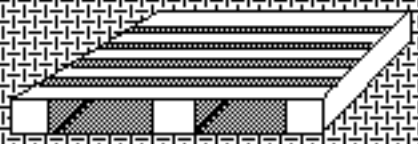
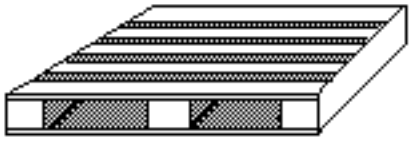
# Labatt Brewery



*based upon "Labatt's Breweries", in the book*
***Cases in Operations Research***
*by C.H. von Lanzenauer, published by Holden-Day, 1975.*



An analyst for Labatt's Ontario Breweries was faced with a question posed by the warehouse manager concerning the repair and replacement policy for pallets used in the shipment of beer.



Should the pallets be repaired when damaged, and if so, how often? This question always arose in early summer when the supply of pallets became tighter as a result of increased summer shipments.

Labatt's belongs to a pallet pool with the other breweries in Ontario and Quebec and their common retail outlets.

The pallets were used for shpments to the retail outlets from the breweries and for the return of empties. Each brewery shipped its products to many locations throughout both provinces. The use of a common bottle and pallet by breweries in Canada allowed the return of empties to any brewery.



New bottles, when shipped to the breweries from the glass manufacturers, were shipped on new pallets. The bill for the new pallets was included with the bill for the new bottles.

From time to time, additional pallets could be ordered by the individual breweries, if required. The number of new pallets purchased by each brewery was recorded, and at the end of each fiscal year, breweries that had purchased more than their share were compensated by those breweries that had purchased less than their share. (A brewery's share of new pallets to be purchased was determined by its share of the market.)

Damaged pallets were repaired by individual breweries if feasible. If a center block had been damaged, the pallet was not repaired.

When questioned, the foreman at Labatt's in charge of pallet repair said: "Pallets are damaged through abuse by the handlers." Often, in repairing a pallet, the new nails would split a center block which would necessitate scrapping of the pallet.

Approximately 10 percent of the damaged pallets were unrepairable.

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Average cost of a new pallet is $4.47
Average cost of repairing a pallet was $2.07

The foreman in charge of repairs considered those over 2 years old not worth repairing, and they were scrapped.

Labatt's current repair policy is to repair a damaged pallet only if the age is no more than two years.

$0.75 was the most ever received for damaged pallets, but the warehouse manager thought that as much as $1.50 might be obtained if the scrapped pallets were in a better condition.

# Average Damage Rates

| description | % damaged in year # one | two | three | four |
|---|---|---|---|---|
| New pallets | 22 | 45 | 33 | -- |
| Pallets repaired in year #1 | -- | 47 | 48 | 5 |
| Pallets repaired in year #2 | -- | -- | 83 | 17 |

*Using the damage rates, we will compute the transition probabilities*

Note that each row sums to 100%!



Current Policy

*pallets over two years old are scrapped when damaged*

*Consider the pallet to age 1 year on the last day of the year. Assume that the state of the system is observed on the last day of the year.*

***Possible states:***

1 New (less than one year old)
2 Age 1, never damaged
3 Age 2, never damaged
4 Age 1, repaired
5 Age 2, repaired second year (& possibly first)
6 Age 2, repaired first year only
7 Age 3

Rather than model a "typical" pallet, which has a limited lifetime (no more than 4 years), we will model a pallet AND its future replacements, so that when a pallet is scrapped, the state of the pallet returns to "New", i.e., the state of the replacement pallet.

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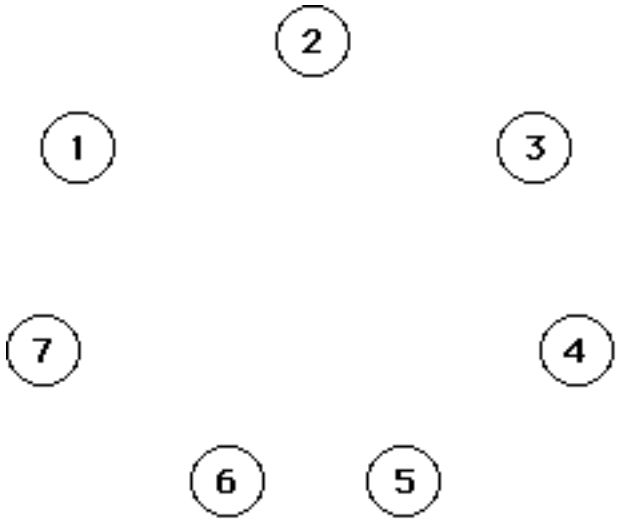
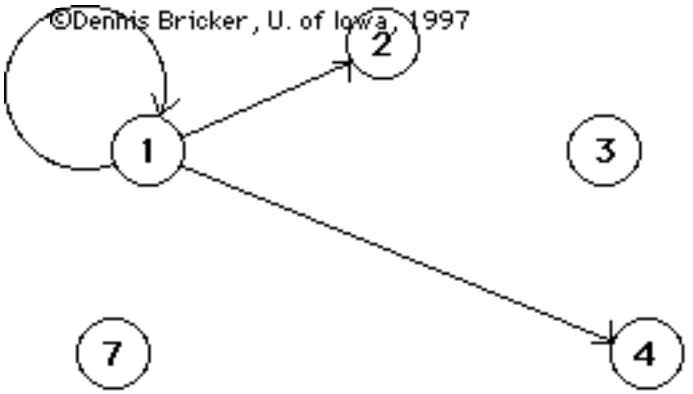



| | *states* |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

*What transitions are possible?*

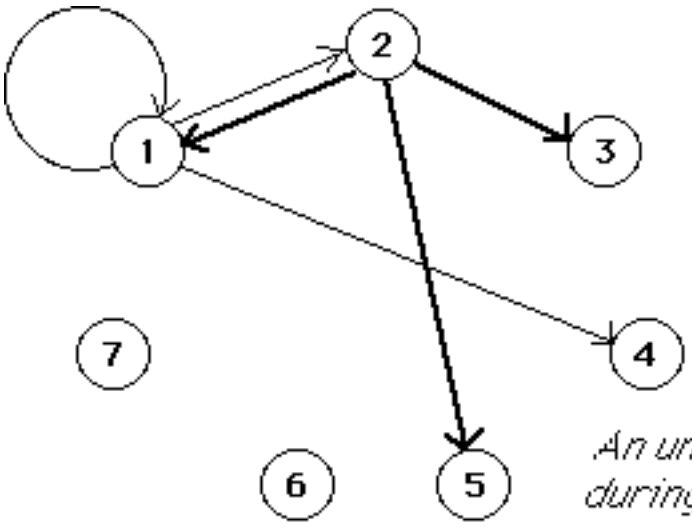



| | states |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |


*A pallet which is new may or may not be damaged during the next year:*

- *if damaged & repairable, it will next be in state 4*
- *if damaged & not repairable, it will be replaced by a new pallet*
- *if not damaged, it will next be in state 2*

