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Eta Takele and Bud Lee
Area Specialist, Farm Management, and Farm Advisor. Cooperative Extension University of California, respectively.

The Economics of a Monorail System

Introduction

The production of avocados on moderate to very steep slopes is expanding rapidly in California. More than 10,000 acres of avocado trees have been planted on such slopes the past several years, particularly in San Diego and Ventura counties, and many of them now are becoming bearing groves. Growers need a safe and feasible way to harvest and remove their fruit from groves on the steeper slopes. Several new approaches have been tried: cableways, agritubes, and even burros and helicopters. One promising prospect that has been field tested in southern California is use of a monorail system. Japanese satsuma mandarin growers have been using monorail systems for many years to remove their citrus fruit from steep hillside plantings. In 1980 more than 60,000 monorail systems were in use. These systems also can be used (at any time) to transport materials such as fertilizers and pesticides into groves.

This paper was prepared to help avocado grove owners and managers make decisions about initial or further investment in a monorail system. It provides information on ownership and operating costs of a monorail system as well as its time requirement for harvesting in order to aid investors in their decision making process.

Physical and Technical Characteristics of the Monorail System

The monorail system consists of a power unit, trailer, and tracks. The power unit engine has a 3 to 6 Vz horsepower range and forward and reverse speeds of 43 meters per minute (140 feet per minute) and 39 meters per minute (128 feet per minute), respectively. Loading capacity is 1,100 pounds. The engine's fuel is a 25:1 gasoline-oil mixture. (Detailed specifications are presented in Appendix 1.)

The power unit runs on a monorail track which runs from the bottom to the top row of trees on a slope. The number of monorails installed in an avocado grove depends on its shape and size. If several monorails are required, the recommended practice is to set them 16 trees apart in horizontal tree rows so that fruit can be picked from 8 trees on each side of a monorail.

A two-foot wide walkway between each two horizontal rows of trees and perpendicular to the monorail track provides a path to move fruit with a motorized wheelbarrow from tree of harvest to monorail trailer for transport to the bottom of the slope. The ELTA motorized wheelbarrow is powered by a two-cycle 50 cc engine and is controlled by hand-operated throttle and brake levers. It is 5.4 feet long, weighs 90 pounds, and has a loading capacity of 220 pounds.

APPENDIX TABLE 1
ELTA LINE CARRIER SPECIFICATIONS

	$1,610.00	$1,931.00
	TYPE RD-10D	TYPE RD-17D
Length	610 mm	740 mm
Width	600 mm	490 mm
Height	740 mm	745 mm
Weight	72 kg with Engine	94 kg with Engine
Transmission	Forward and Reverse	Forward and Reverse
Speed	Forward 43 m/per min. Reverse 39 m/per min.	Forward 43 M/per min. Reverse 39 m/per min.
Brake	1. Speed control brake 2. Parking brake 3. Emergency brake	1. Speed control brake 2. Parking brake 3. Emergency brake
Driving System	Lock pinion drive	Lock pinion drive
Loading Capacity	200 kg (440 lb) 45 degree one trailer	500 kg (1,100 lb) 45 degree two trailer
Engine model	Robin EC-10B	Robin EC-17B
Piston Displacement	98 cc	175 cc
Horse Power Continues Maximum	3.0 Hp/1,600 rpm 4.0 Hp/2,000 rpm	5.0 Hp/1,600 rpm 6.5 Hp/2,000 rpm
Tank Capacity	2.5 liter (0.6 gal)	4.0 liter (1.1 gal)
Reduction Ratio	1:25	1:25
Fuel	Mix. Oil 25:1	Mix. Oil 25:1

VENTURA COUNTY Farm Advisor B.W. "Bud" Lee with K. Aizawa inspecting the first monorail installation in Somis, California.

Ownership and Operating Costs

The cost figures for ownership and operation of a monorail system are based on figures submitted by ELTA.[1] Ownership costs include depreciation, interest on the average investment, and insurance.

Depreciation — the cost of wear and obsolescence — is calculated using a straight line method. Interest charge is calculated at 12 percent of the average investment. The interest charge is the cost of borrowing; or, in cases where owners use their own resources, the interest charge reflects the amount that could have been earned had those resources been invested in the financial market. Insurance costs are to cover the risk of having monorail system equipment destroyed or stolen. Insurance is calculated at 0.6 percent of the average investment.

