

# Assignment 1: Printed circuits

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## Assignment

### Introduction

*MC Manufacturing* has contracted to provide *DISCO Electronics* with printed circuit (“PC”) boards under the following terms: (1) 100,000 PC boards will be delivered to DISCO in one month, and (2) DISCO has an option to take delivery of an additional 100,000 boards in three months by giving Aba 30 days notice. DISCO will pay \$5.00 for each board that it purchases. MC manufactures the PC boards using a batch process, and manufacturing costs are as follows: (1) there is a fixed setup cost of \$250,000 for any manufacturing batch run, regardless of the size of the run, and (2) there is a marginal manufacturing cost of \$2.00 per board regardless of the size of the batch run. MC must decide whether to manufacture all 200,000 PC boards now or whether to only manufacture 100,000 now and manufacture the other 100,000 boards only if DISCO exercises its option to buy those boards. If MC manufactures 200,000 now and DISCO does not exercise its option, then the manufacturing cost of the extra 100,000 boards will be totally lost. MC believes there is a 50% chance DISCO will exercise its option to buy the additional 100,000 PC boards.

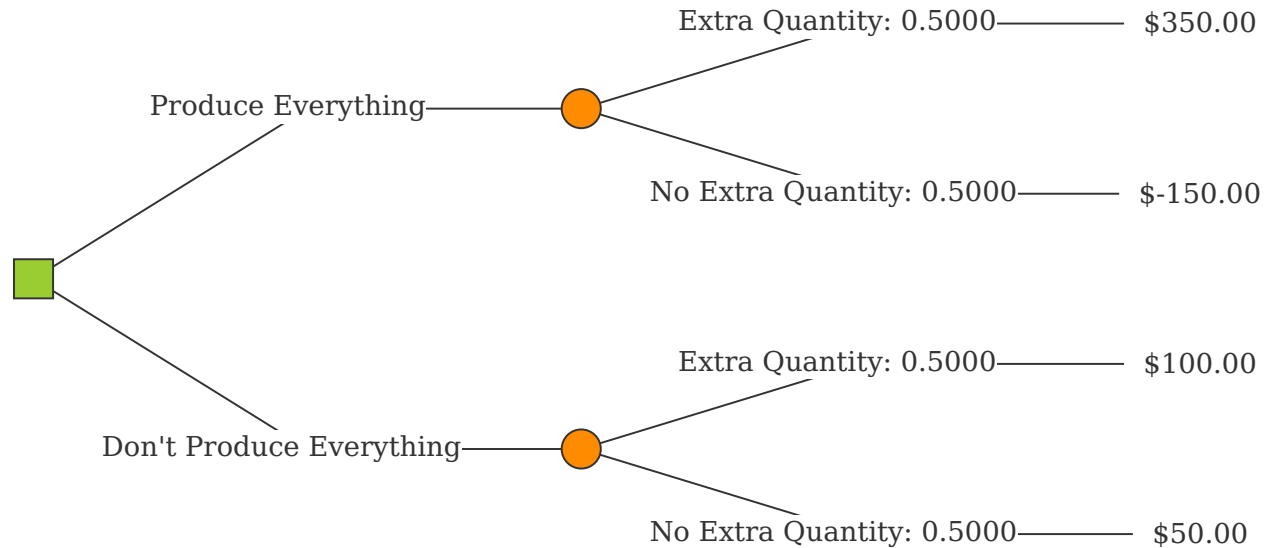
### The decision tree

- Draw a decision tree for the decision that MC faces.

```
library(yaml)
library(radiant)
library(radiant.model)
```

## Solution

```
tree = yaml.load_file(input = "./Board_Production.yaml")  
result = dtree(yl = tree)  
plot(result, final = FALSE)
```



