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APPLICATION OF THE PRINCIPLES OF DECISION UNDER RISK TO A CASE STUDY

by

VINOD KUMAR GUPTA

B. S. (Production Engineering, Condensed Course)

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Doris Grosh
Major Professor

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CHAPTER I

INTRODUCTION

1.1 DEFINITION

Decision Making

The decision making process involves getting the facts about a problem, weighing them with specified criteria, and then deciding which of several alternatives to select.

After a decision has been made and action taken, time and hind sight may show that a better choice among the alternatives could have been found.

1.2 BACKGROUND HISTORY

Decision making theories and methods have dominated the management literature in the past decade. An investigation by Greenwood [4] mentioned that before 1950, decision making was not used in management literature and was not given much importance. Management was more inclined towards human relations, organization theory and economic analysis, than towards decision theory. Later, more emphasis was laid on business decision making. Greenwood [5] added that decision making and methods have been developed in attempts to resolve particular management problems and from the perspective of particular academic disciplines, especially psychology, sociology, mathematics, statistics, and logic. That is why the literature on decision making is scattered and as yet not properly gathered or integrated.

Between 1945 and 1948, an exhaustive survey was made on the literature of decision making by Paul Wasserman and Fred S. Silander. The findings were published in a summarized form by Cornell University in 1958 under a McKinsey Foundation grant entitled Decision Making --- An Annnotated Bibliography [15]. The findings revealed that decision making was used in small groups concerning psychological studies of individual, group and leadership factors. The ideas of management decision making was originated by psychologists, mathematicians, and statisticians; its methods being derived from the fields of mathematics and statistics.

1.3 ROUTINE DECISIONS

Decisions play an important role in our everyday lives--whether or not to study for a quiz, what to order for lunch, or what color tie (or dress) to wear--these are the sorts of decisions we must make daily. Of course not all decisions are trivial. Many involve millions of dollars or even life and death. Indeed, decision making may constitute one of the highest forms of human activity.

The decision to repair the motor of an old car may seem perfectly sound to the owner in the light of an anticipated trip and the car's generally sound condition, at least at the time the decision is made. If the car is totally wrecked in an accident a week after the repair is made, the owner may lose all the money invested in repair, but can he be blamed for a faulty decision? If an investment based on some decision appears highly speculative with very little chance of working out well, can one be credited with a "good" decision, if it brings return beyond one's expectation? In one sense the answer to this question may be 'yes', in another 'no'.

1.4 HOW TO MAKE A BUSINESS DECISION

Peter Drucker [3] said that business decisions will always have to be based on judgement. They will always remain decisions for a future which will continue to be unpredictable. They will always entail risks. But studies made until now have reached a point where every businessman by following fairly simple steps can greatly improve his performance as a decision maker. There are basically four steps involved in decision making and they may be enumerated as follows:

1. Defining the problem--what kind of problem have we to solve? What is its critical factor? When do we have to solve it? What is the cost involved in its solution?
2. Defining expectations: What do we want to gain by solving it?
3. Developing alternative solutions: Which of several plans offers the surest way to avoid unexpected outcomes.
4. Knowing what to do with the decision after it is reached, i.e. implementation of the decision.

Attention to these rules will help the businessman avoid the three most common pitfalls in the making of business decisions. These are:

1. Finding the right answer for the wrong problem-few things are as useless.
2. Making the decision at the wrong time.
3. Making decisions that do not result in action.

Paul Jedamus and Robert Frame [7] explained that if the procedure discussed above is followed step by step, the decision made will be the best, not with certainty but with higher probability (confidence).

1.5 DECISION MAKING IN OTHER FIELDS

Haywood [6] (1954, ex-colonel, U.S. Air Force), an authority on military decision, described military doctrine known as "the estimate of situation" as follows in five formal steps:

1. Determination of the mission.
2. Description of situation and courses of action.
3. Analysis of opposing courses of action.
4. Comparison of own causes of action.
5. The decision.

Klee and Garland [9] used the tree diagram for solving a solid waste disposal planning problem. They used the generalized procedure which is discussed in Chapter 2.

1.6 DIFFERENT SITUATIONS UNDER WHICH ONE HAS TO DECIDE

There are three situations under which one has to decide as explained by Archer [1]:

1. Decision under certainty
2. Decision under uncertainty
3. Decision under risk

1.6.1 Decision Under Certainty

In this situation, the payoff resulting from the selection of a particular strategy is known. It is assumed that the payoff resulting from the decision can be precisely measured; in other words, only one state of nature is assumed to exist. Prediction is involved, based on assumed outcomes. The assumption of certainty simplifies the decision but ignores variations in condition which often exist, leading to improper decisions.

<u>Example</u>

A man wants to invest one thousand dollars for three years. From the present trend of market interest rate, he can choose either of two alternatives, viz.,

1. Invest \$1000 at 5% compounded annually for three years, or
2. Invest \$1000 at 5½% compounded annually for two years and for the third year at 4% compounded annually.

The criterion for selection of a particular alternative is to maximize the interest earned. The solution to the above problem according to this criterion is as follows:

<u>Alternative 1</u>

F = Future value of the deposit after n years

$= P(1+i)^n$

where,

P = present amount

i = interest rate per period

n = number of interest period

F = a future sum of money

The future value of the deposit after three years using this relation is

$$F_1 = 1000(1+5/100)^3$$
$$= 1000 \times (1.05)^3$$
$$= 1000 \times 1.168$$
$$= \$1168.$$

Alternative II

The future value of the deposit after two years is

$$F_2 = 1000(1+11/200)^2$$
$$= 1000(1.055)^2$$
$$= 1000 \times 1.113$$
$$= \$1113.$$

For the third year he has

$P = \$1113.$

$i = 4$ percent

$n = 1$

The future value of deposit after the third year is

$$F_3 = 1113(1+4/100)$$
$$= 1113 \times 1.04$$
$$= \$1157.52$$

From these calculations the first alternative will be selected, since the future value of deposit after three years is greater than from the second alternative.

1.6.2 Decision Under Uncertainty

No information is available concerning the relative frequency with which any state of nature will occur. In this situation, the possible criteria for selecting the optimum strategy are:

a. Maximin criterion.

b. Minimax criterion.

c. Maximax criterion.

d. Hurwicz criterion.

1.6.2.a The Maximin Criterion

The payoff matrix is expressed in terms of profit. In this case the decision maker regards nature as an antagonist and expects the worst possible outcome (the smallest profit). He therefore selects the strategy that will yield the greatest minimum profit. It is one of the most conservative (pessimistic) decision rules.

Example (From Sasaki [13], Page 229)

A decision maker is considering whether to sell ice cream or hot dogs at the baseball game. The payoff (profit) matrix that represents the consequences of possible action under the given states of nature are shown in Table 1.

TABLE 1. PAYOFF (PROFIT) MATRIX

State of nature	ACTION	
	To sell ice cream a_1	To sell hot dogs a_2
Sunshine (θ_1)	\$100	\$98
Cloudiness or rain (θ_2)	\$ 20	\$97

Given these data, what action should a decision maker take using the maximin criterion for selecting a strategy?

If action a_1 is taken the worst that can happen is to earn only $20. Similarly if the decision maker takes action a_2 the worst that can happen is to earn $97. The maximum of the minimum profit is $97; so the optimum decision rule is to take action a_2, that is, to sell hot dogs.

1.6.2.b The Minimax Criterion

The payoff matrix is expressed in terms of loss. In this case, the decision maker expects the worst possible outcomes (the greatest loss), and selects the strategy that will yield the smallest loss.

Example (From Sasaki [13], Page 223)

The states of nature are 'rain' and 'no rain', and the possible actions are 'stay at home', 'go without an umbrella' and 'go out with an umbrella'. The payoff matrix is given in Table 2.

TABLE 2. PAYOFF (LOSS) MATRIX

State of nature	ACTION		
	Stay at home a_1	Go without an umbrella a_2	Go with an umbrella a_3
Rain (θ_1)	4	3	2
No rain (θ_2)	4	0	6

From this data, what would be the best decision using the minimax criterion?

If action a_1 is taken, the worst that can happen (maximum loss) is 4. If action a_2 is taken, the worst is 3. Similarly for action a_3, the worst that can happen is 6. Now the minimum of the maximum loss is 3. Therefore action a_2 will be taken, that is, go without an umbrella.

1.6.2.c The Maximax Criterion

The payoff matrix is usually expressed in terms of profit. In this the payoffs are checked for each strategy and the decision maker selects the strategy with the highest possible payoff. If the criterion is maximax, then in the previous example (Section 1.6.2.a) one will select the first strategy (sell ice cream) because its highest possible payoff is greater than the highest possible payoff of the second strategy. That is, the seller receives $100 for the first strategy compared to $98 for the second strategy.

1.6.2.d The Hurwicz Criterion

The Hurwicz criterion uses the weighted average of the minimum and the maximum payoffs to select the best strategy.

Example (From Sasaki [13] , Page 234)

For three different states of nature, there are two actions (a_1 and a_2) and payoff matrix is given in Table 3.

In applying the Hurwicz criterion, weights are designed to reflect the decision maker's subjective opinion. The weight given to minimum payoff is chosen arbitrarily by decision maker, say, 3/4 and to maximum is ¼. Now the minimum for action (strategy) a_1 is \$2, while the maximum payoff is \$100. Therefore, the Hurwicz criterion would evaluate strategy 1 at the value

$$V = 3/4 \times 2 + 1/4 \times 100$$
$$= 26.5$$

Similarly, the Hurwicz criterion would evaluate strategy 2 at the value

$$V = 3/4 \times 1 + 1/4 \times 99$$
$$= 25.5$$

Hence, by this criterion, the decision maker should select strategy 1.

TABLE 3. PAYOFF (PROFIT) MATRIX

	ACTION	
State of nature	a_1	a_2
A	\$100	\$99
B	\$3	\$97
C	\$2	\$1

1.6.3 Decision Under Risk

In this case the decision maker must review the payoff matrix resulting from the various states of nature, along with their probabilities of occurrence. In order to arrive at a decision, the payoff is weighed by the associated probability. The expected value of a strategy is the sum of the payoffs, each multiplied by its respective probability of occurrence. The appropriate decision is to select the strategy with optimum expected value (largest, for maximization of the payoff unit).

<u>Example</u>

The payoffs mentioned below are profits. The criterion for selection of a strategy is to maximize the profit. There are three states of nature which occur with probabilities (.25,.5,.25) as shown in Table 4.

TABLE 4. PAYOFF (PROFIT) MATRIX

State of nature	Probability of occurrence	Strategies: Inventory Level S_1 200	S_2 250	S_3 300	S_4 350	S_5 400
A	0.25	100	90	70	40	0
B	0.5	100	120	120	90	50
C	0.25	50	100	140	190	160
Expected Values		87.5	107.5	105	102.5	65

The strategies represent different inventory levels. For a particular strategy, the profit is different for the several states of nature as shown above. As mentioned in the beginning, the profit is to be maximized, therefore a strategy with maximum average profit will be chosen.

The optimal strategy is therefore the stocking of 250 units, for the expected value (the average profit from such a decision in the long run) is higher (90 x 1/4 + 120 x 1/2 + 140 x 1/4 = 107.5) than for any other strategy, as summarized in the bottom line of Table 4.

CHAPTER II

THE GENERALIZED PROCEDURE FOR DECISION PROBLEM UNDER RISK

The generalized procedure for analyzing the decision problem in extensive form (as opposed to the so-called normal form where all possible strategies are listed with a table of expected losses) is as follows:

1. Chart the decision flow diagram in the form of a tree (see [11], page 10).
2. Assign payoffs (or utilities) at the tips of the branches of the tree.
3. Assign probabilities at all chance forks.
4. Average out and fold back.

We demonstrate with a simple example the process of finding the strategy which maximizes profit.

The problem is to select a strategy (out of two available), which will maximize the profit. The entries in the payoff matrix are the gross profit. For each strategy, there are two states of nature with their probability of occurrence as shown in Table 5.

TABLE 5. PAYOFF (GROSS PROFIT) MATRIX

State of Nature	Probability of occurrence	Strategy: Inventory level		
		S_1	S_2	S_3
		STOCK 100 UNITS	STOCK 200 UNITS	STOCK 300 UNITS
A	0.25	100	80	60
B	0.75	100	200	175

States of nature A and B represent possible selling outcomes (low sales volume versus high sales volume).

Assume that the expenses incurred for maintaining any inventory level is \$0.25 per unit.

Solution

The demonstration of generalized procedure with the above simple problem is as follows:

2.1 CHART THE DECISION FLOW DIAGRAM

Since there are three strategies (inventory levels), there are three alternatives which are presented in the tree diagram 2.1 (with two states of nature A and B for each strategy).

The symbol small square (□) represents an act, where the decision maker has to decide which strategy to select with respect to the selection criterion. The small circle (O) represents an event, where the cost is averaged out.

2.2 ASSIGN PAYOFFS AT THE TIPS OF BRANCHES OF THE TREE

The expenses incurred for maintaining inventory level is \$0.25 per unit. Therefore:

For strategy S_1, the cost of maintaining inventory level is = 100 x 0.25
= \$25.

For strategy S_2, the cost of maintaining inventory level is = 200 x .25
= \$50.

For strategy S_3, the cost of maintaining inventory level is = 300 x .25
= \$75.

Figure 2.2 is the tree diagram with the payoffs on the branches of

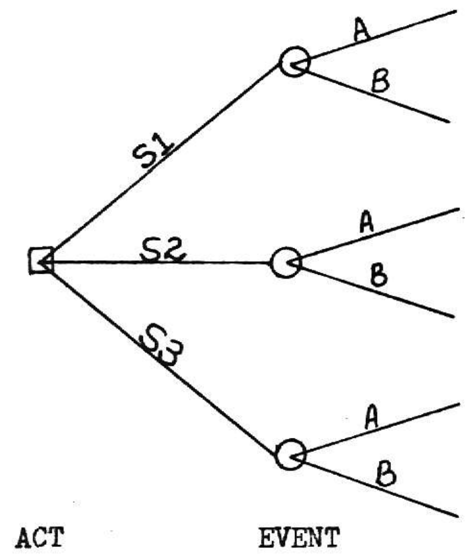

FIGURE 2.1 -Tree Diagram With Possible Acts and Events.