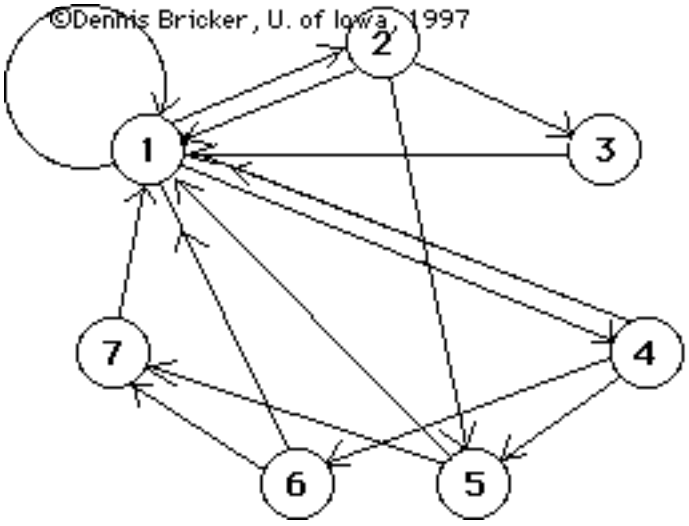





| | states |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

*An undamaged one-year old pallet, during the next year:*

- *if damaged & repairable, it will next be in state 5*
- *if damaged & not repairable, it will be replaced by a new pallet*
- *if not damaged, it will next be in state 3*




| | *states* |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

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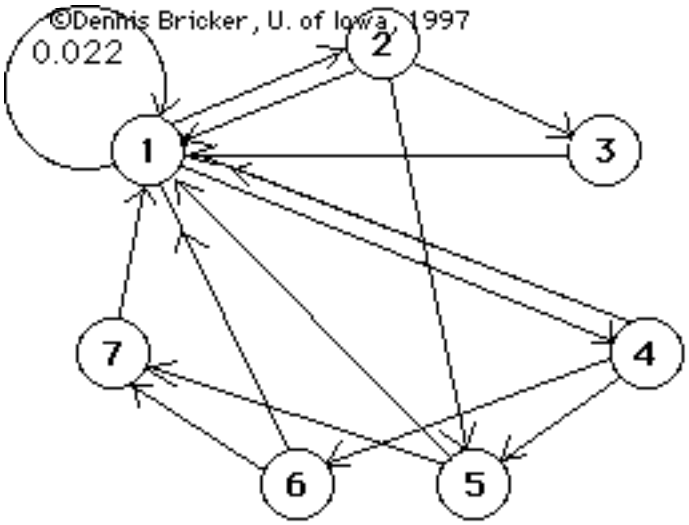
## *Average Damage Rates*

| *description* | *% damaged in year #* *one* | *two* | *three* | *four* |
|---|---|---|---|---|
| New pallets | 22 | 45 | 33 | -- |
| Pallets repaired in year #1 | -- | 47 | 48 | 5 |
| Pallets repaired in year #2 | -- | -- | 83 | 17 |

*Using the damage rates, we will compute the transition probabilities*

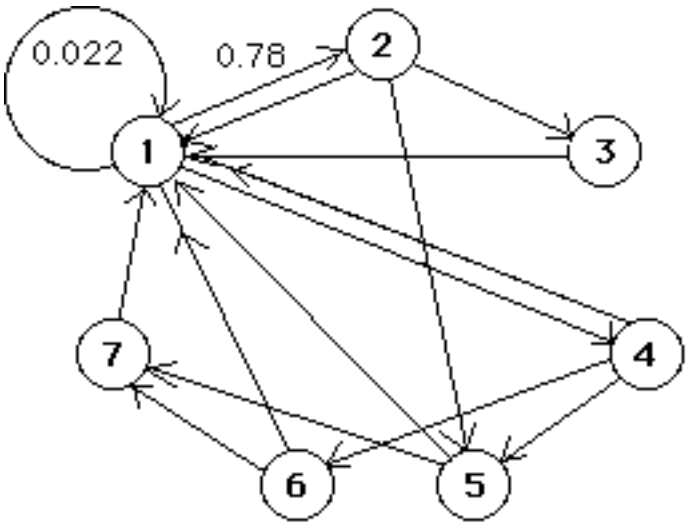



| | *states* |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

$p_{11}$ = probability that new pallet is damaged in first year, but is not repairable

= 0.22 x 0.10 = 0.022

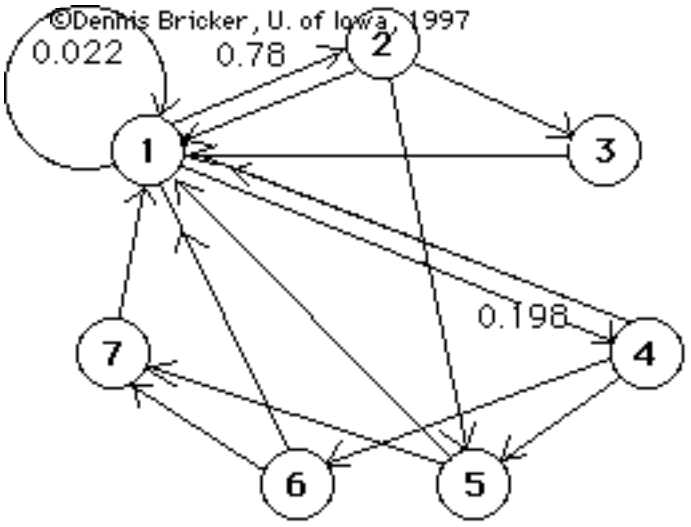





| | *states* |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

$p_{12}$ = probability that new pallet is not damaged in its first year

= 1 – 0.22 = 0.78

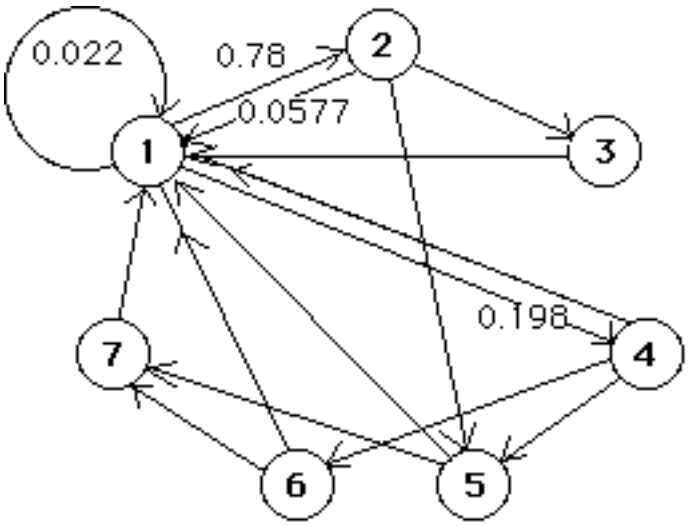



| | *states* |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

$p_{14}$ = probability that new pallet is damaged in its first year, and is repairable

= $0.22 \times 0.90 = 0.198$

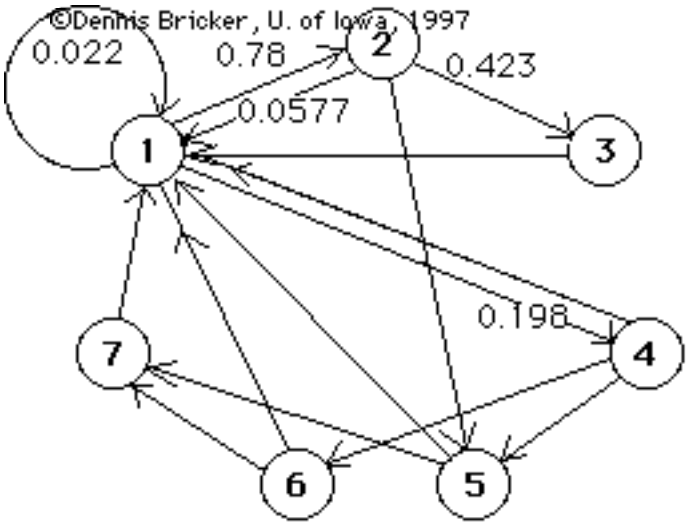





| | *states* |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

$p_{21}$ = probability that undamaged 1-yr-old pallet is damaged next year & is unrepairable