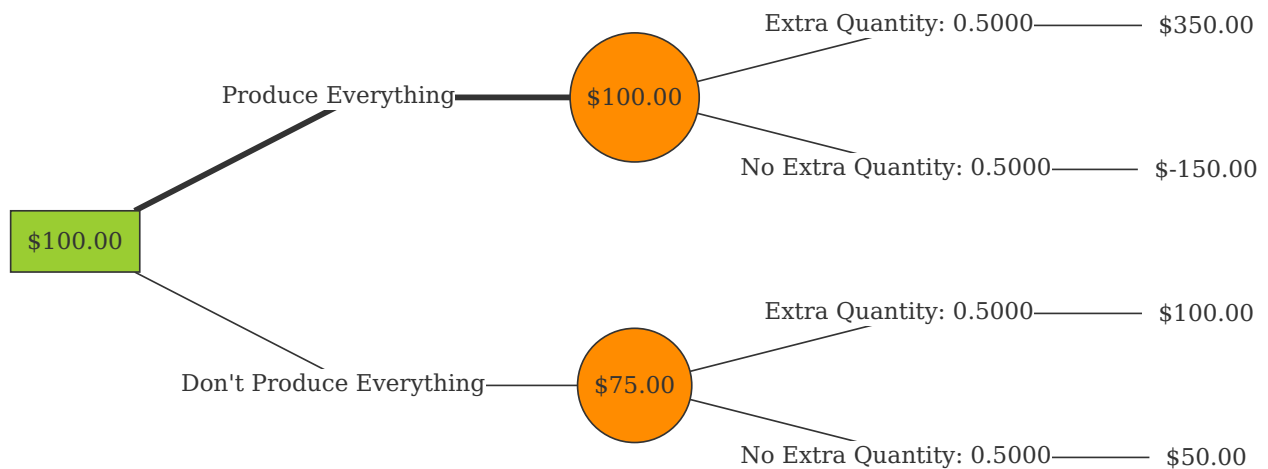
In the Decision Tree initially *MC Manufacturing* need to choose either to produce the whole batch of 200,000 pieces together or to do it in two different moments, each time *MC Manufacturing* starts the batch production procedure, as mentioned in the introduction, *MC Manufacturing* pays \$250,000, *MC Manufacturing* does not know if *DISCO Electronics* will buy the second batch, but *MC Manufacturing* knows its the probability. Also we assume that *MC Manufacturing* does not have an option to produce 0 quantity since in introduction we have that the contract has already been made. In the decision tree above we can see the initial choice to produce everything or not to produce everything and wait for the decision of *DISCO Electronics*, in both branches we have a chance node to indicate possibility that *DISCO Electronics* will ask for another 100,000 PC boards or not. We choose to scale the values by 1,000 to have smaller number during the calculations, so a profit of \$350 indicates a profit of \$350,000. One thing we note immediately is that the alternative to produce everything together avoids the setup cost of \$250,000 twice but at the same moment it is the most risky one, since we have 50% probability to have a loss of \$150,000.

## Expected value

- Determine the preferred course of action for MC assuming it uses expected profit as its decision criterion.

## Solution

```
plot(result, final = TRUE)
```



From the decision tree we can see that the preferred course of action is to produce the two batches together since it has an expected value of \$100,000 against \$75,000 of the other branch in which *MC Manufacturing* produces the two batch separately.

## Utility Function and Certainty Equivalent

Assume that all the information still holds, except assume now that MC has an exponential utility function with a risk tolerance of \$100,000.

We start by defining the functions that will be needed for the solution.

```

utilityFunctionExp <- function(X, R) {
  return(1- exp(-X/R))
}

CertEquivalent <- function(EU, R){
  return(-R*ln(1-EU))
}

CalcExpectedUtilityFunction <- function(profit, R){
  #-----Branch 1-----#
  UF1 <- utilityFunctionExp(profit$profitBranch1, R)
  EU1 <- UF1[1]*0.5 + UF1[2]*0.5 #Expected Utility Branch 1

  #-----Branch 2-----#
  UF2 <- utilityFunctionExp(profit$profitBranch2, R)
  EU2 <- UF2[1]*0.5 + UF2[2]*0.5 #Expected Utility Branch 2

  #----Return Final Result----#
  return(c(EU1, EU2))
}

CalcBranchCE <- function(profit, R){
  CE_vett <- CertEquivalent(CalcExpectedUtilityFunction(profit, R), R)
  return(CE_vett)
}

#Create a DataFrame with Profits per Branch

```

```

index <- 1:2
profitBranch1 <- c(350,-150)
profitBranch2 <- c(100,50)
profit <- data.frame("X"=index,"profitBranch1"=profitBranch1,"profitBranch2"=profitBranch2)
R=100 #Remeber we scaled everything by 1000, so the R goes from 100,000 to 100

```

- Determine MC's preferred course of action.