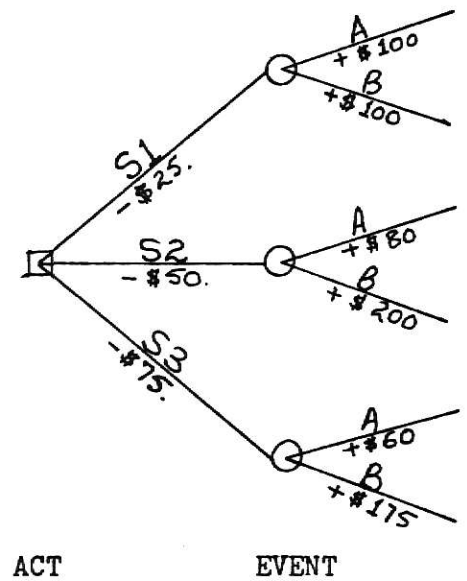

FIGURE 2.2 -Tree Diagram With Partial Cash Flows due to Individual Acts and Events.

the tree. A negative sign with a cost shows outflow and a positive sign shows inflow.

2.3 ASSIGN PROBABILITIES AT ALL CHANCE FORKS

Since the probability at the chance (event) fork is known, the Figure 2.3 represents the third step, with total cash flow shown on the extreme right in small boxes.

2.4 AVERAGE OUT AND FOLD BACK

The starting point for carrying out this computation is the right end of the tree (see Figure 2.3). The total cash flow along the path is written in a small box. Now, proceeding from right to left, one has to check the first node to ascertain whether it is an act or event. The first node here is an event, therefore the cash flows are averaged out and written in small box (above node E1, E2, and E3), in Figure 2.4.

The numbers in small boxes at node E1, E2 and E3 in Figure 2.4 are arrived at as follows:

Node E 1

$$\text{Expected payoff} = 1/4 \times 75 + 3/4 \times 75$$
$$= 18.75 + 56.25$$
$$= \$75.$$

Node E 2

$$\text{Expected payoff} = 1/4 \times 30 + 3/4 \times 150$$
$$= 7.5 + 112.5$$
$$= \$120.$$

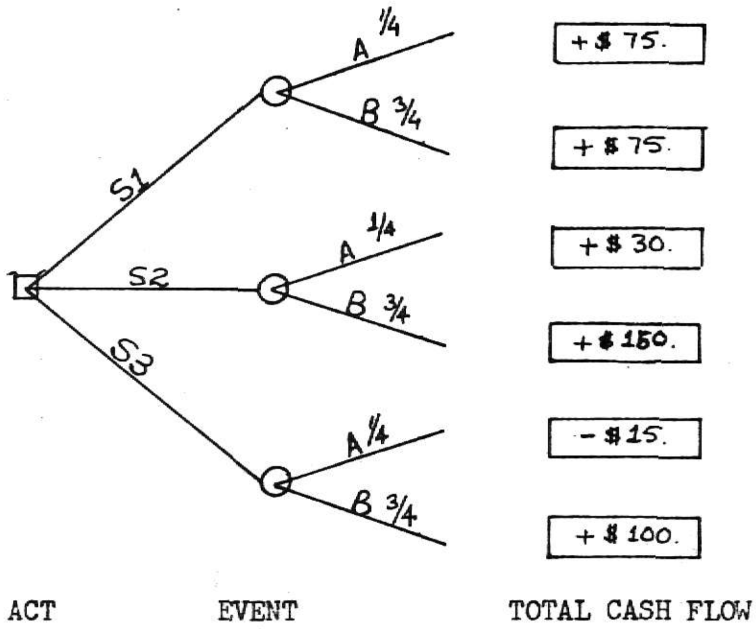

FIGURE 2.3 -Tree Diagram With Total Cash Flows due to Act-Event Sequences.

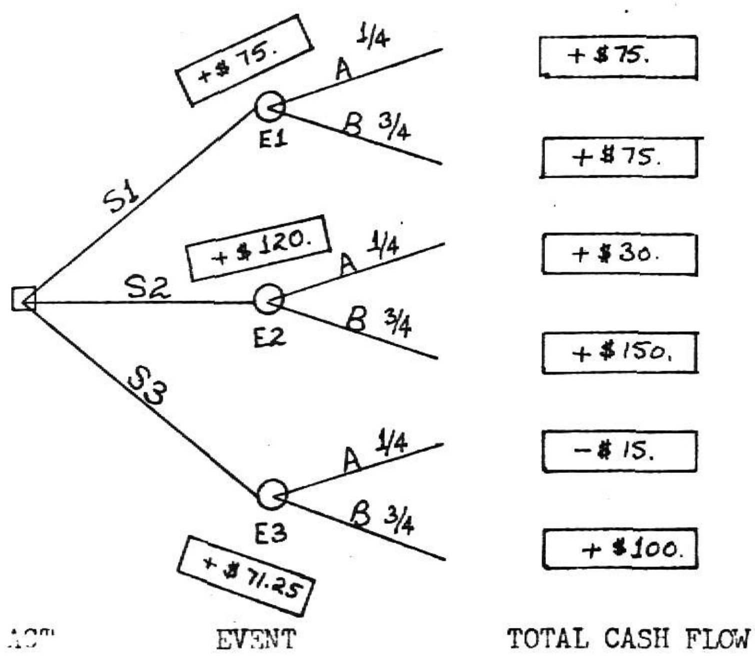

FIGURE 2.4 -Tree Diagram With Final Description.

Node E 3

$$\text{Expected payoff} = 1/4 \times (-15) + 3/4 \times 100$$

$$= -3.75 + 75$$

$$= \$71.25$$

The preceding node is an act in every case, so the branch with maximum partial cash flow will be selected. That is branch S_2.

Therefore, the optimum decision is to maintain inventory level at two hundred units.

CHAPTER III

BACK GROUND OF THE PROBLEM

The problem depicted in this report was made for class room study. An 'Applied Decision Theory' course (550 - 751) is taught in the Industrial Engineering Department at Kansas State University. The teaching schedule is shown in Table 6.

TABLE 6. TEACHING SCHEDULE

TIME SPENT	TOPIC	REFERENCE
One week	Basic ideas of Bayesian Analysis	Measuring Uncertainity an Elementry Introduction to Bayesian Statistics By Samual A. Schmitt.
Three weeks	Prior and Posterior Distribution for Binomial, Normal, Poisson and Gamma Distribution.	Instructor's notes
Seven weeks	Decision Making Under Uncertainty and Risk.	1. Elementry Decision Theory. By Chernoff and Moses. 2. Introduction to Bayesian Decision Processes By Bruce Morgan. 3. Decision Analysis By Howard Raiffa.

TABLE 6 (continued)

TIME SPENT	TOPIC	REFERENCE
One week	A Case Study Involving Decision Making Under Risk	Rositex Company Case Case Number ICH 12C19 EA-C 741 From Harvard Business School
Two weeks	Game Theory	Two--Person Game Theory By Anatol Rapoport.

For the past two years (1970, 1971) the Rositex Company case (1964) was used as a teaching example in the class; the instructor felt that it was time for new problem. The author was asked by the instructor to construct a real world problem for class room use. The main features of the problem were patterned after the Rositex Company case, which discussed a chemical producing company, producing a chemical at a time when the company was shifting to its new plant. The problem presented here concerns manufacturing flywheels under different situations. Since the author's brother in India runs a foundry, manufacturing diesel engine parts, and the author had worked there for three months, he had some knowledge about how decisions were made and how a flywheel was manufactured. The data used in this problem was received from author's brother.

CHAPTER IV

THE MANUFACTURING PROCESS

For manufacturing a flywheel, the following is the sequence of operations for arriving at a finished article:

4.1 SEQUENCE OF OPERATIONS

1. Pattern Making
2. Molding
3. Running of Cupola (melting and pouring)
4. Cleaning and Inspecting
5. Machining
   - (a) setting
   - (b) drilling
   - (c) boring
   - (d) turning and facing

4.2 FOUNDRY PROCESSES

Foundry processes consist of making molds, preparing and melting the metal, pouring the metal into molds, cleaning the castings and reclaiming the sand for reuse. The product of the foundry is a casting, in our case a flywheel.

A casting is defined as a "metal object obtained by allowing molten metal to solidify in a mold", the shape of the object being determined by the shape of the mold cavity. The following are the principle factors in getting a sound flywheel casting:

1. Pattern Making
2. Core Making
3. Molding
4. Melting and Pouring
5. Cleaning and Inspection

4.2.1 Pattern Making

The first step in making a casting of a flywheel is to prepare a model, known as a pattern, which differs in a number of respects from the resulting casting. These differences, known as pattern allowances, compensate for metal shrinkage, provide sufficient metal for machined surfaces, and facilitate molding.

For hand molding and machine molding the type of pattern used is "single", as there are different types of pattern, like single, gated, match-plate, cope and drag, etc. For hand molding the pattern is made of wood (white pine) but for machine molding, it is made of metal, usually aluminum.

The pattern to be made for a given part depends largely on the judgement and experience of the pattern maker and is goverened by the pattern cost and the number of castings to be made. If the casting is large, it is cast singly in a mold.

4.2.1.1 Pattern Allowance

Although the pattern is used to produce a casting of the desired dimensions, it is not dimensionally identical with the casting. For metallurgical and mechanical reasons, a number of allowances must be made on the pattern if the casting is to be dimensionally correct.

4.2.1.1.a Shrinkage Allowance

Shrinkage Allowance is a correction for solidification shrinkage of the metal and its contraction during cooling to room temperature. Pattern shrinkage allowance is the amount the pattern must be made larger than the casting to provide for total contraction. There are tables on "Pattern Shrinkage Allowance" available.

4.2.1.1.b Machine Finish Allowance

Machine Finish Allowance is the amount that dimensions on a casting are made oversize to provide stock for machining. This allowance largely depends upon the metal, the casting design, and method of casting and cleaning.

4.2.1.1.c Pattern Draft

Draft is the taper allowed on vertical faces of a pattern to permit its removal from the sand without tearing the mold cavity surfaces. For hand molding it is 1/16 inch per foot and for machine molding it is about one degree.

4.2.1.1.d Size Tolerance

The variation which may be permitted on a given casting dimension is called its tolerance and is equal to the difference between the minimum and the maximum limits for any specified dimension. This size tolerance allowance is given on a casting weighing one thousand pounds or more. Since the flywheel casting is about one hundred and twenty five pounds, there is no need of this allowance.

4.2.1.1.e Distortion Allowance

Distortion allowance applies only to those castings of irregular shape which are distorted in the process of cooling because of metal shrinkage. But in its present case the casting is not of irregular shape so the question of this allowance does not arise.

4.2.2 Core Making

Cores are forms, usually made of sand, which are placed into a mold cavity to form the interior surfaces of the castings. The void space between the core and mold cavity surface is what eventually becomes the casting. In making a flywheel there is no need for a core.

4.2.3 Molding

Molding consists of all operations necessary to prepare a mold for receiving molten metal. It usually implies ramming molding sand around a pattern placed in a supporting frame, withdrawing the pattern to leave the mold cavity, setting of cores in the mold cavity, and closing of the mold.

There are a number of sand molding processes; the one used for making flywheels is green-sand-molding.

Green-Sand-Molding

Green sand is a plastic mixture of sand grains, clay, water, and other materials which can be used for molding and casting processes. The sand is called "green" because of the moisture present and is thus distinguished from dry sand.

The basic steps in green sand molding are:

1. preparation of the pattern

2. making the mold

3. core setting (not applicable here)

4. closing and weighting

In the case of hand molding the floor molding process is applied, because the casting is heavy enough (the flywheel weighs one hundred and twenty pounds) to result in handling difficulty. The Figure 4.1 shows the floor molding process.

4.2.4 Melting and Pouring

The preparation of molten metal for casting is referred to simply as "melting". Melting is usually done in a specifically designated area of the foundry, and the molten metal is transferred to the molding area in ladles where the molds are poured.

Casting is essentially a remelting process, accomplished in a furnace especially designed for the quantity and type of metal to be cast. For flywheel casting the furnace used is known as cupola as shown in Figure 4.2.

Iron castings are made by remelting scrap iron along with pig iron in the cupola. The construction is very simple, consisting of a vertical stack lined with a refractory material, with provisions for introducing an air blast near the bottom.

Operation of the Cupola

The first operation in preparing a cupola is to clean out the slag and refuse on the lining and around the tuyeres from the previous run. If the lining is broken, it should be repaired so that there are no cracks on the lining. All cracks are closed with fire clay, and a layer of black molding sand is placed on the bottom. This black sand is rammed down and

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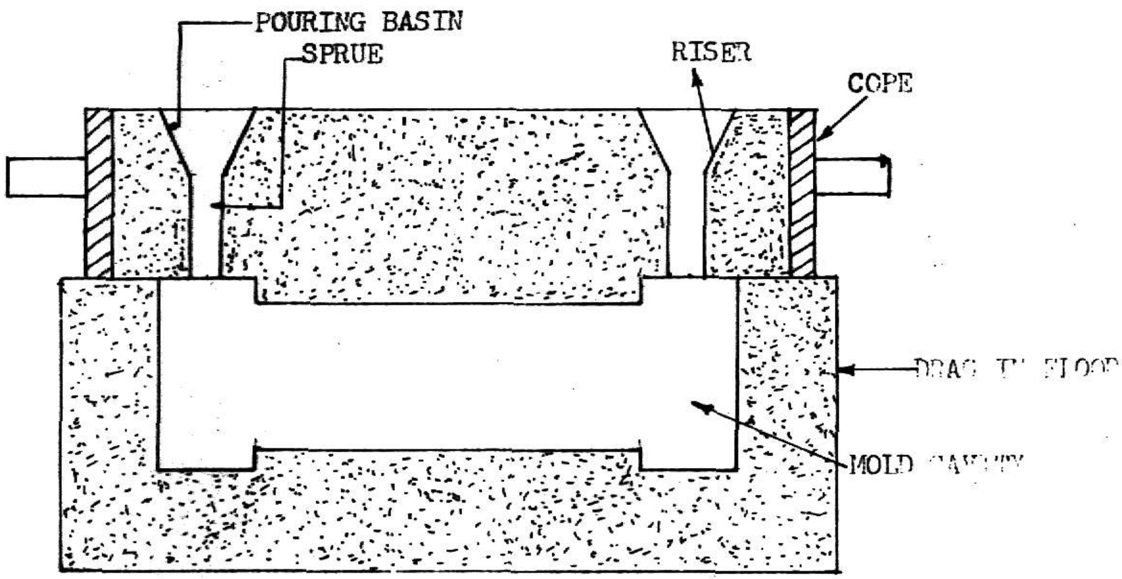

FIGURE 4.1 -Floor Molding.