$= \frac{0.45}{1-0.22} \times 0.10 = 0.0577$




| | states |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

$p_{23}$ = probability that undamaged 1-yr-old pallet is not damaged in its second year

$$= \frac{0.33}{0.33+0.45} = 0.423$$

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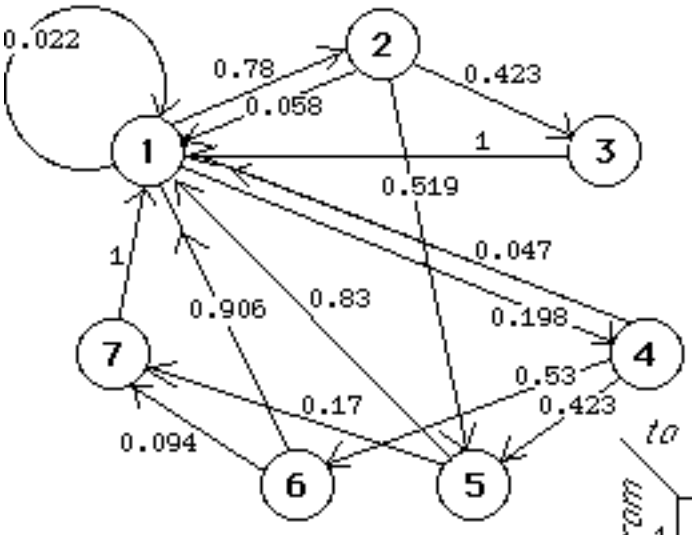


| | states |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

Transition Probability Matrix

| from \ to | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 0.022 | 0.78 | 0 | 0.198 | 0 | 0 | 0 |
| 2 | 0.058 | 0 | 0.423 | 0 | 0.519 | 0 | 0 |
| 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0.047 | 0 | 0 | 0 | 0.423 | 0.53 | 0 |
| 5 | 0.83 | 0 | 0 | 0 | 0 | 0 | 0.17 |
| 6 | 0.906 | 0 | 0 | 0 | 0 | 0 | 0.094 |
| 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

*etc.*

Current Policy

Steady State Distribution

| i | | P<i> |
|---|---|---|
| 1 | New | 0.3339594 |
| 2 | Age 1, undamaged | 0.26048833 |
| 3 | Age 2, undamaged | 0.11018657 |
| 4 | Age 1, repaired | 0.066123962 |
| 5 | Age 2, Repair yr 2 | 0.16316388 |
| 6 | Age 2, repair yr 1 | 0.0350457 |
| 7 | Age 3 | 0.031032156 |

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Current Policy

System costs/revenues by state

| i | | --COST-- |
|---|---|---|
| 1 | New | 3.72 |
| 2 | Age 1, undamaged | 0 |
| 3 | Age 2, undamaged | 0 |
| 4 | Age 1, repaired | 2.07 |
| 5 | Age 2, Repair yr 2 | 2.07 |
| 6 | Age 2, repair yr 1 | 0 |
| 7 | Age 3 | 0 |

*assuming 75¢ scrap value*

Current Policy

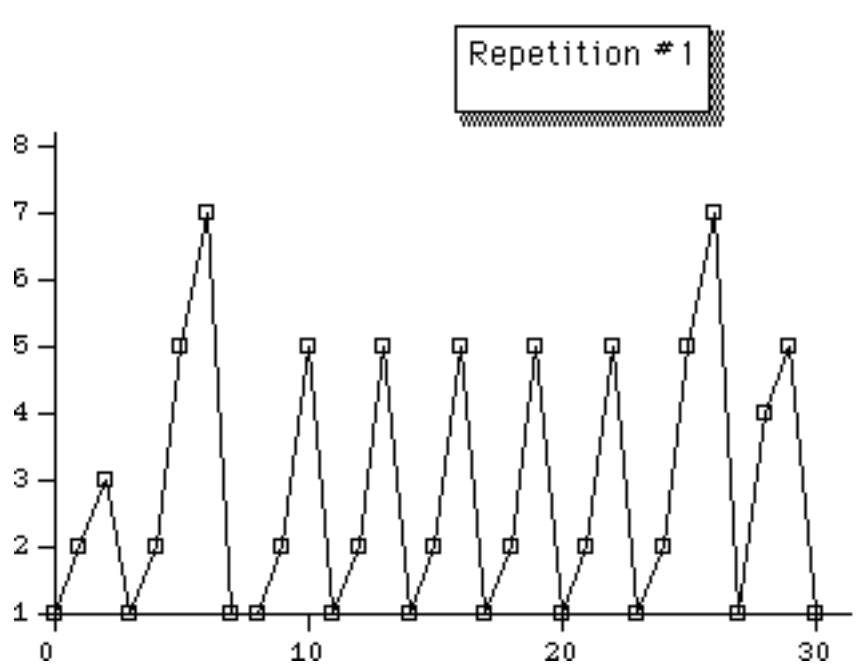
| i | state | Pi | C | Pi×C |
|---|---|---|---|---|
| 1 | New | 0.3339594 | 3.72 | 1.242329 |
| 2 | Age 1, undamaged | 0.26048833 | 0 | 0 |
| 3 | Age 2, undamaged | 0.11018657 | 0 | 0 |
| 4 | Age 1, repaired | 0.066123962 | 2.07 | 0.1368766 |
| 5 | Age 2, Repair yr 2 | 0.16316388 | 2.07 | 0.33774923 |
| 6 | Age 2, repair yr 1 | 0.0350457 | 0 | 0 |
| 7 | Age 3 | 0.031032156 | 0 | 0 |

The average cost/period in steady state is 1.7169548

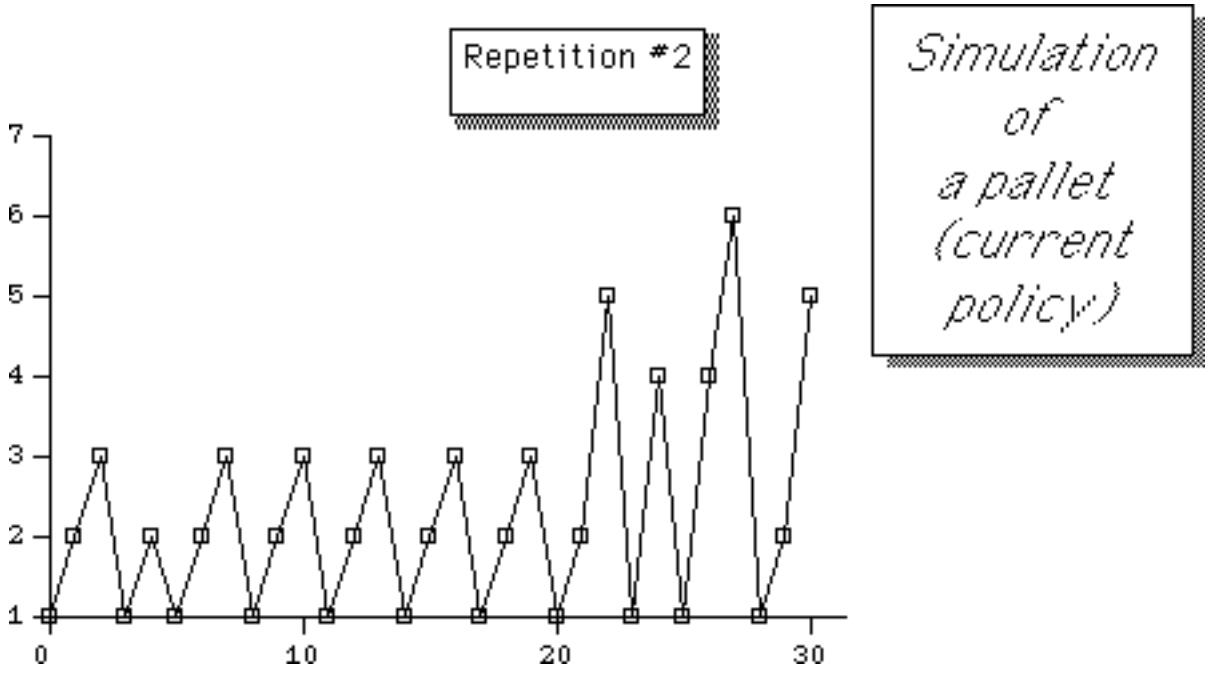
*Annual cost of a pallet, under the current policy, is*