## Solution

```

CE <- CalcBranchCE(profit,R)

CE_Branch1 <- CE[1]*1000
CE_Branch2 <- CE[2]*1000
cat(paste0('Certainty Equivalent of Branch of producing eveything together: ',CE_Branch1),
    paste0('Certainty Equivalent of Branch of producing separately: ',CE_Branch2),
    'NOTE: The values are re-scaled to the right scale.',
    '*****',sep='\n')

```

```

Certainty Equivalent of Branch of producing eveything together: -81356.8167929173
Certainty Equivalent of Branch of producing separately: 71907.0196379839
NOTE: The values are re-scaled to the right scale.
*****

```

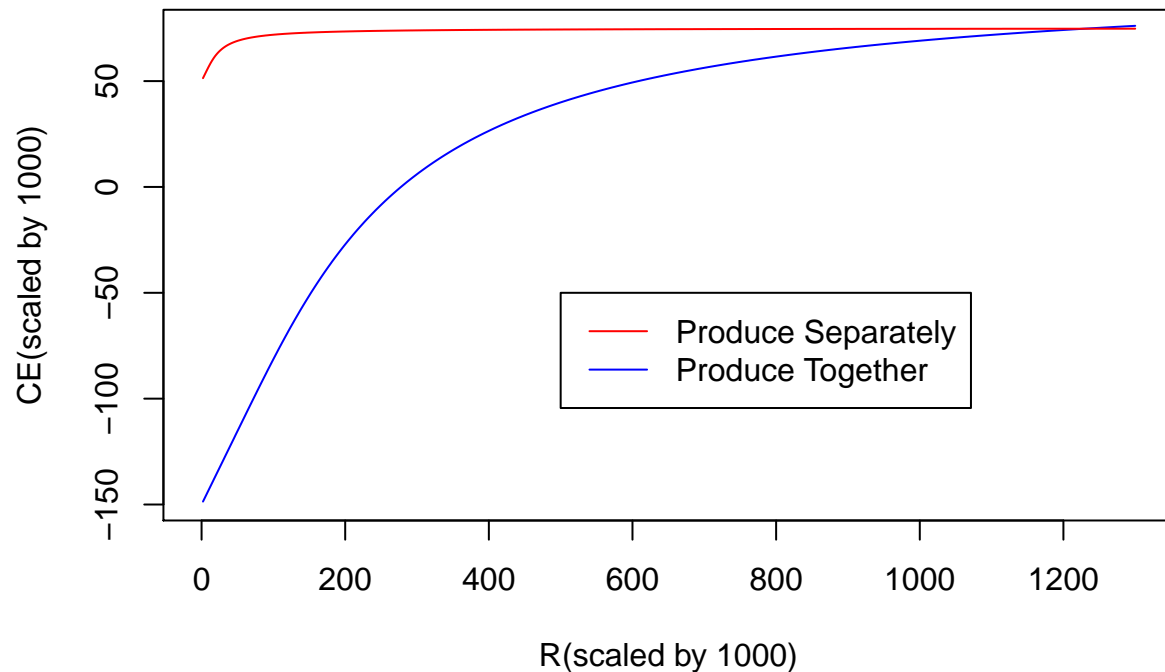
We can see that the preferred course is now the Branch in which we wait before producing the other batch. We have that the Certainty Equivalent in this case is \$71907, which is smaller than the expected value thus in this case *MC Manufacturing* is risk averse.