Operating costs include repairs and maintenance, fuel, and lubrication. Studies by agricultural engineers on the incidence of repairs and maintenance usually provide the basis for determining repair costs of machinery. Because no such study was available for the equipment described here, the authors have assumed repairs and maintenance to cost about 40 percent of the list price. Individual growers or investors should substitute their own actual figures for repairs and maintenance.

Fuel costs are determined by multiplying the fuel consumption requirement per acre by the price of fuel. (It's estimated that *a* tank of fuel — 1 gallon of a 96 percent gas and 4 percent oil mixture — will provide an average of 4 hours engine operation.) Lubrication costs per acre are estimated to be 15 percent of the fuel cost.

The following equipment prices provide the basis for determining ownership and

operating costs. The cost of the monorails is the major outlay and depends on the footage required for an avocado grove. For a 10-acre grove that is 576 feet wide and 760 feet long, two monorails would be installed along its length of a slope, set 288 feet or 16 trees between tracks with 8 trees from each track to the edge of property. At $12 per foot, therefore, the cost for the two monorails would be $18,240 ($12 x 760 x 2). An optional 308 feet of track would be required to tie two tracks together for access of the power unit to move from one track to the other. Otherwise, the power unit would have to be moved from one track to the other by hand. Cost of the additional tracks at $12 per foot will be $3,696. Costs of other items includes:

Power Unit	$1,931
Trailer	410
Wheelbarrow	598

(1) The ELTA *Line Carrier, a* product *of ELTA Machine* Industrial Co., Ltd., Tokyo, Japan, which has a *branch office in* Ventura, *California.*

The annual per acre ownership and operating costs of the system are presented in the following table:

ANNUAL PER ACRE
OWNERSHIP AND OPERATING COST OF A MONORAIL SYSTEM

Item	Cost Per Acre
Ownership Costs:	
Depreciation	$249
Interest on Investment at 12%	149
Insurance on Investment	7
Total Ownership Costs	$405
Operating Costs:	
Repairs and Maintenance	$100
Fuel and Lubrication	2
Total Operating Costs	$102
Total Ownership and Operating Costs	$507

Harvesting Time Requirement

An experiment was conducted in Ventura County to estimate the picking and carrying time requirement for an avocado grove with a monorail system. The following

characteristics of the grove, the monorail system, and the wheelbarrow were considered:

Orchard

Planting distance 18 x 20 (18 feet in row with rows 20 feet apart) — 120 trees per acre.

Monorail

Speed of power unit — Forward 43 meters/minute (140 feet/minute)
— Backward 38 meters/minute (128 feet/minute)
Loading Capacity — 450 pounds

Wheelbarrow

Speed — Low 66 meters/minute ,(216 feet/minute)
— High 85 meters/minute (276 feet/minute)
Loading Capacity — 80-160 pounds

Picking Time

Picking time requirement for the grove was estimated. It took 26.26 hours to harvest an acre of avocados, (120 trees), at an average yield of 2.48 boxes per tree. Assuming that picking time is proportional to yield, the following relationship was established:

$$y = kx$$

Where y = Picking time
k = Constant (number of hours required to pick an acre of fruit at a yield level of 1 box per tree = 10.59 or $\frac{26.26}{2.48}$)
x = Yield per tree

From the above equation, Figure 1 was developed to present the picking time requirement at three yield levels: 2 boxes, 4 boxes, and 6 boxes per tree. For example, at a yield level of 2 boxes per tree, it takes 21.18 (21.18 = 10.59 x 2) hours to pick an acre of fruit. The number of hours required to pick an acre of fruit increases with the yield level. (See Appendix Table 2.)

If the job needs to be done in less time, the number of pickers can be increased to the desired level. This can be done as follows:

$$y_1 = \frac{kx}{p}$$

Where y_1 = Desired picking time
k = Constant = 10.59
x = Yield per tree
p = Desired number of pickers

Thus, if an acre of fruit must be picked in 3 hours in a grove with a yield level of 2 boxes per tree, at least 7 pickers will be required:

$$3 = \frac{10.59 \text{ x } 2}{p}$$

APPENDIX TABLE 2
PICKING TIME PER ACRE

Yield/ Tree (Boxes)	Number of Pickers 1	2	3	4	5	6	7	8	9	10
	HOURS									
2	21.18	10.59	7.06	5.29	4.24	3.53	3.02	2.65	2.35	2.12
4	42.36	21.18	14.12	10.59	8.47	7.06	6.05	5.30	4.71	4.24
6	63.54	31.77	21.18	15.88	12.71	10.59	9.08	7.94	7.06	6.35

Transporting or Carrying Time

Figure 2 shows the relationship of time required to transport picked fruit off a hillside to road transportation at various yield levels and at different wheelbarrow loading capacities. At a yield level of 2 boxes per tree and with the loading capacity of a monorail and wheelbarrow being 10 and 2 boxes, respectively, one operator can transport an acre of fruit in 4½ hours. Carrying time increases with yield. On the other hand, by increasing the wheelbarrow's loading capacity and using two pickers to operate it, carrying time decreases. (See Appendix Table 3.)