$1.7169548

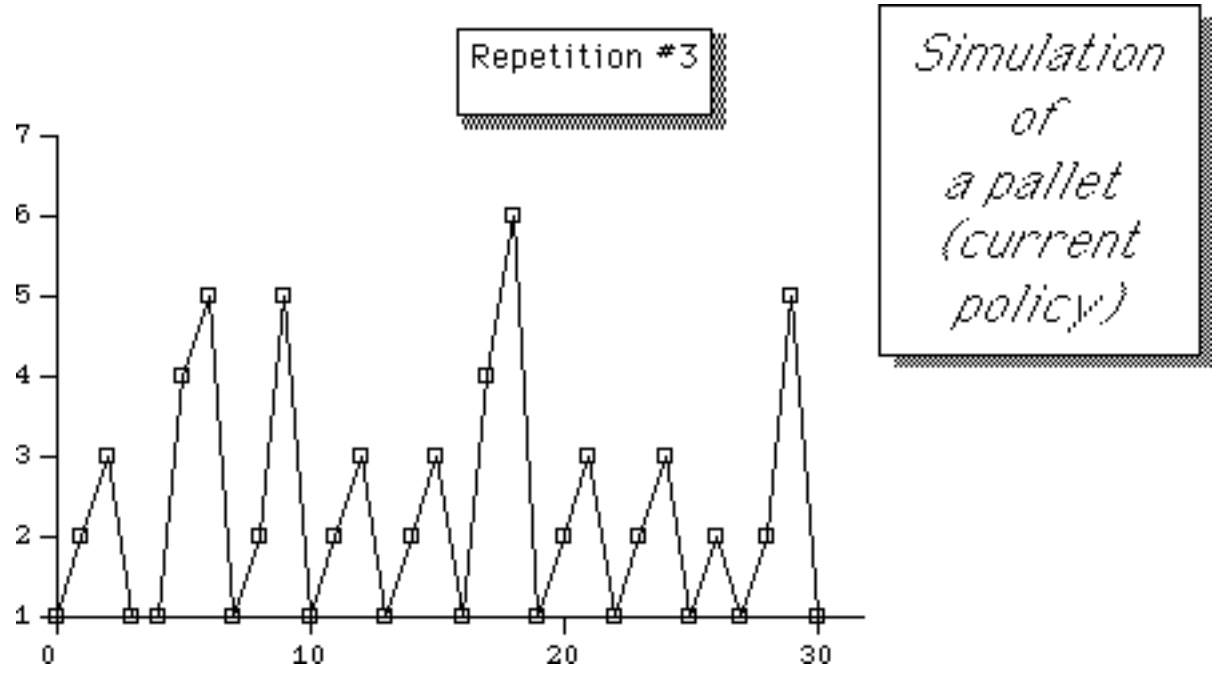


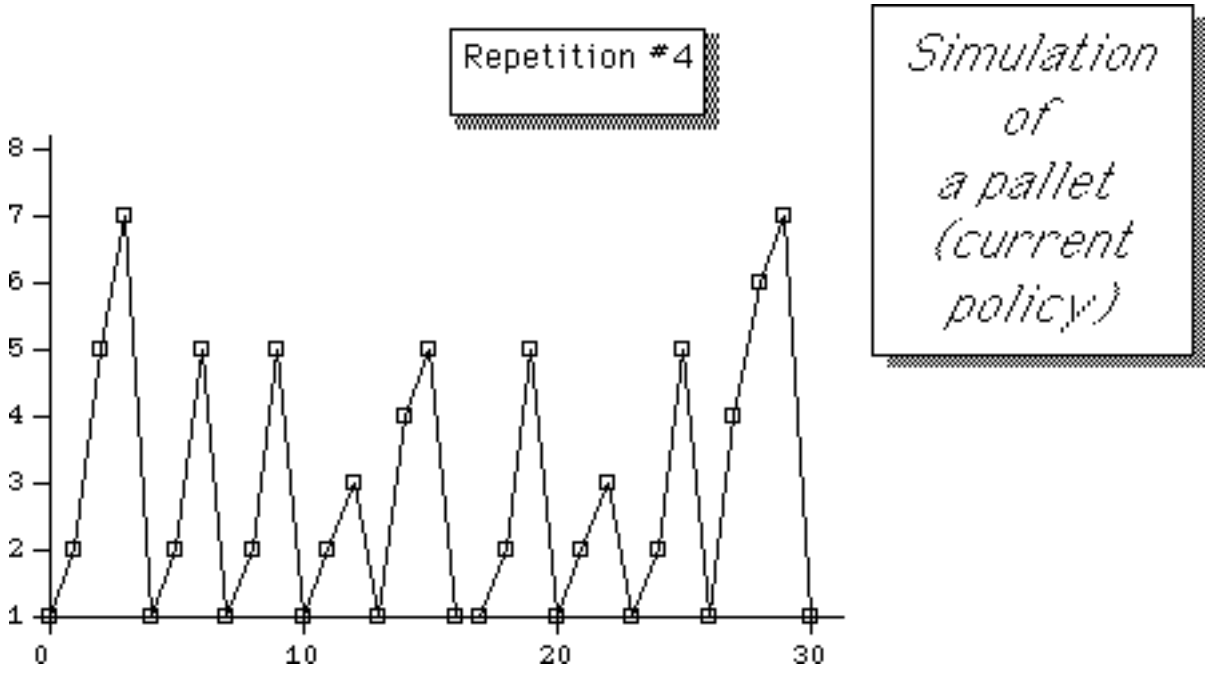



*Simulation of a pallet (current policy)*





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Simulation results:

Current Policy

```
                                  1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0

  1 2 3 1 2 5 7 1 1 2 5 1 2 5 1 2 5 1 2 5 1 2 5 1 2 5 7 1 4 5 1
  1 2 3 1 2 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 5 1 4 1 4 6 1 2 5
  1 2 3 1 1 4 5 1 2 5 1 2 3 1 2 3 1 4 6 1 2 3 1 2 3 1 2 1 2 5 1
  1 2 5 7 1 2 5 1 2 5 1 2 3 1 4 5 1 1 2 5 1 2 3 1 2 5 1 4 6 7 1
```

The array RUN has now been globally defined in the workspace.
Each row of the array represents a repetition of the simulation.
Note: Column 1 represents stage 0, i.e. the initial state.

```
    +/COST[RUN]
59.55 49.2 54.99 57.48

      (+/COST[RUN])÷31
1.9209677 1.5870968 1.773871 1.8541935
```

*annual costs*

Simulation of a pallet (current policy)