Since the difference between the Certainty Equivalent of the two branches is so high, we can say that for a large neighborhood (interval of a value) of  $R = 100,000$  we will have that the preferred branch will be the one in which we wait to produce the other batch. Actually from the plot below we have that the preferred choice is to wait before producing everything until a very big value of  $R$  (between 1,100,000 and 1,300,000). This change of preference is there since for large  $R$  we become more risk seeking.

```

R = seq(2, 1300, 1)
res1 = c()
res2 = c()
for (i in 1:length(R)) {
  vRes = CalcBranchCE(profit, R[i])
  res1[i] = vRes[1]
  res2[i] = vRes[2]
}
plot(R, res1, type="l", col="blue", ylab="CE(scaled by 1000)", xlab = "R(scaled by 1000)",
     xlim=c(-1, max(R)+1), ylim=c(min(res1), max(res2)))
points (R, res2, type="l", col="red")
legend(500,-50,legend=c('Produce Separately','Produce Together'),col=c("red", "blue"), lty=1)

```



## Modification of the process

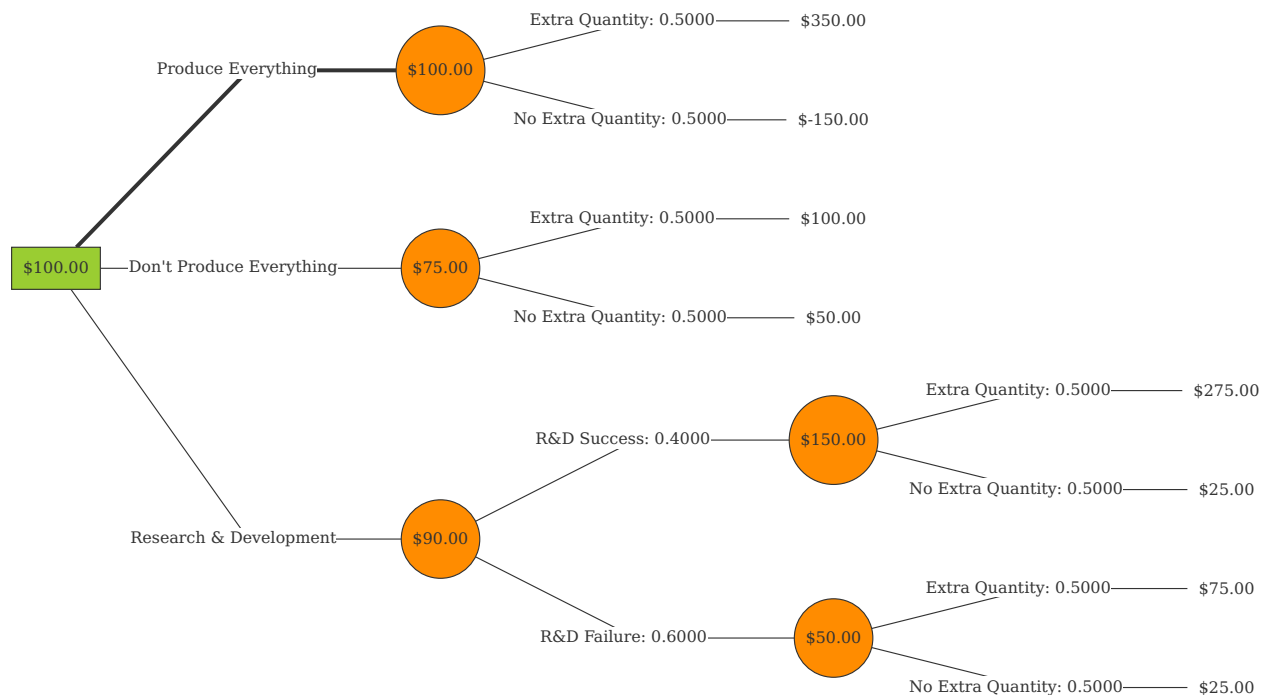
For the decision in the preceding point, MC Manufacturing has created a new option: it can conduct some research and development in an attempt to lower the fixed setup cost associated with manufacturing a batch of the PC boards. This research and development would not be completed in time to influence the setup cost for the initial batch that DISCO has ordered, but would be completed before the second batch would have to be manufactured. The research and development will cost \$25,000, and there is a 0.4 probability that it will be successful. If it is successful, then the fixed setup cost per batch will be reduced by \$200,000 to \$50,000. If the research and development is not successful, then there will be no reduction in the setup cost. There will be no other benefits from the research and development besides the potential reduction in setup cost for the DISCO reorder.

- Using expected profit as the decision criterion, determine whether MC should undertake the research and development.