Therefore, harvesting time can be determined at any yield level by reference to Figures 1 and 2 or Appendix Tables 2 and 3. At a yield level of 2 boxes per tree and with loading capacities of the monorail and wheelbarrow being 10 and 2 boxes, respectively, it takes 25.68 hours (21.18 for picking plus 4,50 hours for carrying) to harvest one acre of avocados.

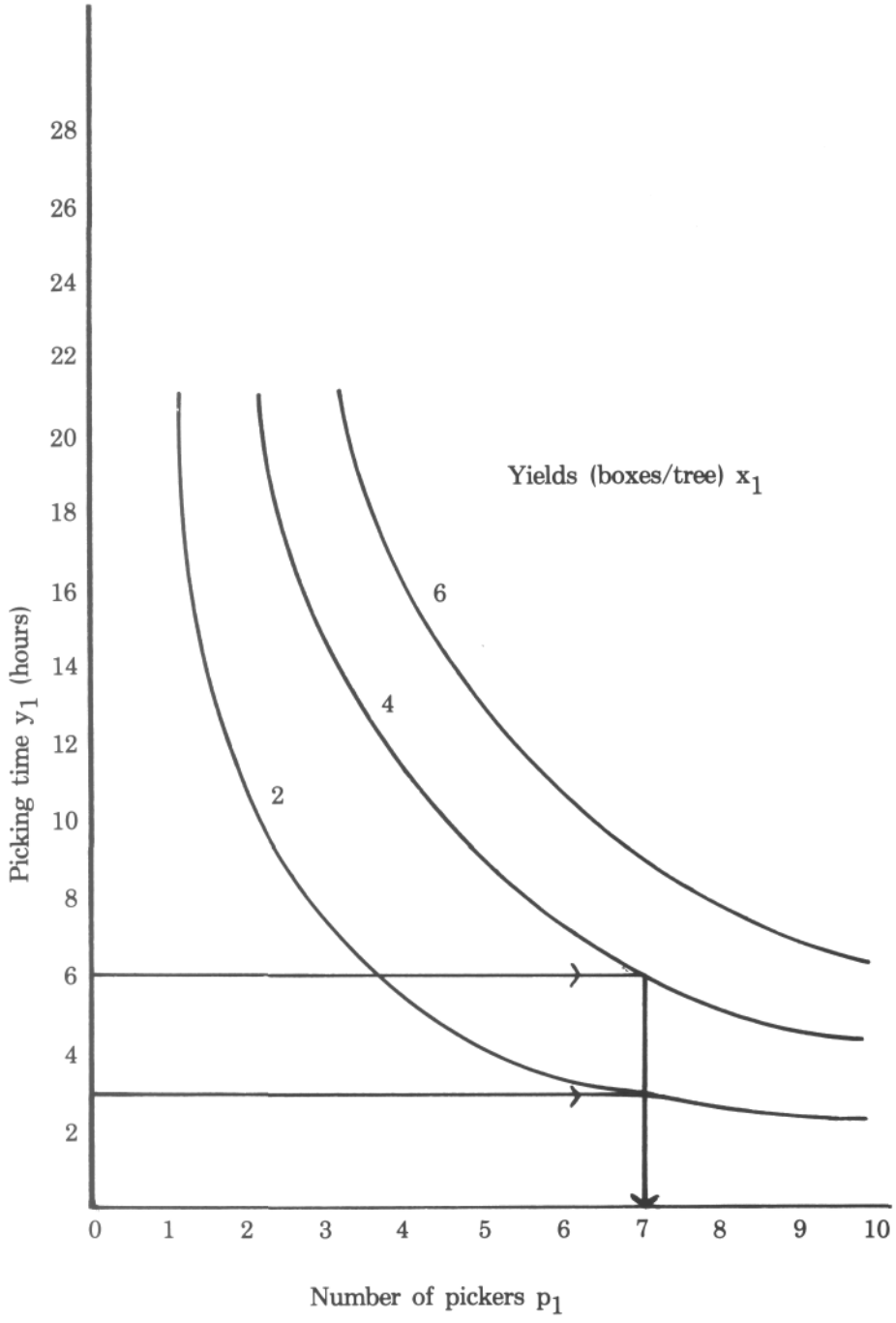

FIGURE 1—The relation of picking time per acre to pickers at varying yield levels.