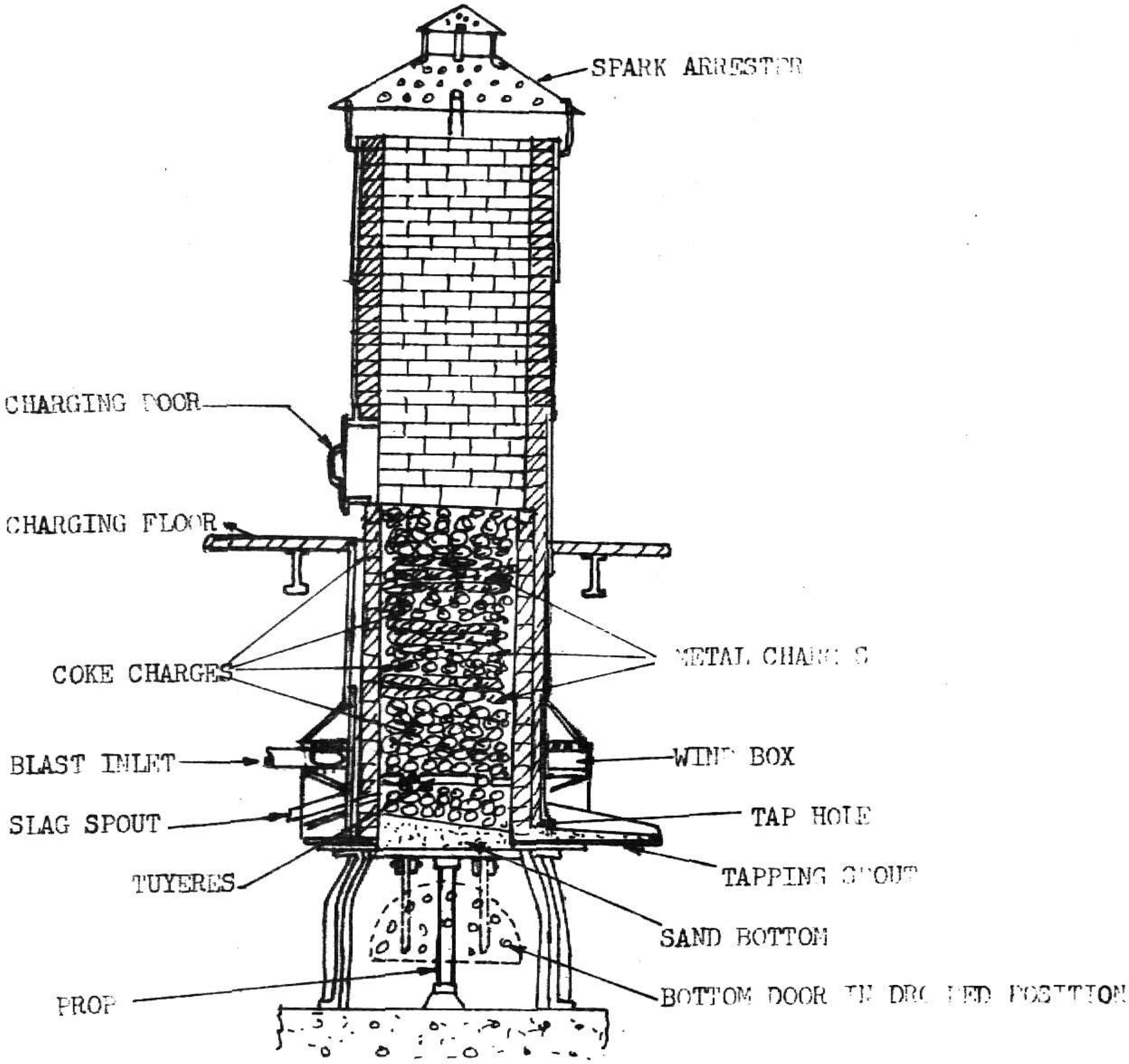

FIGURE 4.2 -Cross Section of a Cupola.

given a slope toward the spout to a depth not less than four inches at the lowest point. A small tap hole about 3/4 to 1 inch in diameter is provided.

The firing of a cupola is started 2½ to 3 hours before the first metal to be tapped. A sufficient amount of wood should be used to ignite a bed of coke. Coke is added from time to time until the bed is built up to its proper height above the tuyeres. The height of coke bed ranges from 20 to 50 inches above the top of the tuyeres. As soon as the coke bed is thoroughly ignited, the pig iron and scrap iron are introduced or charged. Alternate charges of coke and iron are made in a ratio of one part of coke to six or eight parts of iron measured by weight. In addition to charging iron and coke, a fluxing material (limestone) is used to remove impurities in the iron, protect the iron from oxidation, and render the slag more fluid for easy removal from the cupola. Slag that is formed floats on the metal accumulated on the hearth and flows continuously from the slag hole at the rear of the cupola during the heat.

After the cupola is fully charged up to the charging door, the iron should soak in heat about 3/4 of an hour or longer. Before turning on the blast, the tuyere openings must be closed. After the blast has been on a few minutes, molten metal starts accumulating in the hearth. The tap hole is then stopped up until a sufficient amount of molten metal is accumulated in the cupola to warrant pouring operations. After this the tap hole of the cupola is opened intermittently, allowing the metal to flow into a large ladle. It is then closed again with a conical clay plug called a "bot". The ladle filled with molten metal is taken to the molding floor for pouring the molten metal into the mold. Now the molds are left to cool for about twelve hours after which the castings are taken out of the molds.

4.2.5 Cleaning and Inspection

Cleaning encompasses all operations necessary for the removal of sand, scale and excess metal from the casting. The casting is seperated from the molding sand and transported to the cleaning department. Excess metal, in the form of fins, wires, parting line and gates, is cut off. Defective castings may often be salvaged by welding or other repair. After passing inspection the casting is sent to the machine shop for further processing.

4.3 THE MACHINING OPERATION

First of all the casting is positioned on the lathe. Since the casting is round, a four jaw chuck is required to hold the casting on lathe.

Drilling and Boring

Usually drilling consists of producing a hole in an object by forcing a rotating drill against it. But on a lathe the drill is kept stationary and flywheel rotates.

Boring is the enlarging of a hole that has already been drilled, or it is an operation of turning a hole that has been drilled previously with a single-point lathe type tool.

After this, the flywheel is held on a mandrill and is turned, faced, etc. From the machine shop the finished article is sent to shipping department where it is stacked up for accumulation.

4.4 MANUFACTURING SCHEDULE

For a batch of 500 units, the manufacturing schedule was given by the production engineer as follows in Table 7.

TABLE 7. MANUFACTURING SCHEDULE

TIME (in days)	OPERATION
1½	Molding
½	Drying and Closing Molds
1	Cupola Running (Melting and Pouring)
1	Cooling
1	Opening Mold and Inspection of Castings
5	Machining

For the first week the machine shop would be idle; during the second week the second batch would be casted and the first batch would be machined.

CHAPTER V

THE PROBLEM

It was brought to the attention of Mr. Gupta, the president of Gupta Manufacturing Company, by his sales manager, that if the former decided to build a special kind of a prototype unit and submit it for testing to the Kapoor Company, he might succeed in getting a contract for five thousand units from the Kapoor Company with a possibility of subsequent orders at three month intervals. The order from Kapoor Company would be for five thousand flywheels to be delivered on or before the twelfth week after the order is received by the Gupta Manufacturing Company. The selling price per wheel would be sixty rupees. Subsequent orders would depend on the relations between the two firms and the quality of the product. If the shipment arrived after the twelfth week, Kapoor Company had the right to decline the order. A period of fifteen (working) days was granted to various manufacturers to submit their prototype. Kapoor Company would take one week to decide to whom the order should be given.

The president of the Gupta Manufacturing Company arranged a meeting with all heads of different departments to discuss whether or not they should attempt to make a contract with Kapoor Company to manufacture the flywheels. Since there was a deadline involved, the problem had to be discussed from every angle. In the president's opinion it would be profitable from the point of maintaining cordial relations with Kapoor Company to decline the order at the very outset if there was a good chance of not meeting the deadline. Should they accept the order and not meet the deadline, it would jeopardize relations with prospective customers.

The chief design engineer was the first person to be consulted. He stated that it would be possible to build the prototype at a cost of five hundred rupees.

Next the problem was discussed with the production engineer to investigate possible alternatives of meeting the deadline. Three suggestions were put forward by the production engineer, which were as follows:

A1. Start manufacturing of units in the company itself.

A2. Have sister concern (Gupta Supplier Company, refer to Section 5.1) execute the entire order.

A3. Manufacturing part of the order in the company and supply the remaining through the Gupta Supplier Company.

The foundry engineer was consulted next to discuss the first alternative put forward by the production engineer. The discussion was mainly on whether to aim at hand molding or machine molding. The cost associated with the different operations like running the cupola, cleaning, casting etc., was different for hand molding than for machine molding, although the operations required were the same for both processes. From past experience, it was found that with machine molding, the success rate of the entire operation (running of the cupola and obtaining sound castings) was ninety percent. In hand molding, although the success of running the coupla remained the same (compared with machine molding), the chances of obtaining sound castings were only eighty percent. In the event of defective castings, the cost of repair would be one hundred rupees for the machine mold casting and four hundred rupees for the hand mold castings for a batch of five hundred units. This difference in cost of repair was attributed to defects being more common with hand molding. The cleaning cost per wheel was one rupee for manual cleaning and forty five paises (0.45 rupee) for machine cleaning. In this context, the foreman added that if they were sure of getting future orders, it would be worthwhile setting up a cleaning machine. The time for the entire foundry operation was estimated by the foreman as five days for a batch of five hundred units, in either case.

Next in the line of consultation was the machine shop foreman. Two possibilities were immediately apparent. One was to machine the castings in the company itself and the second possibility was to get them machined by another manufacturer. There was only a one percent chance that something would go wrong with the machining operation, if it was carried out in the plant. From the other manufacturer, the machining was assured to be perfect since a defective unit would not be accepted.

Next the relative costs had to be considered before arriving at a decision. The following costs were quoted by the foreman; for machine mold casting, the machining cost would be four rupees per wheel if machined in the factory itself, and six rupees if it was done outside. For hand mold casting, the machining cost was six rupees per wheel, if machined in the factory itself and eight rupees per wheel otherwise. The higher machining cost for hand mold casting was due to a greater machining requirement compared with the machine mold casting. In the event something went wrong with the machining operations, the total loss (cost of repair plus machining cost) for a batch of five hundred units would amount to four thousand rupees for machine mold casting and five thousand rupees for hand mold casting.

The president felt that he should also find out from his foundry engineer the possibility of losses associated with the cupola operation. He was told that if something did go wrong with the foundry operation, it would result in first, loss of labor used for making the molds, and second, additional labor and cost for cleaning and repairing the lining in the cupola. It would amount to a loss of approximately one thousand rupees.

Having obtained all the necessary information for manufacturing the lot in the company itself, it still remained to consider the second possibility, that of executing the order through the sister concern (Gupta Supplier Company). The works manager was asked to investigate the issue.

The works manager found out that the cost per wheel was fifty rupees and in order to obtain any discount on this price, a certain minimum number must be ordered. The details regarding the discount available and the inventory policy of the Gupta Supplier Company were described in Table 8. Also, if some machining was required to put the wheels in final shape, it would need some extra time. The only other factor to be considered was whether or not to take advantage of the discount offered by the Gupta Supplier Company. The answer to this would in fact depend on the situation at hand. For example, if the production in the company at any time lags behind schedule by, say two weeks (1000 wheels, refer to Section 4.4) it would be worthwhile to place an order with the Gupta Supplier Company to bridge this gap in production. The question which arises now is how to place this order, and this was discussed with the works manager.

The two alternatives offered by the works manager were:

A2(1) Place the order the moment production lags behind schedule.

A2(2) Wait till the eleventh week and then make an order with the Gupta Supplier Company for the amount needed to bring the production schedule up to date.

If an order was placed in the eleventh week, Gupta Manufacturing Company runs the risk that the Gupta Supplier Company might not have a sufficient stock to meet the order. The probabilities of the Gupta Supplier Company meeting the order (inventory policy), are shown in Table 8.

TABLE 8. INVENTORY POLICY AND QUANTITY DISCOUNT

Number of Flywheels	Probability of Availability	Quantity Discount Per Wheel (in Rupees)
500	1.0	0.0
600	.9	0.0
700	.8	0.0
800	.7	0.25
900	.6	0.40
1000	.5	0.50
1500	.4	0.60
2000	.25	0.65
3000	.15	0.75
4000	.10	0.85
5000	.00	1.00

5.1 ABOUT THE SISTER CONCERN

Gupta Manufacturing Company has a sister concern named Gupta Supplier Company. Gupta Supplier Company does not manufacture any product but stores certain commodities like flywheels, diesel engine parts, and all kinds of nuts and bolts. All mentioned items can be procurred from the Gupta Supplier Company in accordance with their policy mentioned in Table 8. Gupta Supplier Company purchases various products in bulk from other manufacturers at a low price, stores them for some time and sells them at a profit in the open market.

5.2 SUBSIDIARY PROBLEM S1

The discussion here centers mainly on the procedure that would have to be adopted to meet a deficit in production. The normal weekly production of flywheels should be five hundred units; there is always a possibility that due to unforseen events it may not be possible to meet this weekly schedule. One way of solving this problem is to place an order with the Gupta Supplier Company to update the production schedule. What is the best procedure for placing the order for production lag?

5.3 SUBSIDIARY PROBLEM S2

It was known that if the order from the Kapoor Company is obtained, there would not be sufficient machinery in the existing plant to manufacture the entire order of 5000 units. Should the prototype be approved, one has to consider the steps to be taken to order additional machinery. In this context one has also to evaluate possibilities for cancelling the machinery order (and the terms associated with cancellation) in the event that the prototype failed the test.

5.4 *UNIT USED* (Rupee vs. Dollar)

The units used in this problem are rupees and paises instead of dollars and cents, because the data is from India as already mentioned in Chapter III. Had it been converted in dollars and cents, the decision might have changed because labor costs in India and the United States are so different. The rupee is the basic monetary unit of India and there are one hundred paises per rupee.

CHAPTER VI

6.1 SOLUTION

Following the discussions with his department heads, Mr. Gupta was faced with the problem of arriving at a decision regarding the manufacture of flywheels. Among the risks involved in undertaking the order, the idea of locking up capital in additional machinery did not seem very attractive and so he decided to talk to Mr. Vinoo Khanna, a consultant who was well acquainted with modern decision making. The president felt that his recommendations would certainly be valuable in the present situation.