## Solution

```
tree_RnD = yaml.load_file(input = "./Board_Production_RnD.yaml")
result_RnD = dtree(y1 = tree_RnD)

plot(result_RnD, final = TRUE)
```



Since the R&D will not be completed before the first batch, it would not make any sense to research in case we choose to produce everything together, since it would only extra cost without any benefit for the company. So in case we undergo the R&D(Research and Development) process we will consider only the case we were to produce the two batch separately.

The R&D branch has an Expected Value of \$90,000 which is still lower than the Branch in which we have a production of everything together, so using the expected profit the preferred course is still Branch of producing everything together, thus *MC Manufacturing* should not undertake the R&D.

We decided to keep the two choices of Producing Separately (“Don’t Produce Everything”) and R&D separated, one could have equivalently created another decision node in the “Don’t Produce Everything” branch of either doing or not the R&D.

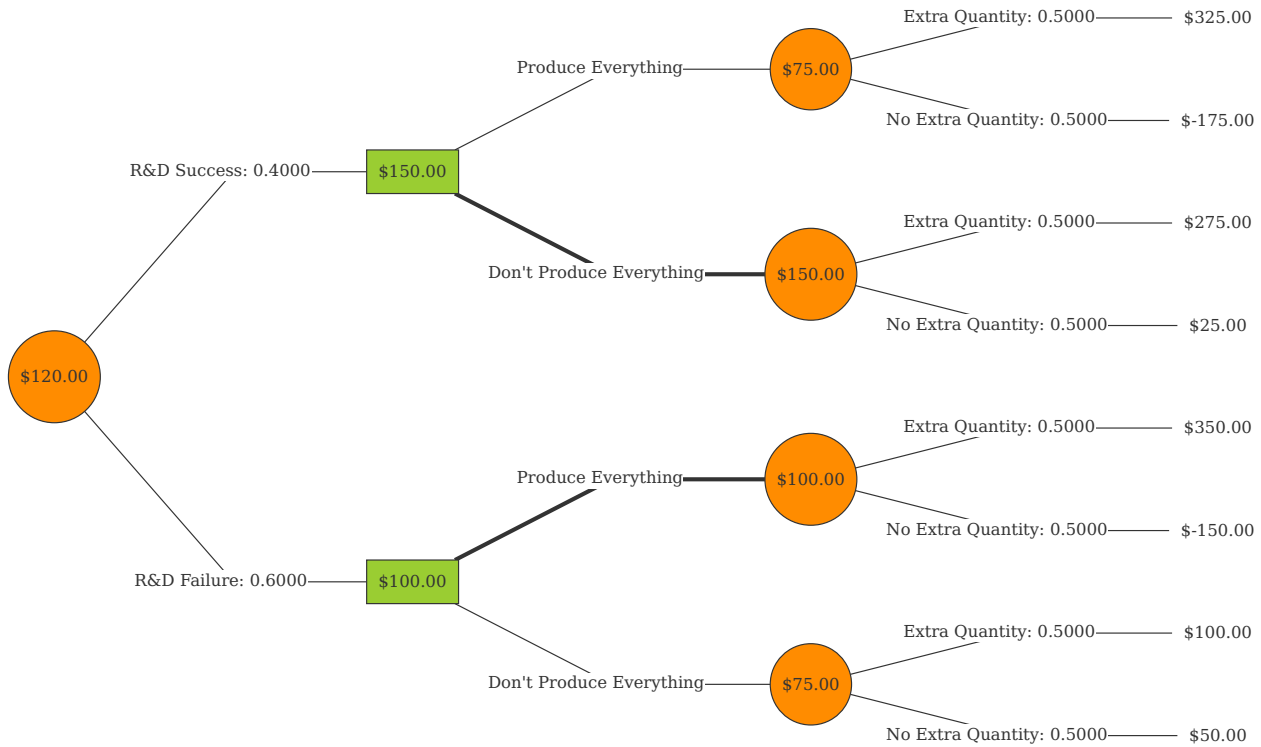
## Value of Information

Using expected profit as the decision criteria, determine the value of learning for certain whether the research and development will be successful before a decision has to be made about whether to initially manufacture 100,000 or 200,000 PC boards.