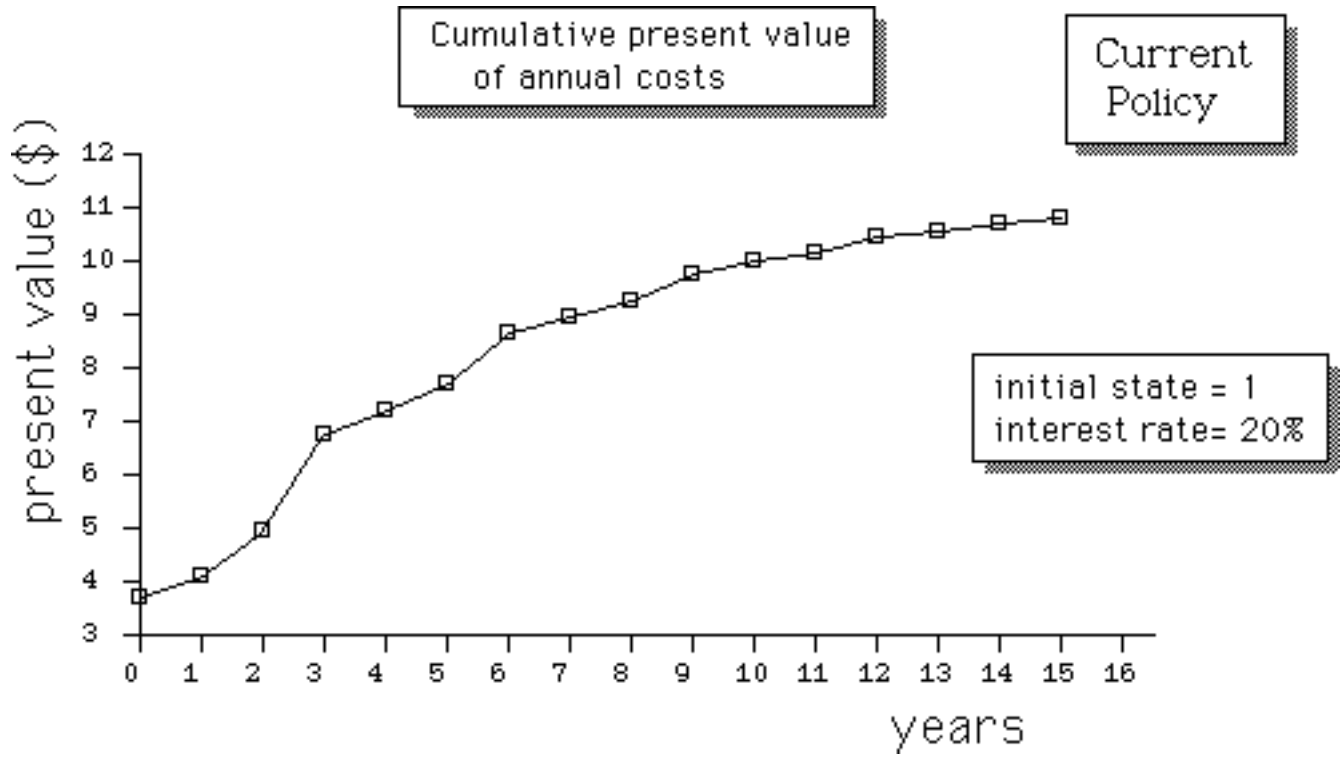
Present Values by Period

Current Policy

| year n | cost Cn | present value PVCn | cumulative present value Vn |
|---|---|---|---|
| 0 | 3.72 | 3.72 | 3.72 |
| 1 | 0.4917 | 0.40975 | 4.12975 |
| 2 | 1.2250767 | 0.85074771 | 4.9804977 |
| 3 | 3.1433512 | 1.819069 | 6.7995667 |
| 4 | 0.89001899 | 0.42921441 | 7.2287811 |
| 5 | 1.2541928 | 0.50403198 | 7.7328131 |
| 6 | 2.8006297 | 0.93792521 | 8.6707383 |
| 7 | 1.1613007 | 0.3240977 | 8.994836 |
| 8 | 1.3026614 | 0.30295741 | 9.2977934 |
| 9 | 2.5345576 | 0.49121425 | 9.7890077 |
| 10 | 1.3515526 | 0.21828329 | 10.007291 |
| 11 | 1.3577965 | 0.1827431 | 10.190034 |
| 12 | 2.3296705 | 0.26128805 | 10.451322 |
| 13 | 1.4833389 | 0.13863861 | 10.589961 |
| 14 | 1.4129901 | 0.11005295 | 10.700014 |
| 15 | 2.1730311 | 0.14104161 | 10.841055 |

initial state = 1
interest rate= 20%





Present value of all future costs, for each initial state:

(using interest rate 20%, i.e. discount factor 0.83333333)

Current Policy

| i | initial state | PV |
|---|---|---|
| 1 | New | 11.387469 |
| 2 | Age 1, undamaged | 8.7786854 |
| 3 | Age 2, undamaged | 9.4895575 |
| 4 | Age 1, repaired | 10.621535 |
| 5 | Age 2, Repair yr 2 | 11.290687 |
| 6 | Age 2, repair yr 1 | 9.3408878 |
| 7 | Age 3 | 9.4895575 |

assuming 20% interest rate



# What are some alternative repair policies?

**Policy: Repair only once**

*If a pallet has been repaired previously and is again damaged, replace it.*

**Policy: Repair in first year only**

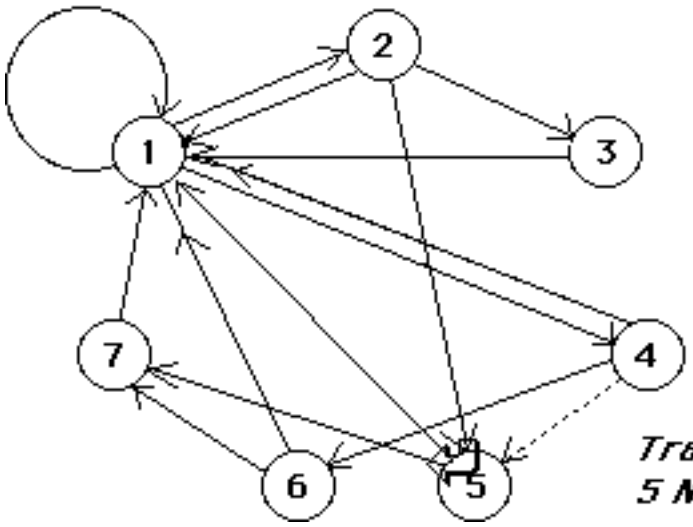
*If a pallet is age 1 or greater, and is damaged, replace it*

**Policy: No repairs**

*Always replace a damaged pallet (thereby eliminating the need for a repair shop.)*

**Policy:**
**Repair only once**

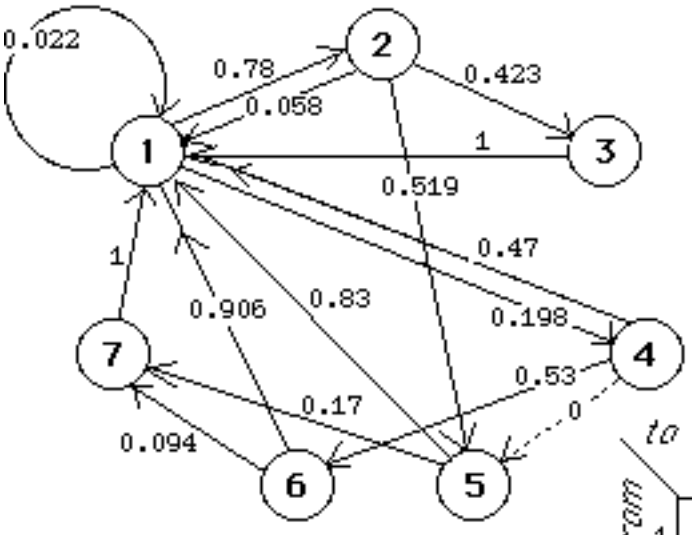
*If a pallet has been repaired previously and is again damaged, replace it.*




| | states |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

***Transitions from state 4 to state 5 NEVER occur, under this policy!***






| | states |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

**Transition Probability Matrix**

| from \ to | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 0.022 | 0.78 | 0 | 0.198 | 0 | 0 | 0 |
| 2 | 0.058 | 0 | 0.423 | 0 | 0.519 | 0 | 0 |
| 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0.47 | 0 | 0 | 0 | 0 | 0.53 | 0 |
| 5 | 0.83 | 0 | 0 | 0 | 0 | 0 | 0.17 |
| 6 | 0.906 | 0 | 0 | 0 | 0 | 0 | 0.094 |
| 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

**Policy:**
**Repair only once**

**Policy:**
**Repair only once**

Steady State Distribution

| i | | P(i) |
|---|---|---|
| 1 | New | 0.34525812 |
| 2 | Age 1, undamaged | 0.26930133 |
| 3 | Age 2, undamaged | 0.11391446 |
| 4 | Age 1, repaired | 0.068361107 |
| 5 | Age 2, Repair yr 2 | 0.13976739 |
| 6 | Age 2, repair yr 1 | 0.036231387 |
| 7 | Age 3 | 0.027166207 |



*Assuming 75¢ scrap value:*

| i | state | Pi | C | Pi×C |
|---|---|---|---|---|
| 1 | New | 0.34525812 | 3.72 | 1.2843602 |
| 2 | Age 1, undamaged | 0.26930133 | 0 | 0 |
| 3 | Age 2, undamaged | 0.11391446 | 0 | 0 |
| 4 | Age 1, repaired | 0.068361107 | 2.07 | 0.14150749 |
| 5 | Age 2, Repair yr 2 | 0.13976739 | 2.07 | 0.2893185 |
| 6 | Age 2, repair yr 1 | 0.036231387 | 0 | 0 |
| 7 | Age 3 | 0.027166207 | 0 | 0 |

The average cost/period in steady state is 1.7151862

*Annual cost per pallet, under this policy, is*

$1.7151862

*which is slightly less than that of the current policy,*

$1.7169548

Policy:
Repair only once

*Assuming 75¢ scrap value:*

Present value of all future costs, for each initial state:

