CONTINUE
C
C
C           SYSTEM SUM CALCULATION  (GROUPING OF CALCULATED VARIABLES)
C
      TMY=((PY*(100-PL))/100)
C  TMY = TOTAL MARKETABLE YIELD
      TMY=PY
      IF(I2.GT.1)  GO TO 333
      CHHP=A*PY*CPAHP
C  CHHP = COST OF HANDPICKING  (DOLLARS / YEAR)
      GRHP=TMY*PA*A
C  GRHP = GROSS RETURN FOR HANDPICKING  (DOLLARS / YEAR)
      NRHP=GRHP-(CHHP+CPA)
C  NRHP = NETRETURN FOR HANDPICKERS  (DOLLARS / YEAR)
      CHA=COL+COT+FORK+CONTAIN
C        CHA IS COST OF HAND HARVESTING/SEASON
      Y(I1,I2)=((PY*PA*A*PL/100.)+CHA)/(PY*A)
      IF(N.LT.5)  GO TO 10
      PRINT877,Y(I1,I2),PY,PA,A,PL,CHA,COL,COT,FORK,CONTAIN,I1,I2
  877 FORMAT  (  5E20.10 /  5E20.10 /  2I10  )
      PRINT 803,A,AH,CIH,CP,HN,PA,PY,SLH,PL
  803 FORMAT(* A=*F4.0* AH=*F5.3* CIH=*F6.0* CP=*F4.0* HN=*F2.0* PA=*F5.
     12* PY=*F4.0* SLH=*F2.0* PL=*F4.0)
      PRINT 804,CPA,XMILE,HOURS,CHHP,GRHP,NRHP,AVETON,COL
  804 FORMAT(7X*CPA*7X*XMILE*7X*HOURS*7X*CHHP*6X*GRHP*6X*NRHP*4X*AVET
     1ON*7X*COL*/8F10.2///)
      GO TO 10
  333 CHA=CFL+COH+COL+COT+FORK+CONTAIN+CTTANK
C  CHA = COST OF MECHANIZED HARVESTING  (DOLLARS / YEAR)
      GRM=TMY*PA*A
C  GRM = GROSS RETURN MACHINE  (DOLLARS / YEAR)
      NRM=GRM-(CHA+CPA)
```

```
   52 NOTT = 2  $ GO TO 56
   53 NOTT = 3  $ GO TO 56
   54 NOTT = 4  $ GO TO 56
   56 CTTANK=NOTT*((TTANK-.1*TTANK)/SLH*2. + R/100.*TTANK/2. + RMLH/100.
     1*TTANK + TIS/100.*TTANK)    $ GO TO 599
   59 CONTINUE
      CTTANK=0
  599 CONTINUE
C
C
C            SYSTEM SUM CALCULATION  (GROUPING OF CALCULATED VARIABLES)
C
      TMY=((PY*(100-PL))/100)
C  TMY = TOTAL MARKETABLE YIELD
      TMY=PY
      IF(I2.GT.1)  GO TO 333
      CHHP=A*PY*CPAHP
C  CHHP = COST OF HANDPICKING  (DOLLARS / YEAR)
      GRHP=TMY*PA*A
C  GRHP = GROSS RETURN FOR HANDPICKING  (DOLLARS / YEAR)
      NRHP=GRHP-(CHHP+CPA)
C  NRHP = NETRETURN FOR HANDPICKERS  (DOLLARS / YEAR)
      CHA=COL+COT+FORK+CONTAIN
C       CHA IS COST OF HAND HARVESTING/SEASON
      Y(I1,I2)=((PY*PA*A*PL/100.)+CHA)/(PY*A)
      IF(N.LT.5)  GO TO 10
      PRINT877,Y(I1,I2),PY,PA,A,PL,CHA,COL,COT,FORK,CONTAIN,I1,I2
  877 FORMAT  (  5E20.10 /  5E20.10 /  2I10  )
      PRINT 803,A,AH,CIH,CP,HN,PA,PY,SLH,PL
803   FORMAT(* A=*F4.0* AH=*F5.3* CIH=*F6.0* CP=*F4.0* HN=*F2.0* PA=*F5.
     12* PY=*F4.0* SLH=*F2.0* PL=*F4.0)
      PRINT 804,CPA,XMILE,HOURS,CHHP,GRHP,NRHP,AVETON,COL
 804  FORMAT(7X*CPA*7X*XMILE*7X*HOURS*7X*CHHP*6X*GRHP*6X*NRHP*4X*AVET
     1ON*7X*COL*/8F10.2///)
      GO TO 10
  333 CHA=CFL+COH+COL+COT+FORK+CONTAIN+CTTANK
C  CHA = COST OF MECHANIZED HARVESTING  (DOLLARS / YEAR)
      GRM=TMY*PA*A
C  GRM = GROSS RETURN MACHINE  (DOLLARS / YEAR)
      NRM=GRM-(CHA+CPA)
```