## Solution

```
tree_PI = yaml.load_file(input = "./Board_Production_PI.yaml")
result_PI = dtree(y1 = tree_PI)

plot(result_PI, final = TRUE)
```



Since we are asked to determine the value of learning for certain the information, we assume the information to be perfect, the Expected Value using this perfect information is \$120,000 while the best expected value without the information on the success of R&D was \$100,000, since the value of information using the expected profit is the difference between the two values, thus  $\$120,000 - \$100,000 = \$20,000$  is the value of such information.

We also have that in case of the failure of R&D, *MC Manufacturing* should decide to produce everything together, while in the case of a successful R&D *MC Manufacturing* should produce the two batches separately using as the measure expected value. In case of the success of R&D and after choosing to produce the two batch separately we have that with a probability of 50% that the second batch will not be needed, so the the research is useful only in one case among a total of 8 possible cases, which is an information that *MC Manufacturing* should take in consideration.

In the model here we decided to show all the possible alternative, for example in the case of failure of R&D it would not make any sense to Produce the boards separately since we already know from point 2 that the other branch is more convenient in this case using as measure the expected value. The choice was made so that, in case the company were to decide to bargain/change any of the provided cost or revenue, we could see it's repercussion on every branch. Another reason was the completeness of the structure.

## Appendix

Here we print the structure of the yaml file.

### Exercise 1 & 2

```
summary(result, input = FALSE, output = TRUE)
```

Variable input values:

setup cost	250.0
manufacture cost	200.0
unit_revenue	500.0
prob_extra	0.5
prob_not_extra	0.5
cost_toghether_extra	650.0
cost_toghether_not_extra	650.0
cost_not_together_extra	900.0
cost_not_together_not_extra	450.0
revenue_extra	1000.0
revenue_not_extra	500.0
payoff_toghether_extra	350.0
payoff_toghether_not_extra	-150.0
payoff_not_toghether_extra	100.0
payoff_not_toghether_not_extra	50.0

Initial decision tree:

	Probability	Payoff	Cost	Type
Board Production Decision				
--Produce Everything				decision
--Extra Quantity	50.00 %	350.00		chance
°--No Extra Quantity	50.00 %	-150.00		chance
°--Don't Produce Everything				decision
--Extra Quantity	50.00 %	100.00		chance
°--No Extra Quantity	50.00 %	50.00		chance

Final decision tree:

	Probability	Payoff	Cost	Type
Board Production Decision		100.00		
--Produce Everything		100.00		decision
--Extra Quantity	50.00 %	350.00		chance
°--No Extra Quantity	50.00 %	-150.00		chance
°--Don't Produce Everything		75.00		decision
--Extra Quantity	50.00 %	100.00		chance
°--No Extra Quantity	50.00 %	50.00		chance

### Exercise 4

```
summary(result_RnD, input = FALSE, output = TRUE)
```

Variable input values:



setup_cost	250.0
manufacture_cost	200.0
research_cost	25.0
setup_RnD_cost	50.0
unit_revenue	500.0
prob_extra	0.5
prob_not_extra	0.5
prob_RnD_success	0.4
prob_RnD_fail	0.6
cost_toghether_extra	650.0
cost_toghether_not_extra	650.0
cost_not_together_extra	900.0
cost_not_together_not_extra	450.0
revenue_extra	1000.0
revenue_not_extra	500.0
payoff_toghether_extra	350.0
payoff_toghether_not_extra	-150.0
payoff_not_toghether_extra	100.0
payoff_not_toghether_not_extra	50.0
cost_RnD_success_extra	725.0
cost_RnD_success_not_extra	475.0
cost_RnD_fail_extra	925.0
cost_RnD_fail_not_extra	475.0
payoff_RnD_success_extra	275.0
payoff_RnD_success_not_extra	25.0
payoff_RnD_fail_extra	75.0
payoff_RnD_fail_not_extra	25.0

Initial decision tree:

	Probability	Payoff	Cost	Type
Board Production Decision RnD				
--Produce Everything				decision
--Extra Quantity	50.00 %	350.00		chance
°--No Extra Quantity	50.00 %	-150.00		chance
--Don't Produce Everything				decision
--Extra Quantity	50.00 %	100.00		chance
°--No Extra Quantity	50.00 %	50.00		chance
°--Research & Development				decision
--R&D Success	40.00 %			chance
--Extra Quantity	50.00 %	275.00		chance
°--No Extra Quantity	50.00 %	25.00		chance
°--R&D Failure	60.00 %			chance
--Extra Quantity	50.00 %	75.00		chance
°--No Extra Quantity	50.00 %	25.00		chance

Final decision tree:

	Probability	Payoff	Cost	Type
Board Production Decision RnD				
--Produce Everything		100.00		
--Extra Quantity	50.00 %	350.00		chance
°--No Extra Quantity	50.00 %	-150.00		chance
--Don't Produce Everything		75.00		decision
--Extra Quantity	50.00 %	100.00		chance

	°--No Extra Quantity	50.00 %	50.00	chance
°--Research & Development			90.00	decision
	--R&D Success	40.00 %	150.00	chance
	--Extra Quantity	50.00 %	275.00	chance
	°--No Extra Quantity	50.00 %	25.00	chance
°--R&D Failure		60.00 %	50.00	chance
	--Extra Quantity	50.00 %	75.00	chance
	°--No Extra Quantity	50.00 %	25.00	chance

## Exercise 5

```
summary(result_PI, input = FALSE, output = TRUE)
```

Variable input values:

setup_cost	250.0
manufacture_cost	200.0
setup_RnD_cost	50.0
research_cost	25.0
unit_revenue	500.0
prob_extra	0.5
prob_not_extra	0.5
prob_RnD_success	0.4
prob_RnD_fail	0.6
revenue_extra	1000.0
revenue_not_extra	500.0
cost_success_toghether_extra	675.0
cost_success_toghether_not_extra	675.0
cost_success_not_toghether_extra	725.0
cost_success_not_toghether_not_extra	475.0
payoff_success_toghether_extra	325.0
payoff_success_toghether_not_extra	-175.0
payoff_success_not_toghether_extra	275.0
payoff_success_not_toghether_not_extra	25.0
cost_fail_toghether_extra	650.0
cost_fail_toghether_not_extra	650.0
cost_fail_not_toghether_extra	900.0
cost_fail_not_toghether_not_extra	450.0
payoff_fail_toghether_extra	350.0
payoff_fail_toghether_not_extra	-150.0
payoff_fail_not_toghether_extra	100.0
payoff_fail_not_toghether_not_extra	50.0

Initial decision tree:

	Probability	Payoff	Cost	Type
Board Production Decision RnD				
--R&D Success	40.00 %			chance
--Produce Everything				decision
--Extra Quantity	50.00 %	325.00		chance
°--No Extra Quantity	50.00 %	-175.00		chance
°--Don't Produce Everything				decision
--Extra Quantity	50.00 %	275.00		chance
°--No Extra Quantity	50.00 %	25.00		chance

°--R&D Failure	60.00 %		chance
--Produce Everything			decision
--Extra Quantity	50.00 %	350.00	chance
°--No Extra Quantity	50.00 %	-150.00	chance
°--Don't Produce Everything			decision
--Extra Quantity	50.00 %	100.00	chance
°--No Extra Quantity	50.00 %	50.00	chance

Final decision tree:

	Probability	Payoff	Cost	Type
Board Production Decision RnD		120.00		
--R&D Success	40.00 %	150.00		chance
--Produce Everything		75.00		decision
--Extra Quantity	50.00 %	325.00		chance
°--No Extra Quantity	50.00 %	-175.00		chance
°--Don't Produce Everything		150.00		decision
--Extra Quantity	50.00 %	275.00		chance
°--No Extra Quantity	50.00 %	25.00		chance
°--R&D Failure	60.00 %	100.00		chance
--Produce Everything		100.00		decision
--Extra Quantity	50.00 %	350.00		chance
°--No Extra Quantity	50.00 %	-150.00		chance
°--Don't Produce Everything		75.00		decision
--Extra Quantity	50.00 %	100.00		chance
°--No Extra Quantity	50.00 %	50.00		chance