(using interest rate 20%, i.e. discount factor 0.83333333)

| i | PV |
|---|---|
| 1 | 11.40129 |
| 2 | 8.7882537 |
| 3 | 9.5010753 |
| 4 | 10.666072 |
| 5 | 11.301878 |
| 6 | 9.3522251 |
| 7 | 9.5010753 |

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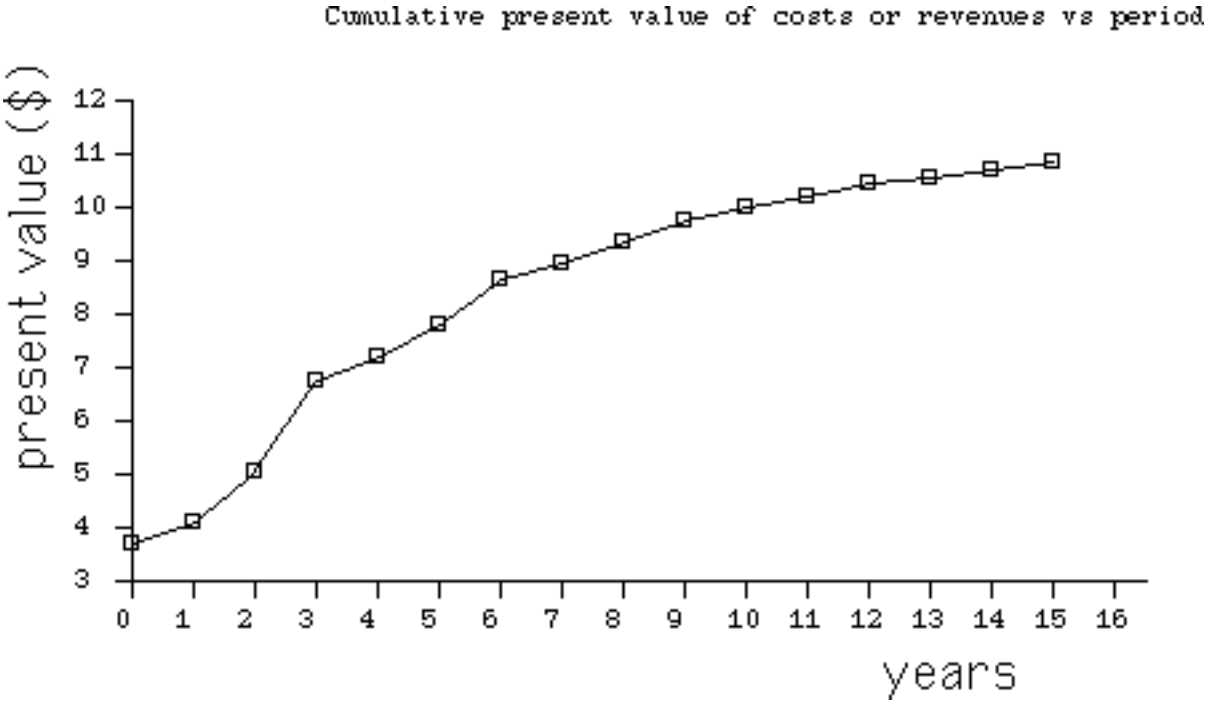
Policy:
Repair only once

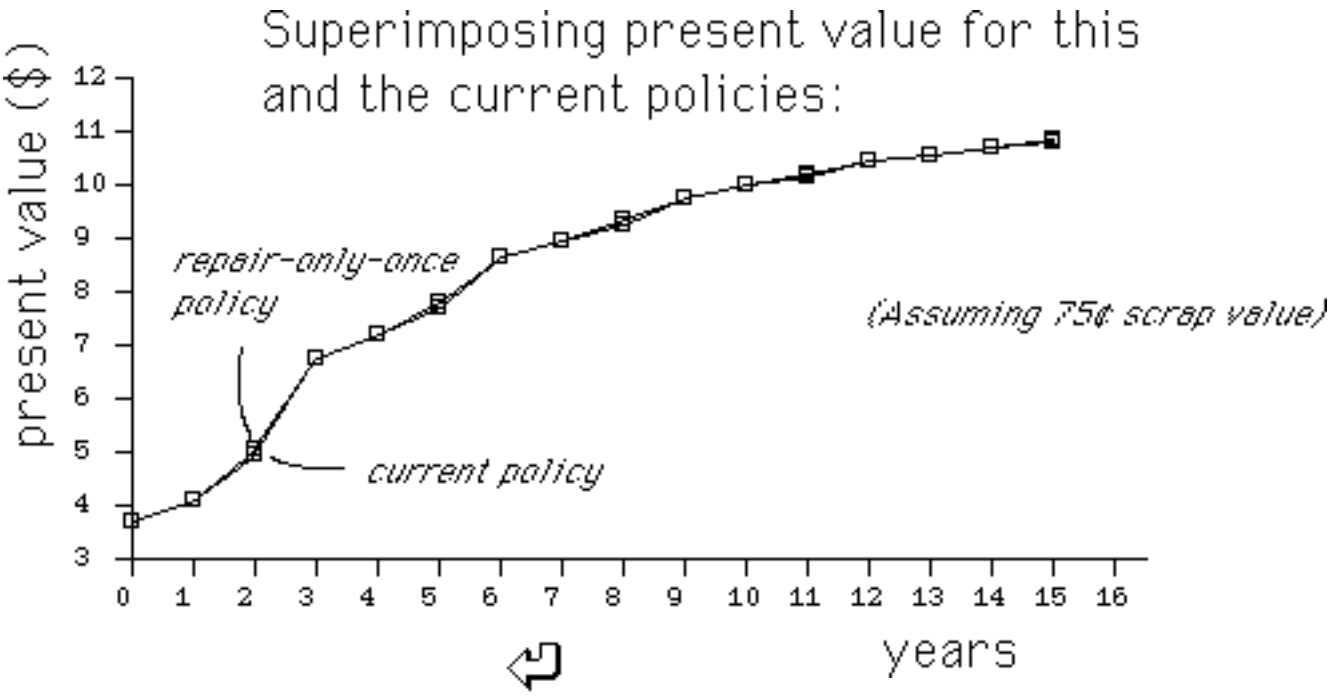
Present Values by Period

| n | Cn | PVCn | Vn |
|---|---|---|---|
| 0 | 3.72 | 3.72 | 3.72 |
| 1 | 0.4917 | 0.40975 | 4.12975 |
| 2 | 1.3632708 | 0.94671583 | 5.0764658 |
| 3 | 2.9289745 | 1.6950084 | 6.7714742 |
| 4 | 0.91987306 | 0.44361162 | 7.2150858 |
| 5 | 1.5014744 | 0.60340889 | 7.8184947 |
| 6 | 2.4965153 | 0.83607792 | 8.6545726 |
| 7 | 1.1930783 | 0.33296626 | 8.9875389 |
| 8 | 1.5865413 | 0.36897879 | 9.3565177 |
| 9 | 2.217937 | 0.42985104 | 9.7863687 |
| 10 | 1.3726005 | 0.22168264 | 10.008051 |
| 11 | 1.6381974 | 0.22048169 | 10.228533 |
| 12 | 2.0385921 | 0.22864167 | 10.457175 |
| 13 | 1.4904986 | 0.13930778 | 10.596483 |
| 14 | 1.6694245 | 0.13002574 | 10.726508 |
| 15 | 1.9231645 | 0.1248239 | 10.851332 |