```
C   NRM = NET RETURN MACHINE   (DOLLARS / YEAR)
      REHPRP=NRM-NRHP
C   REHPRP = BREAK EVEN HANDPICKERS REPLACEMENT POINT
      Y(I1,I2)=((PY*PA*A*PL/100.)+CHA)/(PY*A)
      IF(N.LT.5)  GO TO 10
      PRINT877,Y(I1,I2),PY,PA,A,PL,CHA,COL,COT,FORK,CONTAIN,I1,I2
      PRINT 878,CFL,CCH,CTTANK
  878  FORMAT    (   3E20.10   )
      PRINT 904,CPA,CHA,GRM,NRM,CHHP,GRHP,NRHP,REHPRP,COL
 904  FORMAT(7X*CPA*7X*CHA*7X*GRM*7X*NRM*6X*CHHP*6X*GRHP*6X*NRHP*4X*BEHP
     1RP*7X*COL*/9F10.2 //)
  10  CONTINUE
      IF(N.EQ.5) N=0
  11  CONTINUE
      PRINT 71,   A,AH,CIH,CP,HN,PA,PY,SLH,PL
  71  FORMAT    (2X*A=*F5.1* AH=*F5.2* CIH=*F6.0* CP=*F6.2* HN=*F5.2* PA
     1=*F6.2* PY=*F5.2* SLH=*F3.1* PL=*F5.2 /)
      PRINT72,CLH,FC,HP,R,RMLH,SFC,SVH,TIS,CPAHP
  72  FORMAT(2X*CLH=*F5.2* FC=*F3.2* HP=*F5.1* R=*F4.1* RMLH=*F4.1* SFC=
     1*F4.1* SVH=*F6.2* TIS=*F3.1* CPAHP=*F5.2 /)
      PRINT 73,WAGE,HOURS,DAYS,TRCT,XFORK,XMILE,PROC,TRELL
  73  FORMAT (2X*WAGE=*F5.2* HOURS=*F5.2* DAYS=*F4.1* TRCT=*F5.2* XFORK=
     1*F6.2* XMILE=*F5.2* PROC*F5.2* TRELL=*F5.1 /)
      PRINT 74,TAINER,NOHC,HPCT,TOTE,TTANK,TRWIDE
  74  FORMAT (2X*TAINER=*F5.2* NOHC=*F5.2* HPCT=*F5.2* TOTE=*F7.2* TTANK
     1=*F7.2* TRWIDE=*F5.1 /)
      RETURN
      END

IAKURT=3,NUMHOR=101,NUMVR=41,XMAX=450.,XMIN=50.,YMAX=99.,YMIN=00.
TITLE YEILD OF GRAPES=4 TON/ACRE PL=0  AH CHANGED TO .5 ACERS/HOUR
TITLE COST/TON = (CHA + PL)/PY*A   IF PL=0 NO PRODUCT LOSS

    100       1.0    20000      150       1.0    100.0       4.0       5.0        0.
   13.00     0.24    140.0     10.0       4.0      8.5       5.0       1.5     28.50
    3.00     18.0     20.0     5.00     450.0     13.5       2.0     633.0
   40.00     15.0    25.00   2500.0     800.0      8.0
```

APPENDIX E

TABLE 1--Sub Program Functions for an Economic Analysis of Mechanical Grape Harvesting

Symbol	Basic Equations and Description of the Function
CFL =	$\frac{1.03*FC*HP*A*HN}{AH * SPC}$ Cost of fuel and lubricants
COH =	$\frac{CIH - (SVH/100)*CIH}{SLH} + (\frac{R}{100}) * [\frac{CIH + (SUH/100)(CIH)}{2}] + \frac{TIS*CIH}{100} + \frac{RMLH*CIH}{100}$ Cost of harvester system overhead
COL =	$\frac{A*CLH}{AH}$ Cost of labor to operate machine system
CHA =	CFL + COL + COH Cost of mechanized harvest
CPA =	CD*A Cost of production
TMY =	PY* (100-PL)/100 TOTAL MARKETABLE YIELD
GRM =	TMY*PA*A Gross return per year
NRM =	GRM - (CHA + CPA) Net return machine dollars/year
CHHP=	A * PY * CPAHP Cost of handpicking dollars/year
GRHP =	TMY*PA*A Cross return handpickers dollars/year
NRHP =	GRHP - (CHHP + CPA) Net return for handpickers dollars/year
BEHPRP =	NRM - NRHP Breakeven point between handpickers and machine