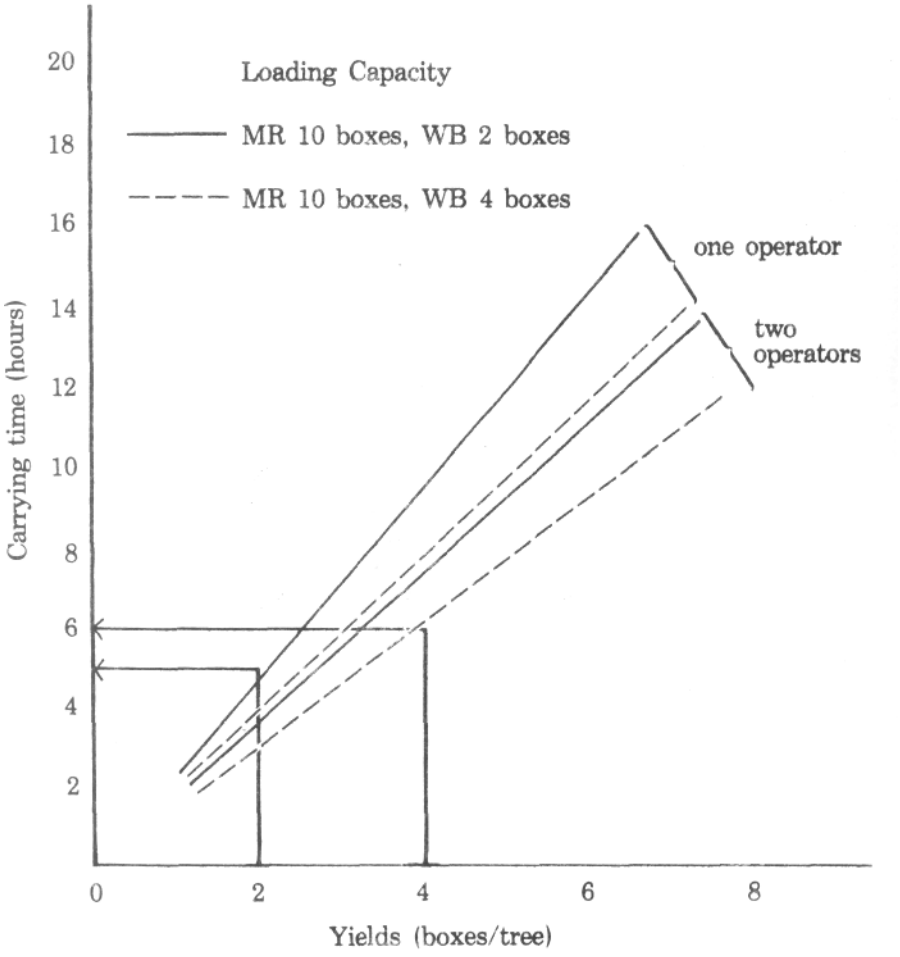

FIGURE 2—The relation of carrying time per acre to various yield levels at different loading capacities of the monorail.

APPENDIX TABLE 3
APPROXIMATE CARRYING TIME PER ACRE

Loading Capacity of a MR and WB and Number of Operators

	MR-10 WB-2	MR-10 WB-2	MR-10 WB-4	MR-10 WB-4
Yield/Tree (Boxes)	1 Operator (hours)	2 Operators (hours)	1 Operator (hours)	2 Operators (hours)
2	4.50	3.90	4.00	3.00
4	9.50	7.20	7.70	6.00
6	14.00	10.50	11.40	9.00

SUMMARY

Based on a 10-acre avocado grove, annual ownership and operating costs per acre of the monorail system is estimated to be $507. Each grower also can calculate harvesting labor costs as follows: Determine the labor time requirement from Tables 1 and 2 based on the yield of the specific orchard. Then, multiply the labor time by the wage rate. Total harvesting cost per acre using the monorail system, therefore, is the sum of the per acre ownership, operating, and labor costs.

ACKNOWLEDGEMENT

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