r=20%
initial state: 1

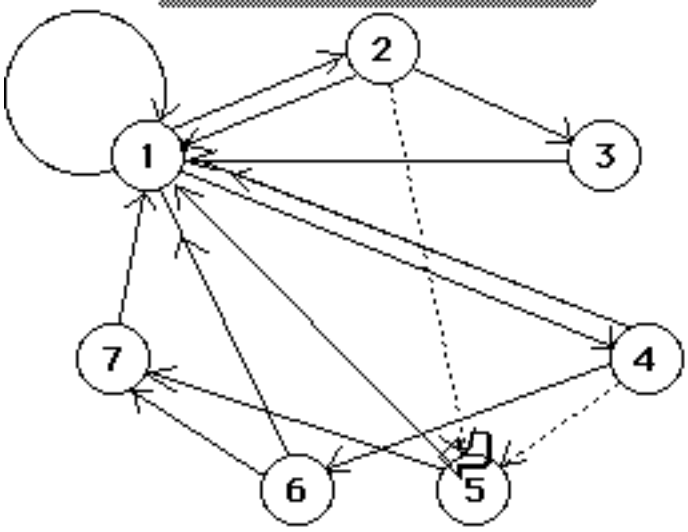




**Policy:**
**Repair in first year only**

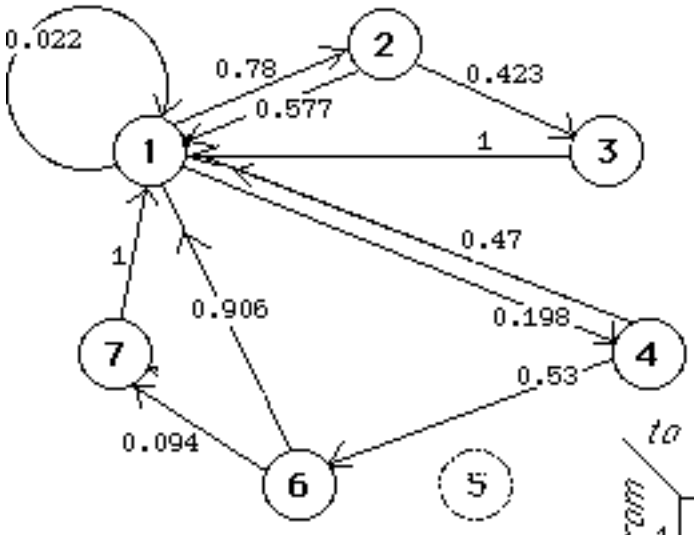
*If a pallet is age 1 or greater, and is damaged, replace it*




| | states |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

***Transitions into state 5 will never occur!***






| | states |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

**Transition Probability Matrix**

| from \ to | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 0.022 | 0.78 | 0 | 0.198 | 0 | 0 | 0 |
| 2 | 0.577 | 0 | 0.423 | 0 | 0 | 0 | 0 |
| 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0.47 | 0 | 0 | 0 | 0 | 0.53 | 0 |
| 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 6 | 0.906 | 0 | 0 | 0 | 0 | 0 | 0.094 |
| 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

**Policy:**
**Repair in first year only**

Policy:
Repair in first year only

Transition Probability Matrix

| from \ to | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 0.022 | 0.78 | 0 | 0.198 | 0 | 0 |
| 2 | 0.577 | 0 | 0.423 | 0 | 0 | 0 |
| 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| 4 | 0.47 | 0 | 0 | 0 | 0.53 | 0 |
| 5 | 0.906 | 0 | 0 | 0 | 0 | 0.094 |
| 6 | 1 | 0 | 0 | 0 | 0 | 0 |

*Let's eliminate the state*
Age 2, repaired 2nd year
*and renumber the states*

i
1 New
2 Age 1, undamaged
3 Age 2, undamaged
4 Age 1, repaired
5 Age 2, repaired
6 Age 3



*Assuming 75¢ scrap value:*

Policy:
Repair in first year only

| i | State | Pi | C | Pi×C |
|---|---|---|---|---|
| 1 | New | 0.41275506 | 3.72 | 1.5354488 |
| 2 | Age 1, undamaged | 0.32194895 | 0 | 0 |
| 3 | Age 2, undamaged | 0.13618441 | 0 | 0 |
| 4 | Age 1, repaired | 0.081725502 | 2.07 | 0.16917179 |
| 5 | Age 2, repaired | 0.043314516 | 0 | 0 |
| 6 | Age 3 | 0.0040715645 | 0 | 0 |

The average cost/period in steady state is 1.7046206

*The annual cost per pallet will be* $1.7046206

Policy:
Repair in first year only

Present value of all future costs, for each initial state:

(using interest rate 20%, i.e. discount factor 0.83333333)

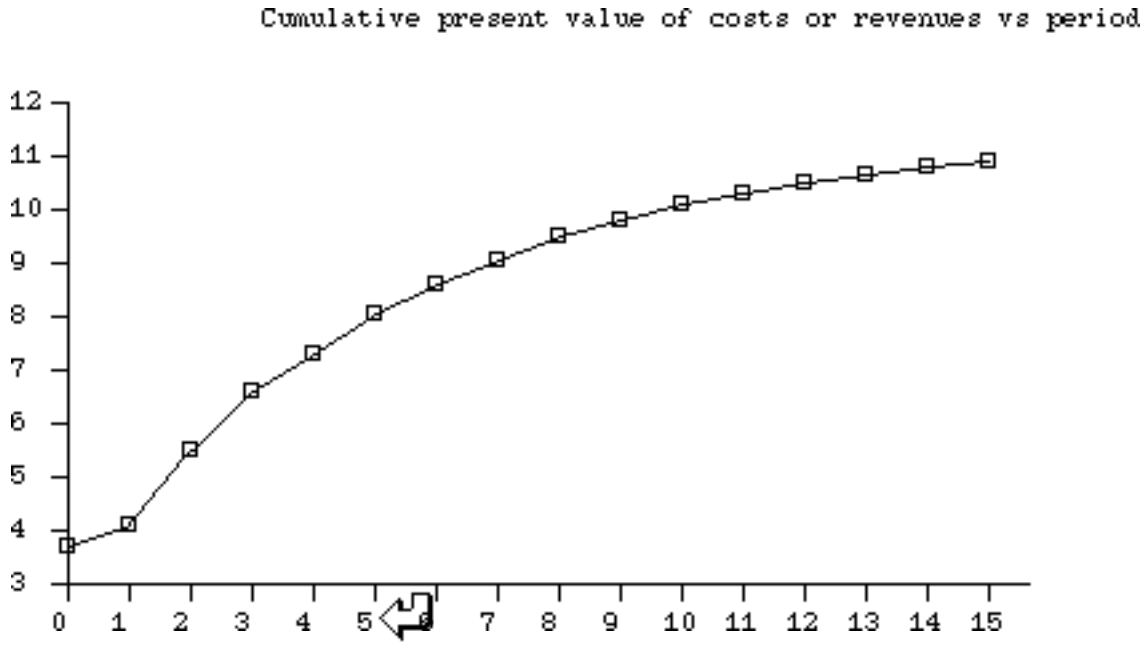
| i | State | PV |
|---|---|---|
| 1 | New | 11.480285 |
| 2 | Age 1, undamaged | 8.8924378 |
| 3 | Age 2, undamaged | 9.5669045 |
| 4 | Age 1, repaired | 10.72563 |
| 5 | Age 2, repaired | 9.417023 |
| 6 | Age 3 | 9.5669045 |



Policy:
Repair in first year only

Present Values by Period

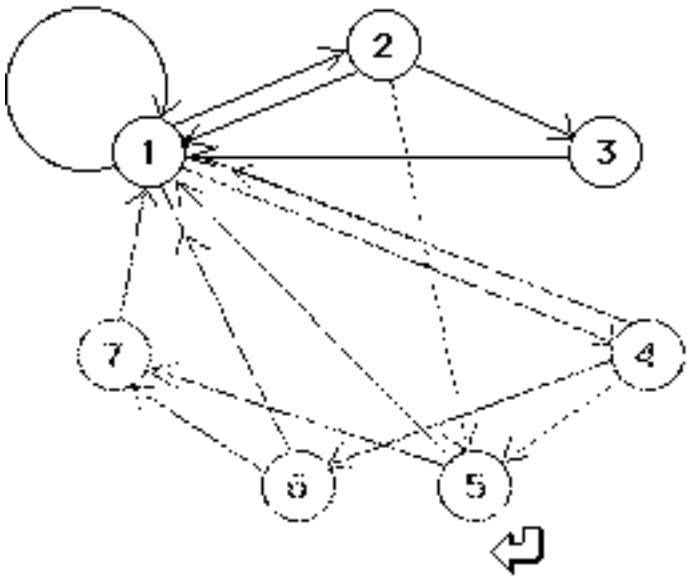
| n | Cn | PVCn | Vn |
|---|---|---|---|
| 0 | 3.72 | 3.72 | 3.72 |
| 1 | 0.4917 | 0.40975 | 4.12975 |
| 2 | 2.0312238 | 1.4105721 | 5.5403221 |
| 3 | 1.8927972 | 1.0953688 | 6.6356908 |
| 4 | 1.3905154 | 0.67058035 | 7.3062712 |
| 5 | 1.9267595 | 0.77432145 | 8.0805926 |
| 6 | 1.6221106 | 0.54324155 | 8.6238342 |
| 7 | 1.6918101 | 0.47215315 | 9.0959873 |
| 8 | 1.75084 | 0.40718943 | 9.5031768 |
| 9 | 1.665803 | 0.32284378 | 9.8260206 |
| 10 | 1.7226107 | 0.27821125 | 10.104232 |
| 11 | 1.7034514 | 0.22926409 | 10.333496 |
| 12 | 1.6983235 | 0.19047828 | 10.523974 |
| 13 | 1.7111102 | 0.159927 | 10.683901 |
| 14 | 1.7010238 | 0.1324869 | 10.816388 |
| 15 | 1.7053782 | 0.11068838 | 10.927076 |