When Mr. Khanna arrived at the plant, Mr. Gupta first gave him a general briefing on the current condition of the firm and then described the immediate problem, relating in detail the suggestion and points of view that had been expressed already. He added that he had implicit faith in his subordinates and he considered them experts in their own fields. Nevertheless, the risk involved had to be evaluated before arriving at the final decision. With this in mind, the president asked Mr. Khanna to study the situation and suggest whether or not it was worthwhile taking the risk.

To come up with a reasonable solution, Mr. Khanna felt the need to study the problem thoroughly and analyize each suggestion offered by plant personnel. He summerized the important aspects of the problem as follows:

Order Period -------------------------------------- Twelve Weeks

Number of units to be manufactured---------------- 5000

Period for producing prototype -------------------15 days

Cost of manufacturing prototype ------------------500. rupees

Alternatives

The following three alternatives were given by production engineer:

A1. Start manufacturing of units in the company itself.

A2. Have Gupta Supplier Company supply the entire order.

A3. Manufacturing part of the order in the company and supply remaining through the Gupta Supplier Company.

Alternative A1

The following points were discussed:

1. Whether to use hand molding or machine molding.
2. Whether to clean manually or by machine.
3. Whether to machine the castings in the plant itself or get them machined from another manufacturer.

The cost associated with different operations is summarized in Table 9.

Alternative A2

The cost per wheel was fifty rupees. Sometimes additional machining was required to put the flywheel in final shape.

Two ways of placing an order with Gupta Supplier Company was discussed, as follows:

1. Place the order the moment production lags behind schedule.
2. Wait until the eleventh week and then place an order with Gupta Supplier Company for the number of flywheels needed to bring the production schedule up to date.

The inventory policy and discount per wheel as given by Gupta Supplier Company were given in Table 8.

TABLE 9. DIFFERENT OPERATIONS WITH THEIR ASSOCIATED COST

Operation	Cost	
	Hand Molding	Machine Molding
1. Cost of repair of defective castings	400 rupees for a batch of 500 units	100 rupees for a batch of 500 units
2. Cleaning cost		
a. manually	1 rupee per wheel	1 rupee per wheel
b. machine cleaning	0.45 rupee per wheel	0.45 rupee per wheel
3. Machining cost		
a. in plant itself	6.00 rupees per wheel	4.00 rupees per wheel
b. outside the plant	8.00 rupees per wheel	6.00 rupees per wheel
4. Loss due to inaccurate machining	5000. rupees for a batch of 500 units	4000. rupees for a batch of 500 units
5. Loss due to faulty cupola operation	1000. rupees for a batch of 500 units	1000. rupees for a batch of 500 units

The reports, in his opinion, were fairly exhaustive. Nevertheless, there were some points that were not clear and needed further clarification. The foundry engineer had to be consulted to provide additional cost data for operation of the mold and cupola, as well as the labor costs in the above operations. The figures that were given to him by the foundry engineer were as follows:

Labor cost for machine mold----------------------one rupee/wheel

Labor cost for hand mold-------------------------two rupees/wheel

Labor cost for running the cupola----------------two rupees/wheel

Next, Mr. Khanna asked the foundry engineer to give an estimate of raw material per wheel and the associated costs. The foundry engineer supplied the following information:

Cost of pig iron (60 kgs.@Rs.0.45/kg)------------Rs. 27.00

Cost of coal (12 kgs. of coal was required for a casting of 60 kgs. @Rs.0.20/kg)-Rs. 2.40

Cost of other materials (kerosene oil, wood, black lead etc.)-------------------------------Rs. 2.00

Total cost per wheel-----------Rs. 31.40

Mr. Khanna next asked the works manager what was the regular weekly income from other business transactions. To this the works manager replied that the normal weekly income (from past statistics) averaged about Rs. 1500.00. However, should they decide to undertake the present order, it will not be possible to continue producing the usual product line since they have to devote all the time to fulfill the present commitment.

With sufficient information on the problem, Mr. Khanna laid down four alternatives, three of which had already been suggested by the plant personnel. The fourth alternative was to refuse the order, if the management decided not to undertake the risk of locking up capital in the additional machinery needed to complete the project. If on the other hand the management was prepared to take this risk, then the criterion for accepting the order had to be one of maximizing the expected profit earned by the company. At this point Mr. Khanna applied the generalized procedure for solving problems of this nature. The steps involved in this procedure have already been described in Chapter 2 and detailed descriptions are given as follows:

1. Chart the Decision Flow Diagram (Tree Diagram)

   In this diagram, all possible alternatives are shown as in Figures 6.1, 6.1a, 6.1b, 6.1c, and 6.1d.

2. Assign Payoffs At The Tips Of The Branches Of The Tree

   As shown in Figures 6.2, 6.2a, 6.2b, 6.2c, and 6.2d, the total amount to be spent or earned on a particular event or act is mentioned on the branches of the tree.

3. Assign Probabilities At All Chance Forks

   Since certain stages of the operation involve chance factors, the probability of success or failure in these operations is incorporated as shown in Figure 6.3, 6.3a, 6.3b, 6.3c, and 6.3d.

4. Average Out And Fold Back

   The starting point for carrying out this computation is the end of tree as shown in Figures 6.4, 6.4a, 6.4b, 6.4c, and 6.4d. The total cash flow along the path is written in a small box. Proceeding from right to left, since the first node is an event, the cost was averaged out. The next fork was an act. The criterion for making such a decision was based on maximizing profit, the branch with higher cash flow was chosen. In the same the process was repeated depending upon fork (event or act).

6.2 SUMMARY

Here is the outline about the generalized procedure represented in diagrams. Figures 6.1, 6.1a, 6.1b, 6.1c, and 6.1d show the different possible alternatives. This is the first step which is called tree diagram. The symbol small square (□) represents a node where the decision maker has to decide which branch to choose, depending upon the criterion for selection. The symbol circle (0) represents a chance node. Where each branch coming out from the node has an ascertainable probability of happening. To summarize:

□ represents an act (of the decision maker)

0 represents an event (of nature)

Now for Alternative A1, Figures 6.1a, and 6.1b represent the different possible happenings. Figures 6.2a and 6.2b are shown with partial cash flow on the branches for different operations, which in fact correspond to the second step of generalized procedure. In Figures 6.3a and 6.3b total cash flow is shown on the extreme right in a small box and for the chance forks (events) the associated probabilities are mentioned. The last step is shown in Figures 6.4a and 6.4b. The partial cash flow in small boxes at different node was determined according to whether it was an event or an act. If it was an event, cash flow was averaged out. If it was an act, the path with maximum partial cash flow was selected.

For example, the number on the branch (Build Prototype-Kapoor Company Order-Start Manufacturing-Hand Molding-Running Cupola-O.K-Casting O.K-Manual Cleaning-To Machine Shop-Machining O.K-To Shipping Department) tip was found as follows:

Total Cash Flow = -500+300000-10000-157000-10000-0-5000-30000

= 300000-212500

= 87500.

The number on the other branches tip were found in a similar manner.

At the end of the analysis the decision to build the prototype was recommended by Mr. Khanna, then start manufacturing in the plant using machine molding. He also added that the machining of flywheels in the plant is more profitable than getting the flywheels machined from another manufacturer.

<u>Calculation for different chances of getting order</u>

It was not certain with how much probability Gupta Manufacturing Company would get the order. As suggested by the sales manager the following combinations were tried:

Case No.	Probability of Getting Order	Not Getting Order
1	.25	.75
2	.50	.50
3	.60	.40
4	.75	.25

The cash flow at Node OR in Figure 6.4 with the different probabilities (stated above) was averaged out (a node being an event) as follows:

Case 1

Expected profit = 1/4x96800.7+3/4x17500.

= 24220.17+4375.

= 28595.17

Case 2

Expected profit = 1/2x96880.7+1/2x17500.

= 48440.35+8250.

= 56690.35

Case 3

Expected profit = 6/10x96880.7+4/10x17500.

= 58128.42+7000.

= 65128.42

Case 4

Expected profit = 3/4x96880.7+1/4x17500.

= 72660.51+4375.

= 77035.51

The next step is to decide whether to make the prototype unit or not. The criterion for selection of a branch (as already stated), is to select that branch with maximum partial cash flow. The expected return at Node OR under different assumption on the probability of getting the order are Rs.28595.17, 56690.35, 65128.42, 77035.51. Node P in Figure 6.4 is an event, therefore the decision would be to build the prototype even when the chances of getting the order was only twenty five percent.

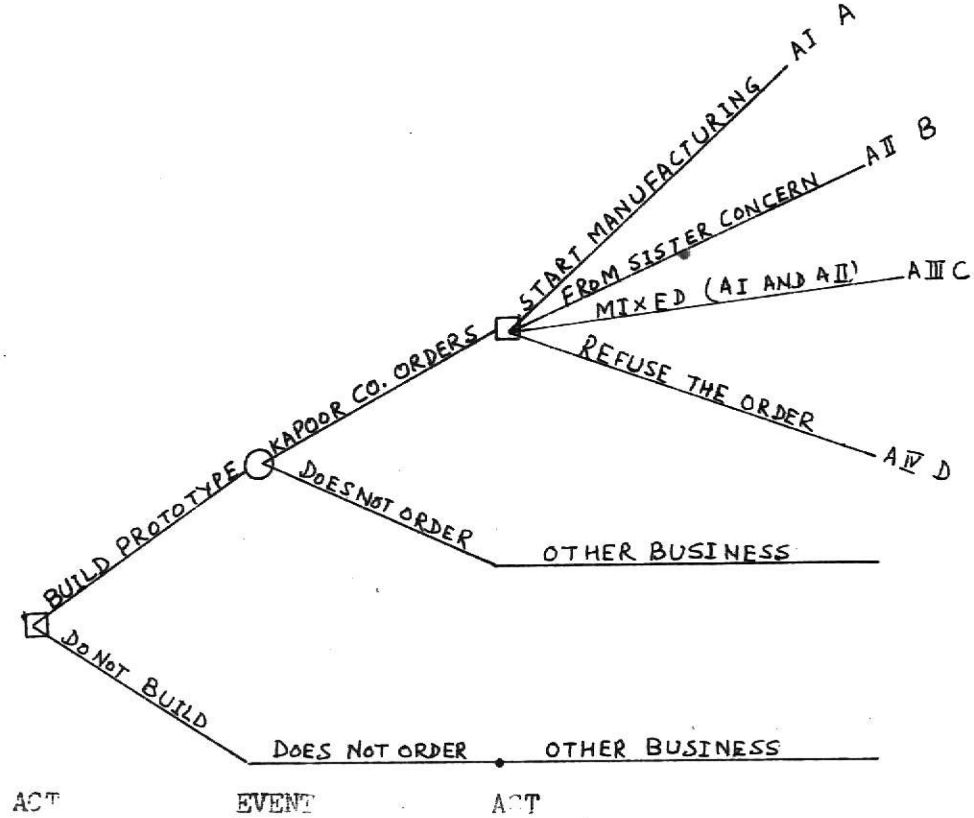

FIGURE 6.1 -Tree Diagram With Possible Acts and Events.

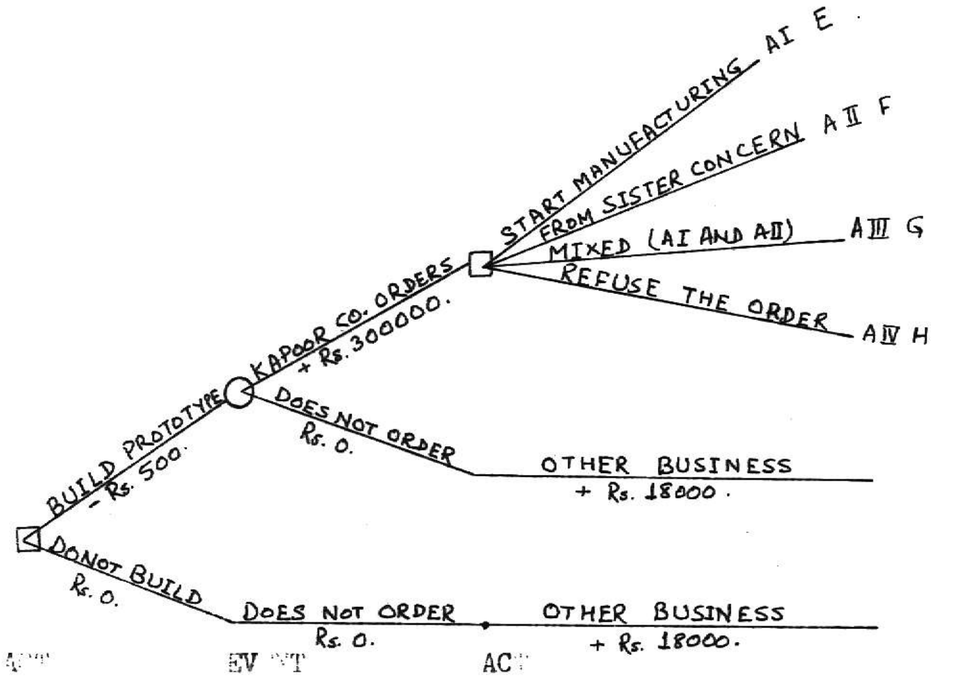

FIGURE 6.2 -Tree Diagram With Partial Cash Flows due to

Individual Acts and Events.