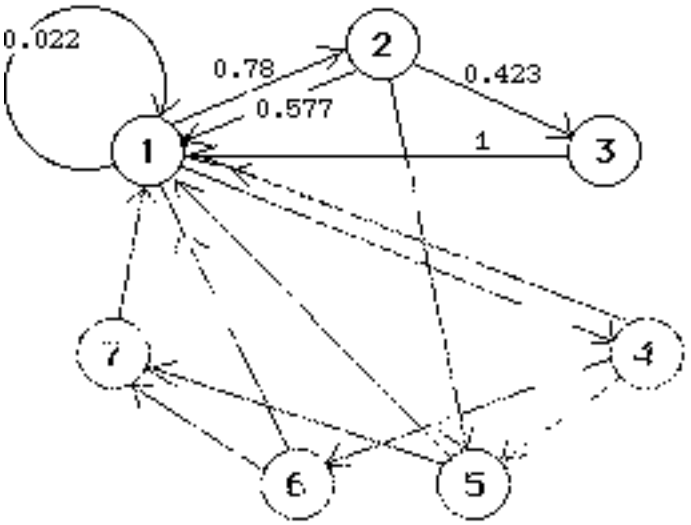

**Policy:**
**No repairs**

*Always replace a damaged pallet (thereby eliminating the need for a repair shop.)*




| | *states* |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |
| 4 | Age 1, repaired |
| 5 | Age 2, repaired 2nd year |
| 6 | Age 2, repaired 1st year only |
| 7 | Age 3 |

***Only states 1, 2, & 3 are possible!***




| | states |
|---|---|
| 1 | New |
| 2 | Age 1, undamaged |
| 3 | Age 2, undamaged |

**Policy:**
**No repairs**

**Transition Probability Matrix**

| from \ to | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 0.22 | 0.78 | 0 |
| 2 | 0.577 | 0 | 0.423 |
| 3 | 1 | 0 | 0 |



*Assuming a 75¢ scrap value:*

**Policy:**
**No repairs**

| i | Pi | C | Pi×C |
|---|---|---|---|
| 1 | 0.47394713 | 3.72 | 1.7630833 |
| 2 | 0.36967876 | 0 | 0 |
| 3 | 0.15637411 | 0 | 0 |

The average cost/period in steady state is 1.7630833

*The annual cost per pallet will be* $1.7630833

*Assuming a 75¢ scrap value:*

Policy:
No repairs

Present value of all future costs, for each initial state:

(using interest rate 20%, i.e. discount factor 0.83333333)

| i | State | PV |
|---|---|---|
| 1 | New | 11.877869 |
| 2 | Age 1, undamaged | 9.2003991 |
| 3 | Age 2, undamaged | 9.8982239 |

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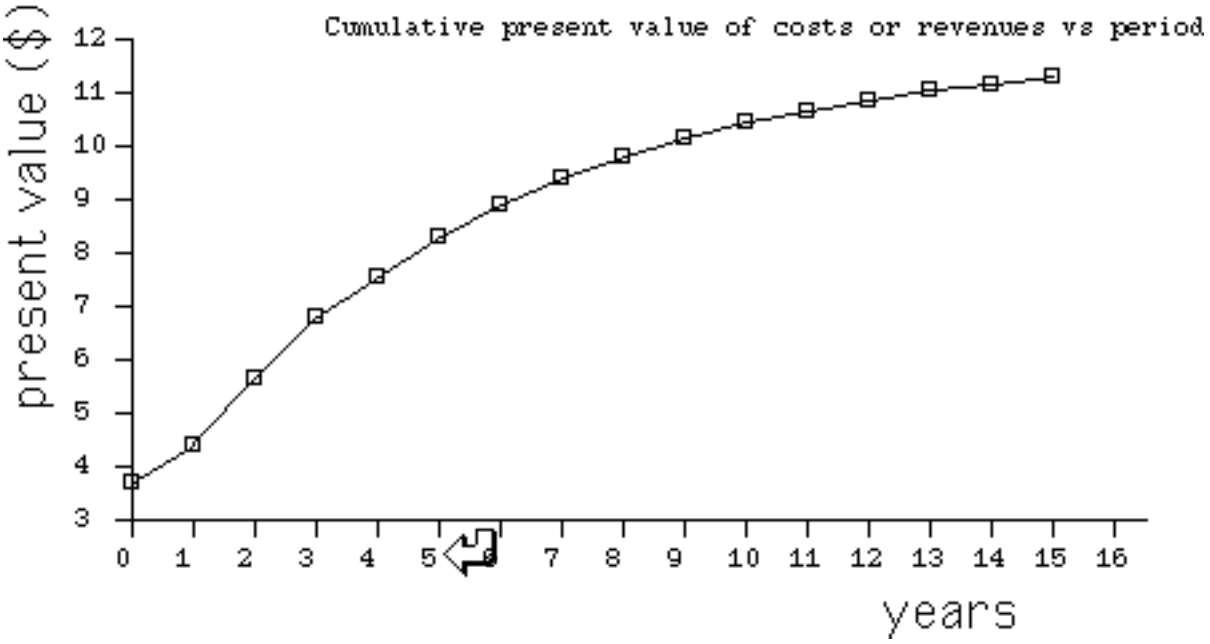
Policy:
No repairs

Initial state: 1, interest rate= 20%

Present Values by Period

| n | Cn | PVCn | Vn |
|---|---|---|---|
| 0 | 3.72 | 3.72 | 3.72 |
| 1 | 0.8184 | 0.682 | 4.402 |
| 2 | 1.8542712 | 1.2876883 | 5.6896883 |
| 3 | 2.0036456 | 1.1595171 | 6.8492054 |
| 4 | 1.5453582 | 0.74525377 | 7.5944592 |
| 5 | 1.8535378 | 0.74489526 | 8.3393545 |
| 6 | 1.764365 | 0.59088228 | 8.9302368 |
| 7 | 1.732239 | 0.48343612 | 9.4136729 |
| 8 | 1.786719 | 0.41553373 | 9.8292066 |
| 9 | 1.7548243 | 0.3400967 | 10.169303 |
| 10 | 1.761727 | 0.28452875 | 10.453832 |
| 11 | 1.7668662 | 0.23779896 | 10.691631 |
| 12 | 1.7605801 | 0.19746078 | 10.889092 |
| 13 | 1.7637876 | 0.16485044 | 11.053942 |
| 14 | 1.7633598 | 0.13734204 | 11.191284 |
| 15 | 1.7626352 | 0.11440467 | 11.305689 |

*Assuming a 75¢ scrap value:*






## Summary

| Policy | Annual Cost per Pallet | |
|---|---|---|
| | 75¢ scrap value | $1.50 scrap value |
| Current policy | $1.7169548 | |
| Repair only once | $1.7151862 | |
| Repair First Year Only | $1.7046206 | |
| Never Repair | $1.7630833 | |