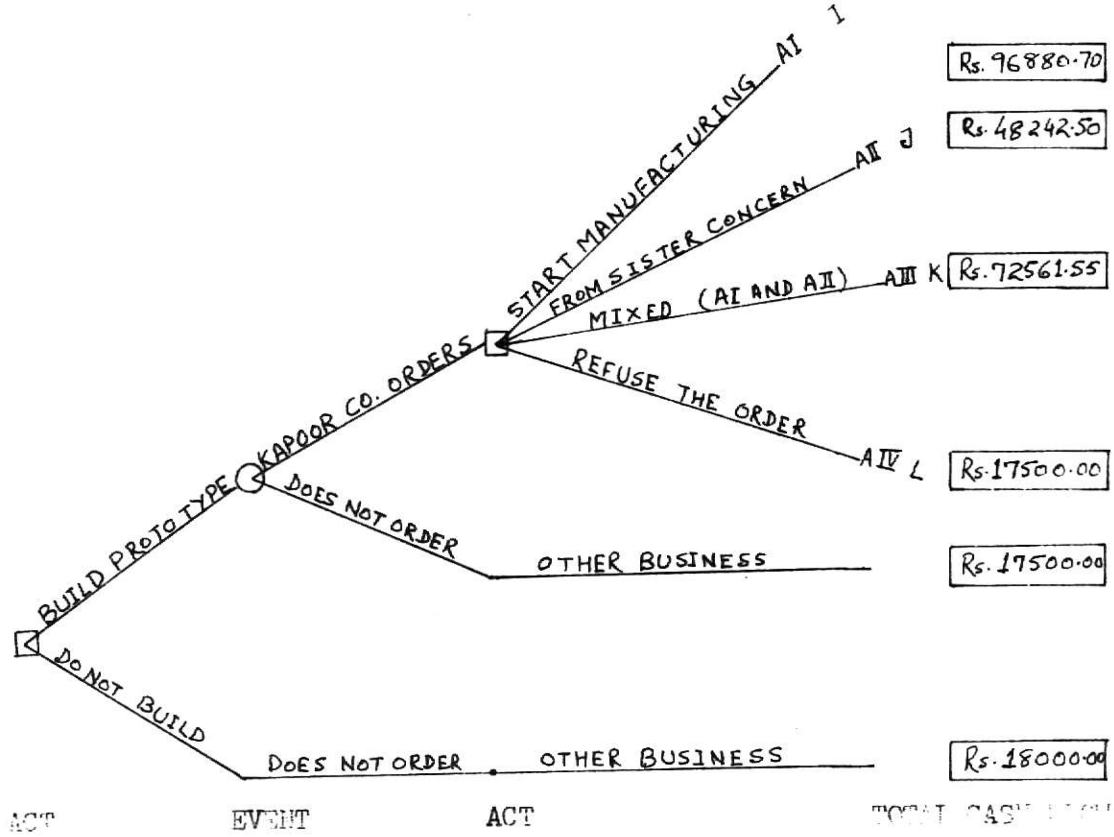

FIGURE 6.3 -Tree Diagram With Total Cash Flow due to Act-Event Sequences.

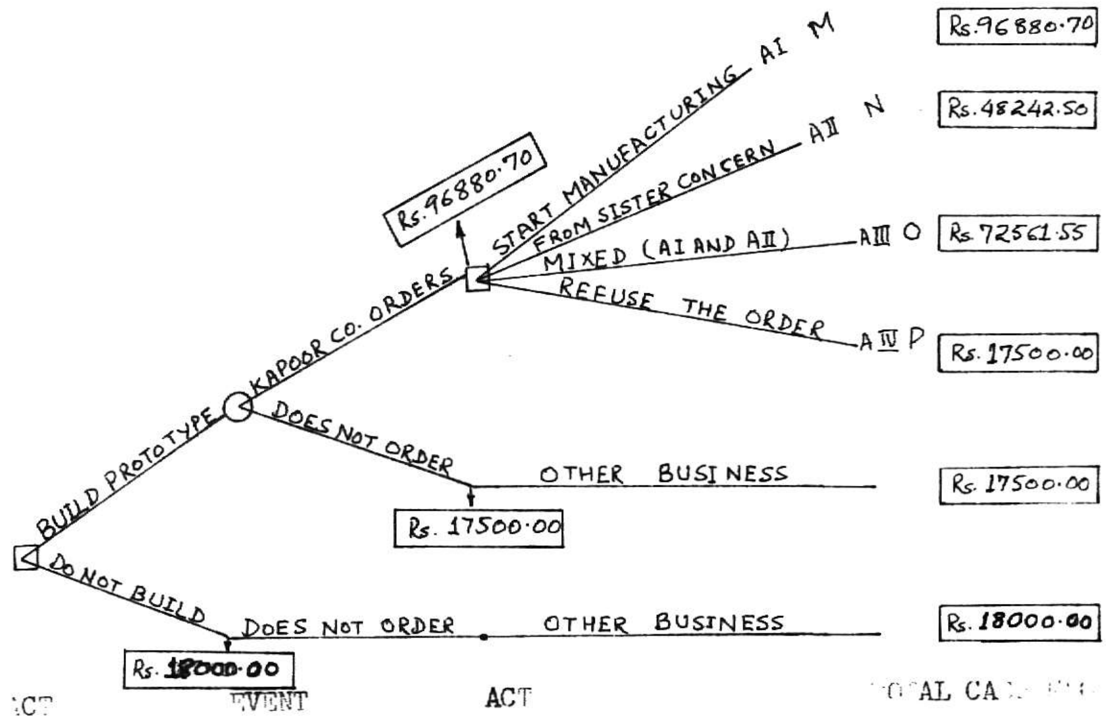

FIGURE 6.4 -Tree Diagram With Final Description.

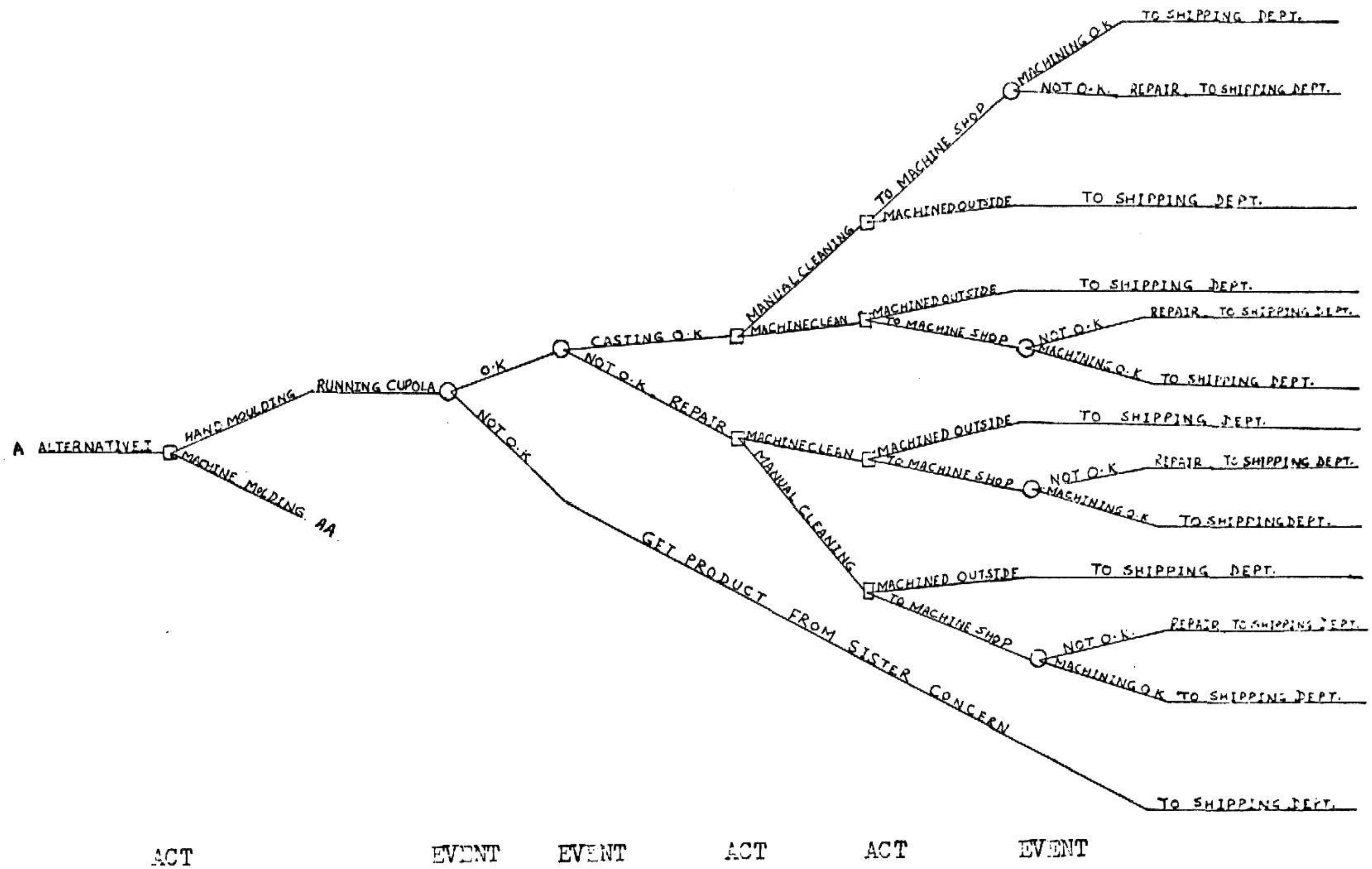

FIGURE 6.1a -Tree Diagram With Possible Acts and Events.

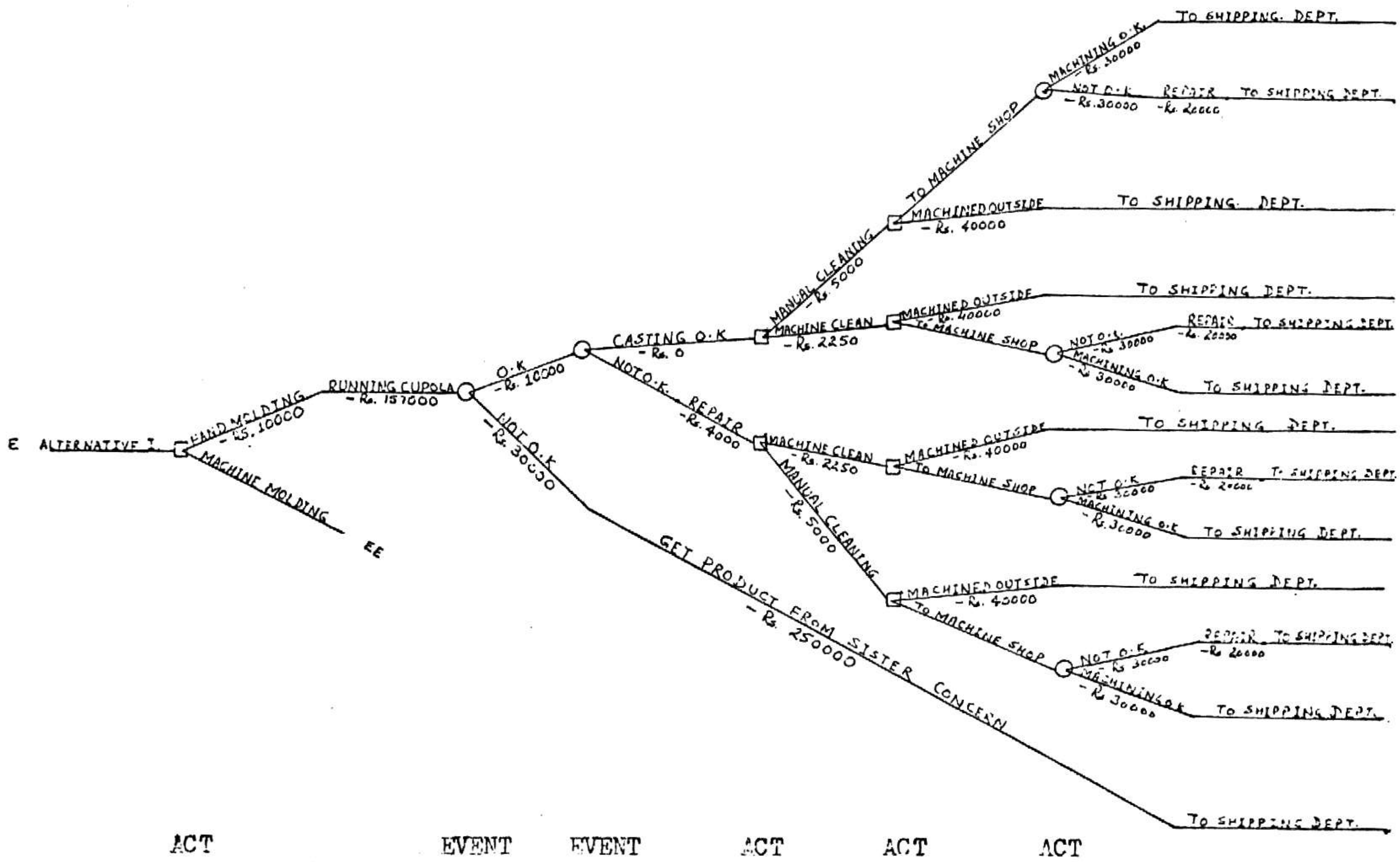

FIGURE 6.2a -Tree Diagram With Partial Cash Flows due to Individual Acts and Events.

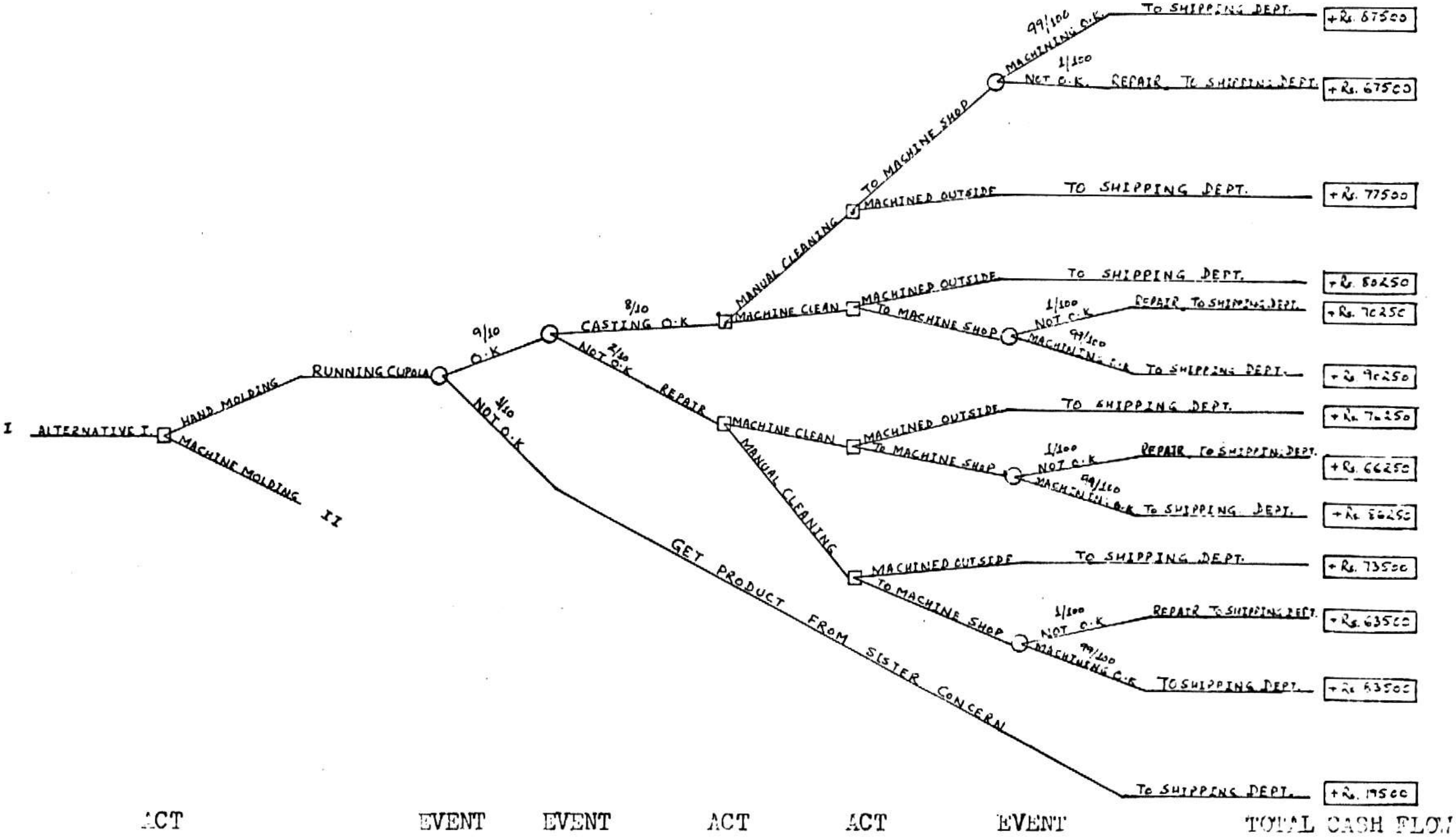

FIGURE 6.3a -Tree Diagram With Total Cash Flows due to Act-Event Sequences.

The numbers on Nodes H1, H2, H3, H4, CH, and RH in Figure 6.4a are calculated as follows:

Node H1:

Expected payoff = 99/100x87500+1/100x67500.

= 86625+675.

= 87300.

Node H2:

Expected payoff = 99/100x90250+1/100x70250

= 89347.5+702.5

= 90050.

Node H3:

Expected payoff = 99/100x86250.+1/100x66250.

= 85437.5+612.5

= 86050.

Node H4:

Expected payoff = 99/100x83500 1/100x63500.

= 82665.+635.

= 83300.

Node CH:

Expected payoff = 8/10x90050+2/10x86050.

= 72040.+17210.

= 89250.

Node RH:

Expected payoff = 9/10x89250+1/10x19500.

= 80325.+1950.

= 82275.

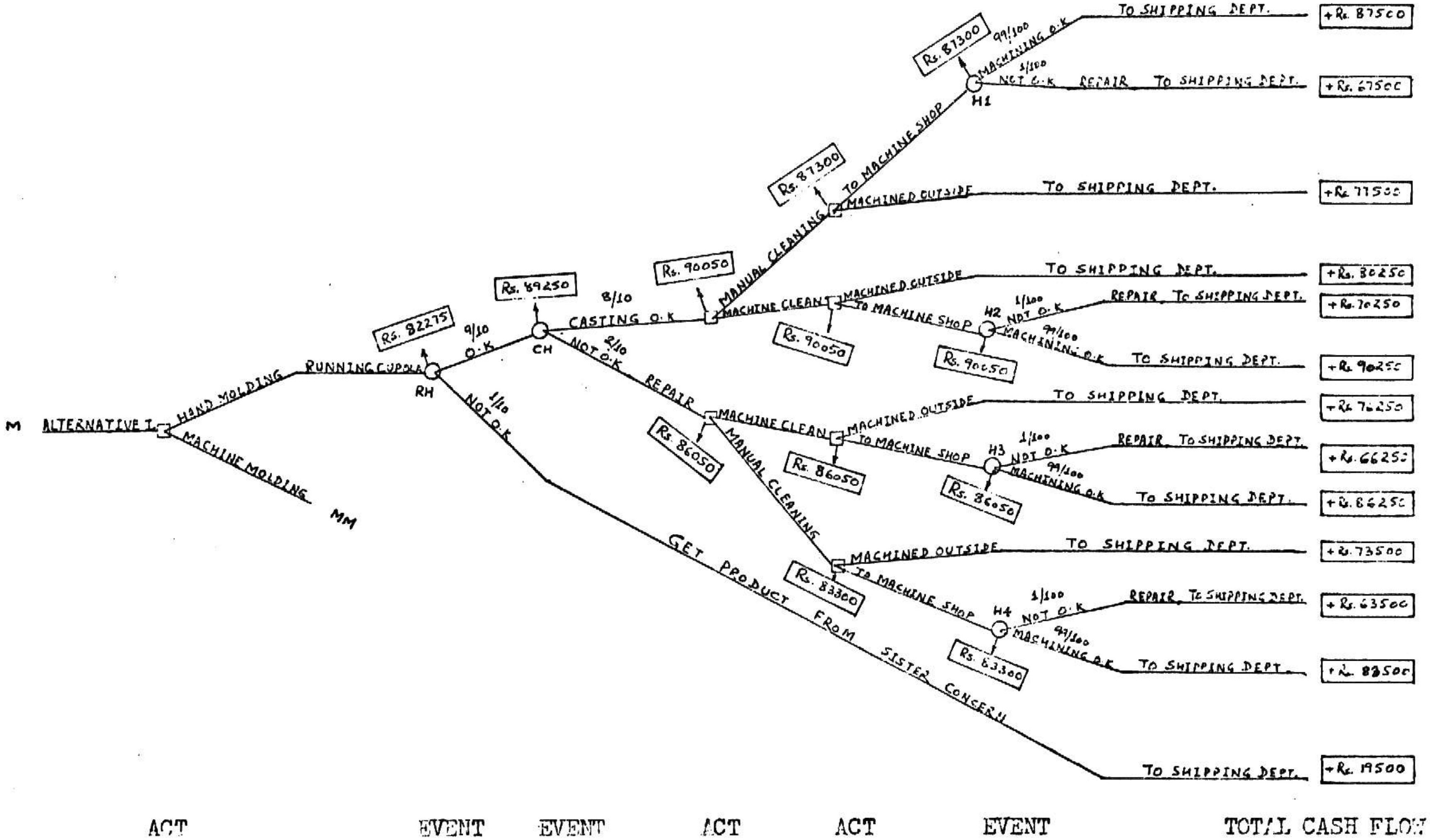

FIGURE 6.4a -Tree Diagram With Final Description.

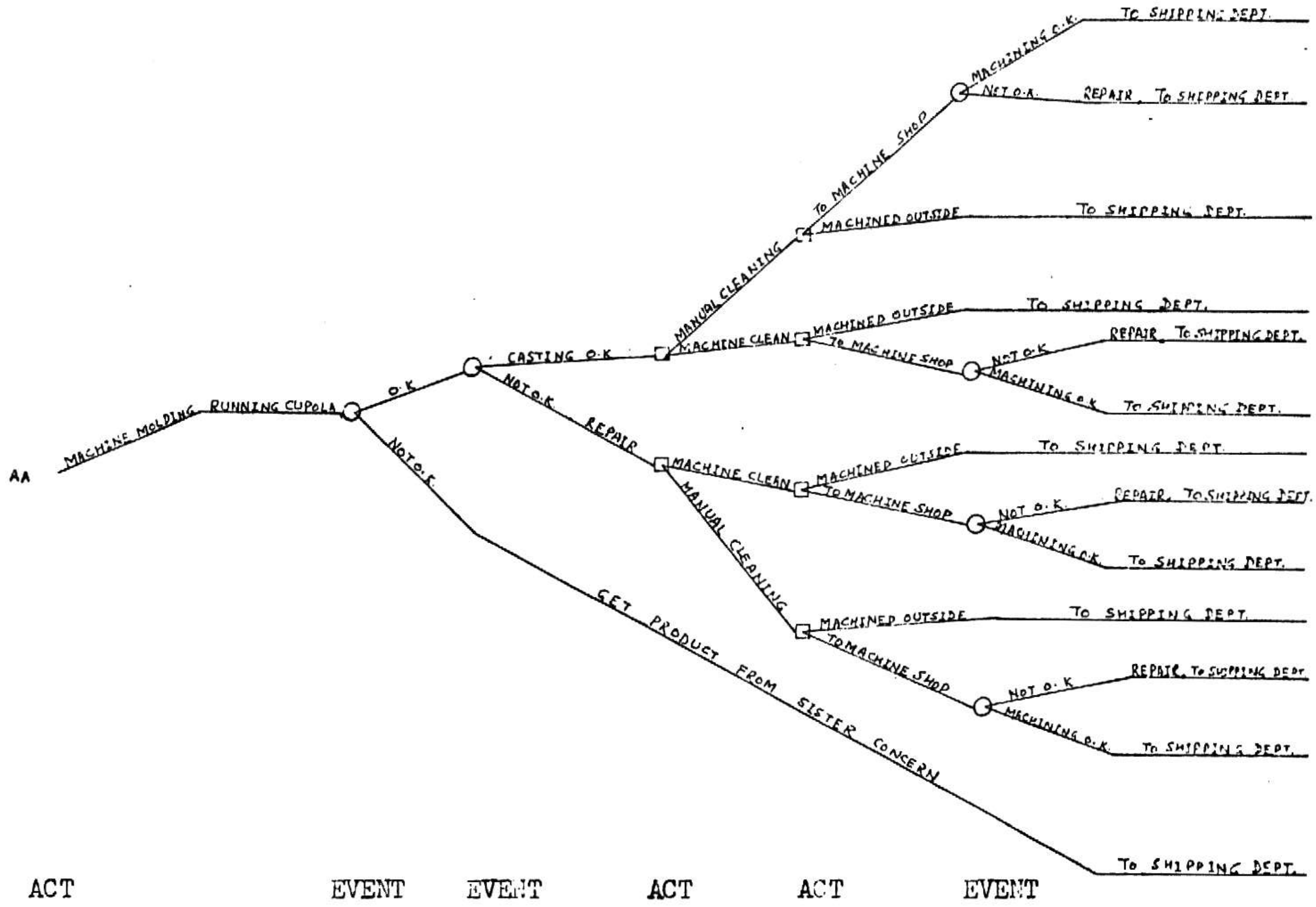

FIGURE 6.1b -Tree Diagram With Possible Acts and Events.

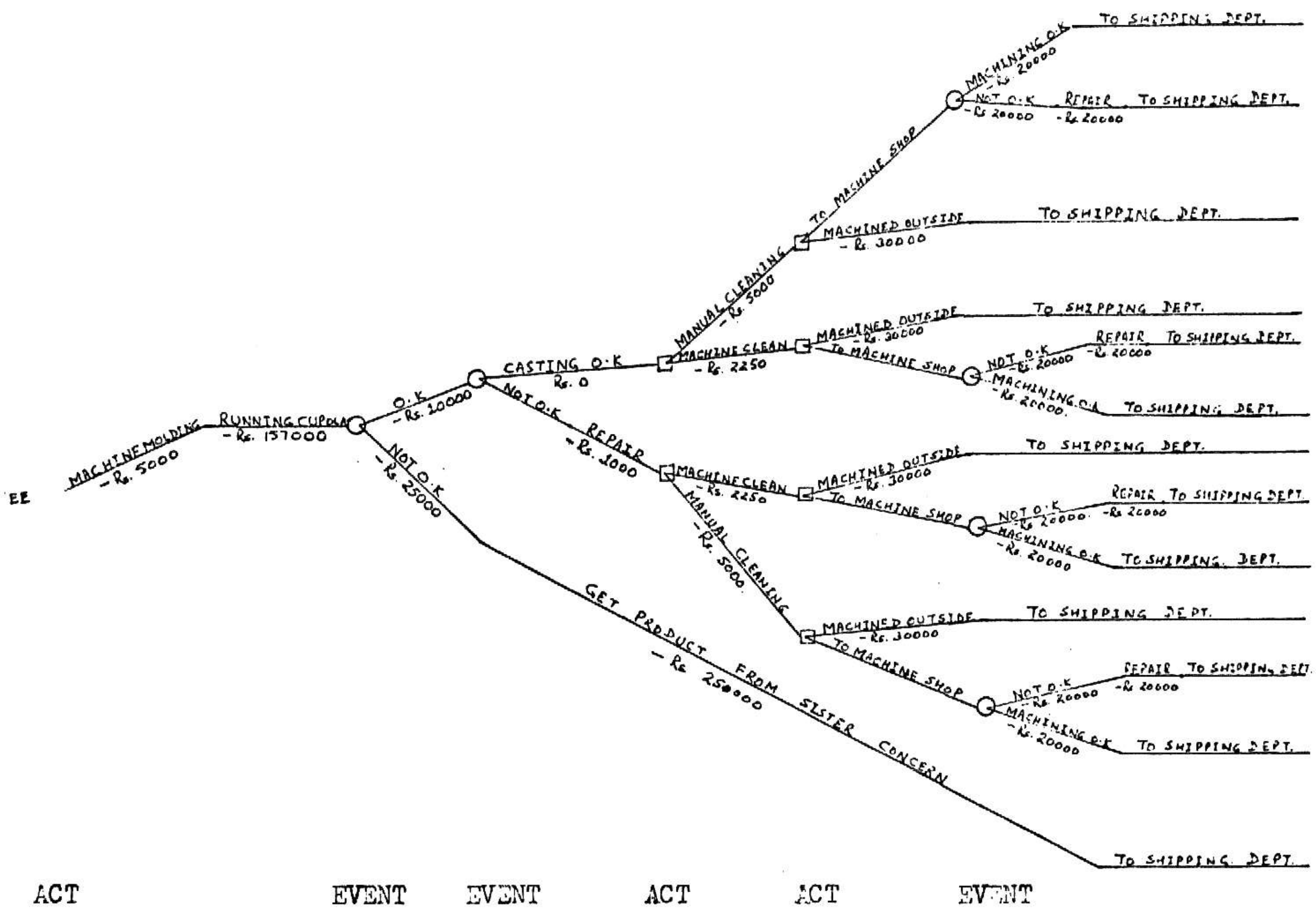

FIGURE 6.2b -Tree Diagram With Partial Cash Flows due to Individual Acts and Events.

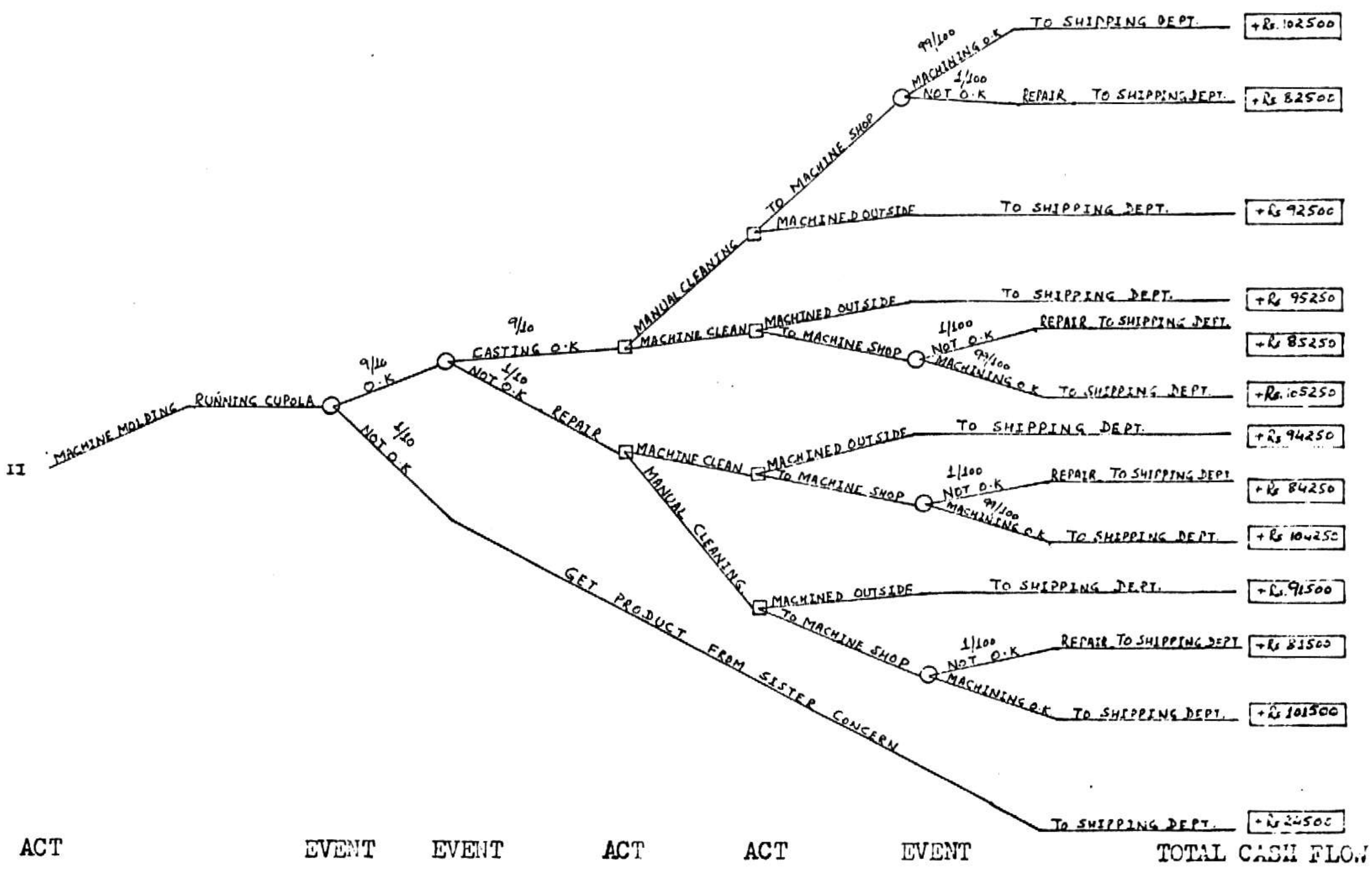

FIGURE 6.3b -Tree Diagram With Total Cash Flows due to Act-Event Sequences.

The numbers on Nodes M1, M2, M3, M4, CM and RM in Figure 6.4b in small boxes are calculated as follows:

Node M1:

Expected payoff = 99/100x102500+1/100x82500.

= 101475.+825.

= 102300.

Node M2:

Expected payoff = 99/100x105250+1/100x82250.

= 104197.5+822.5

= 105020.

Node M3:

Expected payoff = 99/100x104250+1/100x84250.

= 103207.5+842.5

= 104050.

Node M4:

Expected payoff = 99/100x101500+1/100x81500.

= 100485.+815.

= 101300.

Node CM:

Expected payoff = 9/10x105020+1/10x104050.

= 94518.+10405.

= 104923.

Node RM:

Expected payoff = 9/10x104923+1/10x24500.

= 94430.7+2450.

= 96880.7

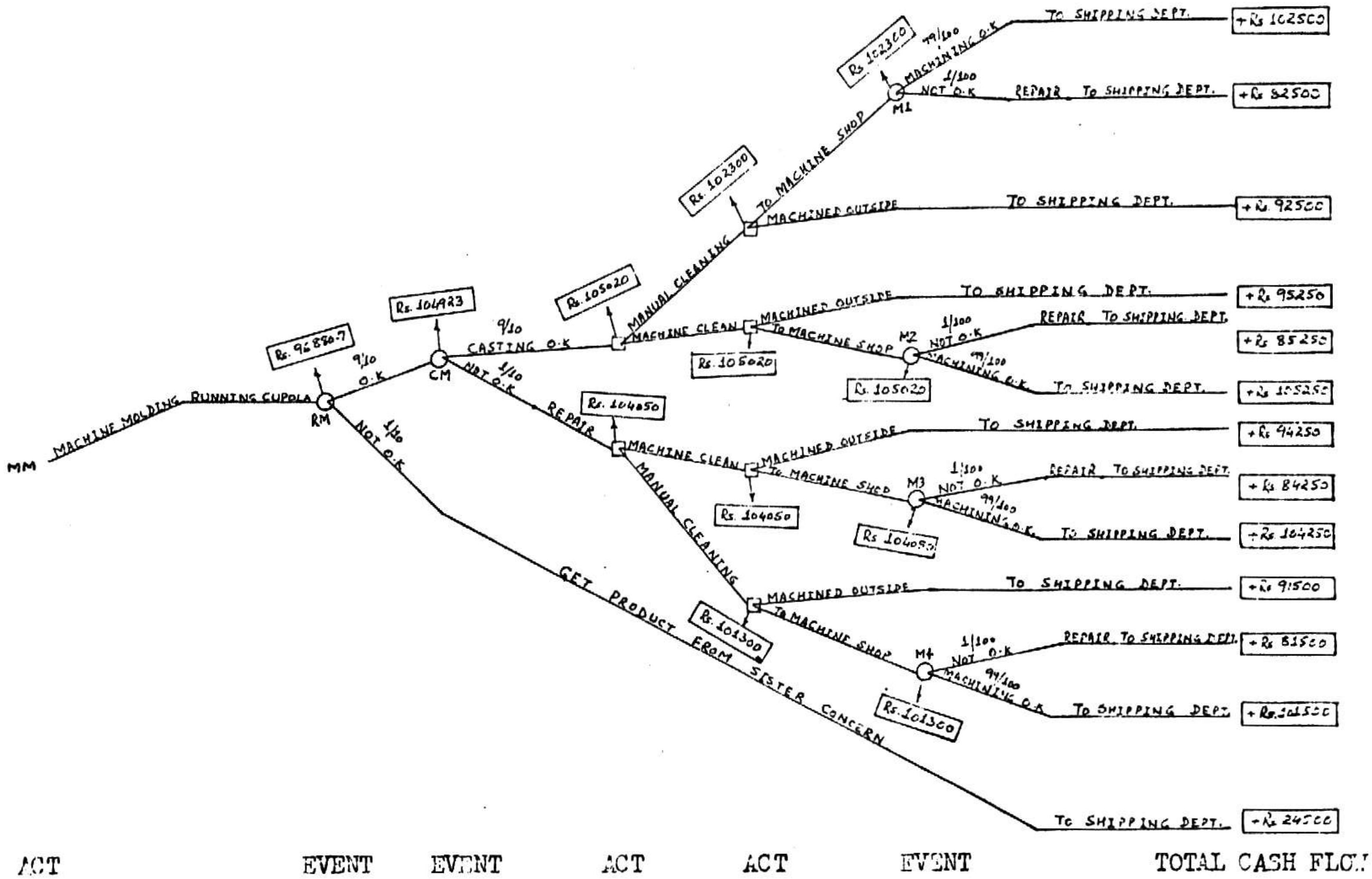

FIGURE 6.4b -Tree Diagram With Final Description.

Alternative A2

As was mentioned earlier, sometimes additional machining operation may have to be carried out to put the flywheels in the final form. Mr. Khanna assumed a hypothetical case that there is fifty percent possibility that the entire lot of flywheels will be in final form with the Gupta Supplier Company. If they are not in the final form, there are two possibilities. One half of the lot will be in the final form and other half will require additional machining to meet the customer's specifications. The cost for enlarging the bore (additional machining), would be one rupee per wheel on the average, according to the machine shop foreman. If the machining operation (enlarging bore) was not satisfactory, repair costs would amount to one hundred and fifty rupees for two hundred and fifty units.

The numbers at Node S1, S2 in Figure 6.4c are calculated as follows:

Node S1:

Expected payoff = 99/100x47000+1/100x45500

= 46530.+455.

= 46985.

Node S2:

Expected payoff = 1/2x49500.+1/2x46985.

= 24750.+23492.50

= 48242.50

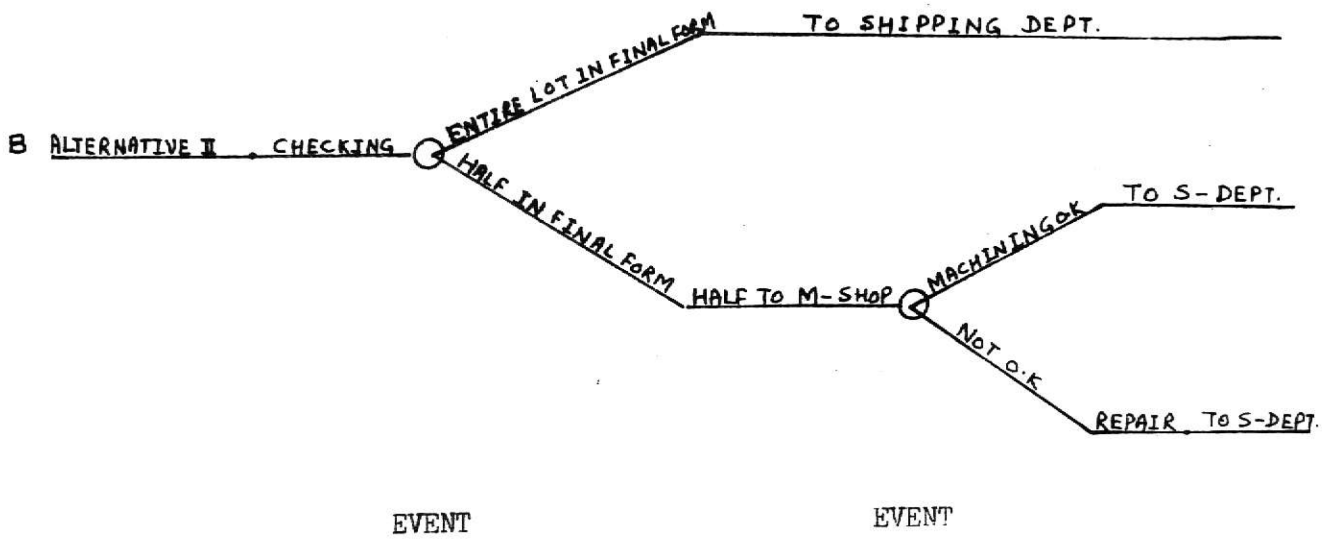

FIGURE 6.1c -Tree Diagram With Possible Acts and Events.

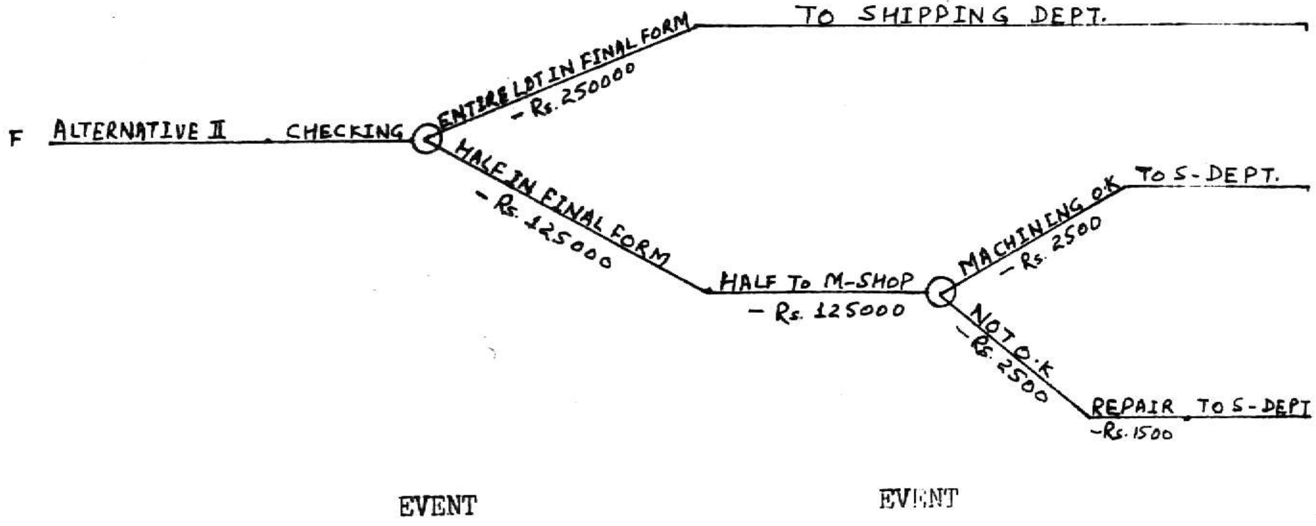

FIGURE 6.2c -Tree Diagram With Partial Cash Flows due to Individual Acts and Events.

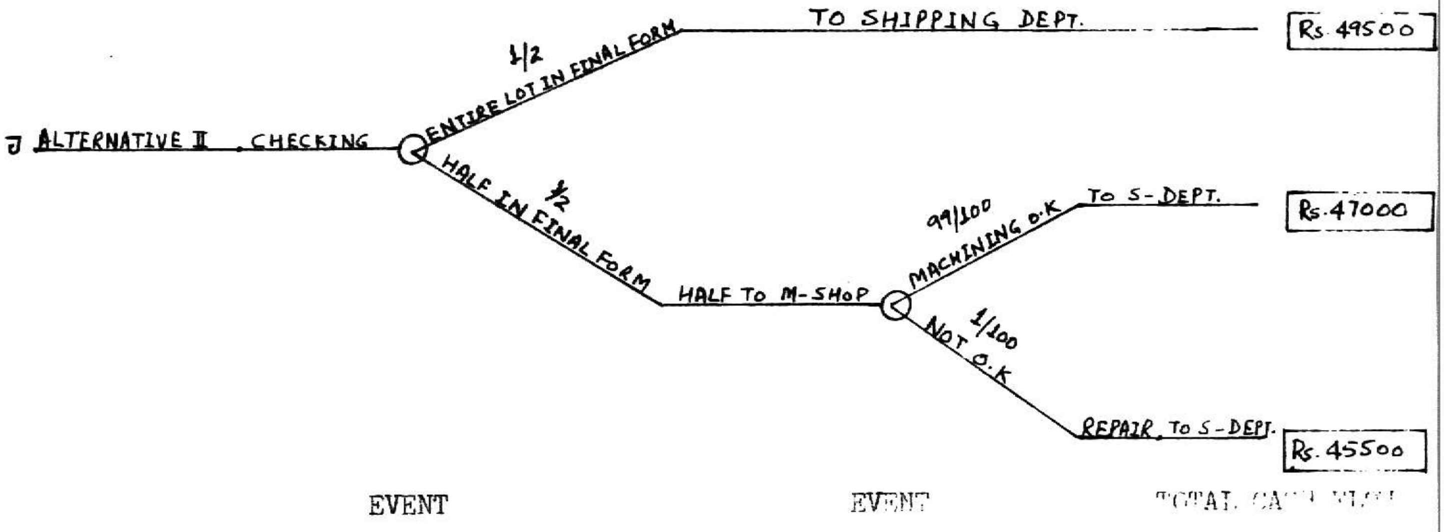

FIGURE 6.3c -Tree Diagram With Total Cash Flows due to Act-Event Sequence.

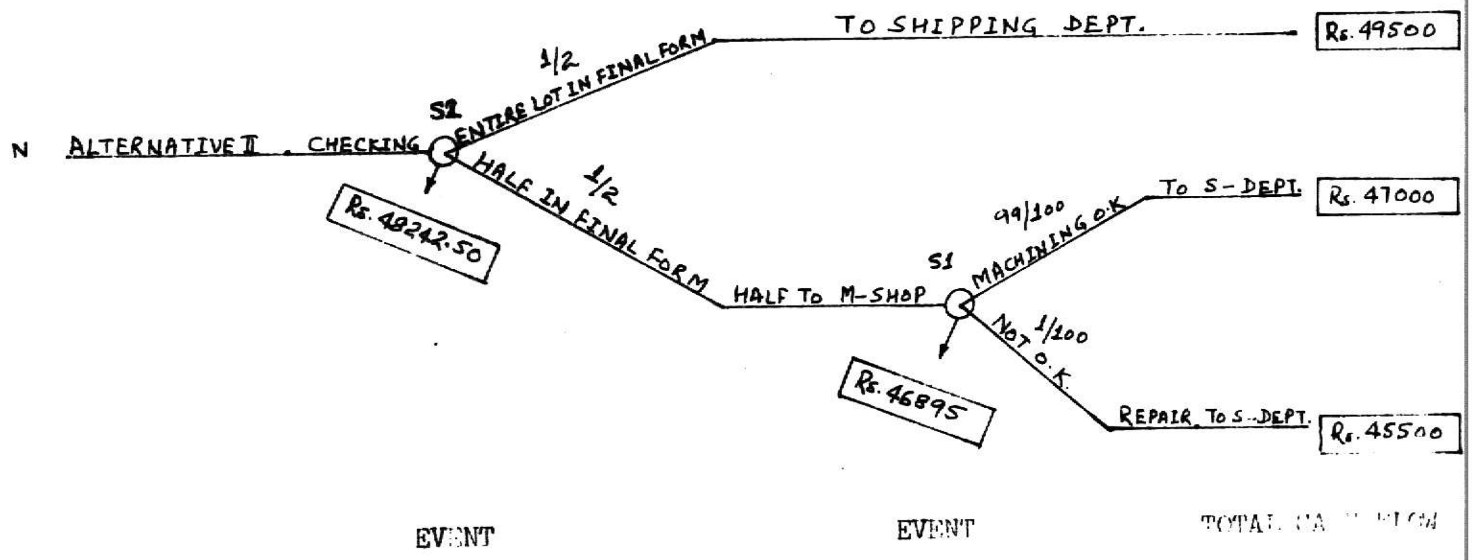

FIGURE 6.4c -Tree Diagram With Final Description.

<u>Alternative A3</u>

This alternative is a mixture of the first two alternatives. Mr. Khanna considered the hypothetical case that fifty percent of the lot would be supplied through the Gupta Supplier Company and the rest would be manufactured in the plant itself. For example, if Gupta Manufacturing Company lags behind by two weeks schedule, it would mean that one thousand units would have to be received from Gupta Supplier Company. The hypothetical case was taken because the future cannot be predicted correctly. The numbers on the branches M and S of Figure 6.2d are taken from first two alternatives. Because the expected payoff for manufacturing was Rs.96880.70 (Node RM, Figure 6.4b), for half of lot the expected payoff would be Rs.48440.35 as indicated on branch M. Similarly if the order was supplied through Gupta Supplier Company the expected payoff for the entire lot was Rs. 48242.50. Therefore for half of lot it would be Rs.24121.25, as mentioned on the branch S.

The figure on Node MI in Figure 6.4d is obtained as follows:

Node MI:

$$\text{Expected payoff} = 24121.25+48440.35$$
$$= 72561.55$$

C ALTERNATIVE III 50% LOT FROM SISTER CONCERN 50% IS TO BE MANUFACTURED

FIGURE 6.1d -Tree Diagram With Possible Acts and Events.

S M

G ALTERNATIVE III 50% LOT FROM SISTER CONCERN 50% IS TO BE MANUFACTURED

Rs. 24121.25 Rs. 48440.35

FIGURE 6.2d -Tree Diagram With Partial Cash Flows due to Individual Acts and Events.

K ALTERNATIVE III 50% LOT FROM SISTER CONCERN 50% IS TO BE MANUFACTURED Rs. 72561.55

FIGURE 6.3d -Tree Diagram With Total Cash Flow due to Act-Event Sequences.

MI

O ALTERNATIVE III 50% LOT FROM SISTER CONCERN 50% IS TO BE MANUFACTURED Rs. 72561.55

Rs. 72561.55

FIGURE 6.4d -Tree Diagram With Final Description.

6.3 SOLUTION TO SUBSIDIARY PROBLEM S1

Mr. Khanna was faced with the two alternatives offered by the works manager, as already stated (A2(1), A2(2)). Before giving any solution for this problem, Mr. Khanna asked the works manager to explain how production lag could occur. Here is the explanation given by the works manager:

The production lag would occur in case there is something wrong with the cupola operation. In that case the weekly production of five hundred wheels would not be met. Another reason for a production lag could be that the cupola operation is satisfactory but an excessive number of castings are too defective to repair, resulting in the waste of that part of weekly production. In order to offset this backlog, Gupta Manufacturing Company would need to supply the deficit from some other source in order to meet the production schedule. With this information Mr. Khanna, finalized the scheme to be adopted (based on the inventory policy and discount offered by Gupta Supplier Company):

Wait until the end of the seventh week and let the production lag accumulate. Then place the order with Gupta Supplier Company in the beginning of the eighth week. This decision was based on the information provided by the president of the Gupta Supplier Company, that a period of two weeks would be needed to execute an order of two thousand and five hundred units and a period of four weeks for an order of five thousand units. This period would also cover the machining time if necessary. By this procedure the privilege of taking advantage of the discount policy could also be utilized. In case something goes wrong after the eighth week, the order for backlog will be placed the moment production lags behind schedule.

6.4 SOLUTION TO SUBSIDIARY PROBLEM S2

As there was not enough information for this subsidiary problem, Mr. Khanna asked the president, Mr. Gupta, to get information from the machinery manufacturer. Two days later, Mr. Gupta supplied the following information:

A time of four weeks would be required for the installation of machines on the customer's premises. The terms for cancellation were as follows:

> If the machinery order was to be cancelled, it must be done one week before the expiration of order period (at the start of the fourth week) with a penalty which was fifteen percent of price of machine. If the machinery order was to be cancelled at the end of the fourth week (order period), the penalty would be thirty percent of price of machine.

The solution for this problem put forward by Mr. Khanna was as follows: As soon as Gupta Manufacturing Company decided to make the prototype, place the machinery order (since there was not sufficient machinery in the existing plant to manufacture the entire lot), keeping in mind the terms mentioned by machine manufacturer. The submission period of the prototype was fifteen working days (three weeks) and so by the end of this period, there would be enough machinery to start manufacturing the order. Since the first operation was molding, the molding machine would be requested first. After castings were obtained in sound condition, the next operation was machining, for which lathes were required. The lathes could be fixed even at the end of the first week after the manufacturing started, because the castings would be ready only at the end of the first week as mentioned in Section 4.4.

Now Mr. Khanna explained that if the machinery was going to be installed, overhead costs also ought to be considered since it would effect the profit (lower the profit). The rate of overhead varies according to the type of work, so different overhead rates were suggested by the general manager of Gupta Manufacturing Company (like sixty percent, seventy-five percent, hundred percent of labor) to cover the expenses for office clerks, machine depreciation etc.

The labor cost per wheel from different operations (for example: cupola running, molding, cleaning, machining, etc.) was mentioned earlier by the department heads as follows:

labor cost for making mold ------------------------Rs.1.00

labor cost for running cupola ---------------------Rs.2.00

labor cost for cleaning ---------------------------Rs.0.45

labor cost for machining --------------------------Rs.4.00

Total labor cost per wheel -------------------Rs.7.45

For different overhead, the profit varies as shown in Table 10. The expected payoff from manufacturing with machine molding neglecting overhead cost is Rs.96880.7 (node RM, Figure 6.4b). Therefore Net profit = Expected payoff - overhead.

As seen in Table 10, with any of the three different overhead rates, the profit for the Kapoor venture exceeds the profit from the other business. So the decision would be to build the prototype and start manufacturing as soon as the order is received.

TABLE 10. DIFFERENT OVERHEAD RATES AND NET PROFIT

Overhead Rate in Percent	Overhead per Wheel	Overhead for 5000 Wheels	Net Profit
60	Rs.4.47	Rs.22350	Rs.74530.7
75	Rs.5.58	Rs.27900	Rs.68980.7
100	Rs.7.65	Rs.37250	Rs.59630.7

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REFERENCES

1. Archer, Stephen H.,"A Setting For Information and Decisions", The Acadamy of Management Journal, VII, 269-287, Dec., 1964.

2. Chernoff, H., and Lincoln E. Moses, Elementary Decision Theory, John Wiley and Sons Inc., New York, 1959.

3. Drucker, P., "How to Make a Business Decision", Nation's Business - The Chamber of Commerce of the United States, April, 1956.

4. Greenwood, W. T., "Decision Making: Theory and Practice", Management and Organizational Behavior Theory, 283-285, 1965.

5. Greenwood, W. T., Decision Theory and Information System, South Western Publishing Company, New Rochelle, New York, 1969.

6. Haywood, O. G., "The Estimate of the Situation", U. S. Military Doctrine Journal of the Operation Research Society of America, November 1954.

7. Jedamus, P., and Robert Frame, Business Decision Theory, McGraw Hill Book Company, New York, 1969.

8. Kahr, A. S., and S. I. Buchin, Rositex Company, ICH 12C19, Intercollegiate Case Clearing House, Harvard Business School, Boston, Massachusetts, 1964.

9. Klee, Albert J., and George A. Garland, "Decision Tree in Solid Wastes Planning", Public Works, July, 1968.

10. Martino, R. L., and Elinor Svendsen Stein, Decision Patterns, MDI Publications, Wayne, Pennsylvania, 1969.

11. Raiffa, Howard, Decision Analysis, Addison Wesley Publishing Company, Inc. Massachusetts, 1970.

12. Rappaport, Alfred, Information for Decision Making, Prentice Hall, Inc., Englewood Cliffs, New Jersey, 1970.

13. Sasaki, Kyohei, Statistics for Modern Business Decision Making, Wadsworth Publishing Company, Inc., Belmont, California, 1968.

14. Schlaifer, Robert, Analysis of Decision Under Uncertainty, McGraw-Hill Book Company, New York, 1969.

15. Wasserman, P., and Fred S. Silander, Decision Making -- An Annotated Bibliography, Graduate School of Business and Public Administration, Cornell University, Ithaca, New York, 1964.

16. Class Notes, Advanced Topics in Operations Research, Industrial Engineering Department, Spring Semester, 1971.

APPLICATION OF THE PRINCIPLES OF DECISION UNDER RISK TO A CASE STUDY

by

VINOD KUMAR GUPTA

B. S. (Production Engineering, Condensed Course)

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ABSTRACT

The purpose of this report is the construction of a case study example for the course Applied Decision Theory taught in the Industrial Engineering Department, describing how business decisions are made under risk. The problem presented here concerns manufacturing flywheels under different situations. An order for five thousand flywheels by the Kapoor Company was put in the open market. Any manufacturer may succeed in getting the order on approval of the prototype unit. Gupta Manufacturing Company analyzed the problem in order to decide whether to bid on the order. The production engineer of Gupta Manufacturing Company gave three alternatives for execution of the order:

1. Start manufacturing of the flywheels in the company itself.
2. Have a sister concern (Gupta Supplier Company) execute the entire order.
3. Manufacture part of the order in the company and supply the remaining through the Gupta Supplier Company.

A bueiness decision making consultant named Vinoo Khanna was asked to study the problem and give his comments. He used the extensive form of the generalized procedure for decision making under risk which is:

1. Chart the decision process diagram in the form of a tree diagram.
2. Assign payoffs (utilities) at the tips of the branches of the tree.
3. Assign probability at all chance form.
4. Average out and fold back.

Keeping in mind the criterion (maximize profit) for selection of an

alternative, Mr. Khanna suggested that Gupta Manufacturing Company build the prototype and start manufacturing if the prototype is approved.