4.2.1 Weibull Exercises

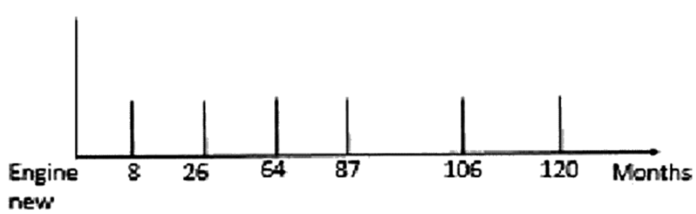
Using a Weibull Analysis software application

Module 4.2A

1

Perkins engine

A Perkins diesel D200 series engine was monitored on board ship over 10 years and the following figure indicates the failure pattern of the engine. It is assumed that after each failure the engine is returned to the "as new" condition by maintenance.



From the diagram, this engine failed and was renewed at the following ages:

- 8, 26-8=18, 64-26=38, and so on.

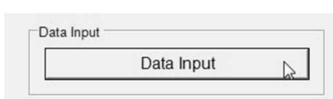
2

Use OREST to perform the following:

1. Using Trend Analysis determine at the 5% significance level whether a Weibull analysis on this data is feasible. That is to say, there should be **no significant change** (growth or deterioration) in reliability over the period covered.
2. Fit a Weibull distribution to the data. Plot the Weibull, Probability Density, Survival, Hazard, and Cumulative Distribution functions.
3. From the Kolmogorov-Smirnov goodness-of-fit test is your data sample **adequately represented** by a Weibull distribution?
4. Examine the Hazard Function curve. From the shape of the curve, does this item become more unreliable as it ages?

3

Enter general data

1


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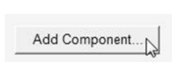

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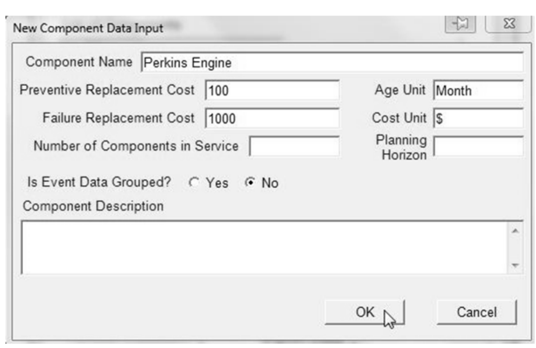

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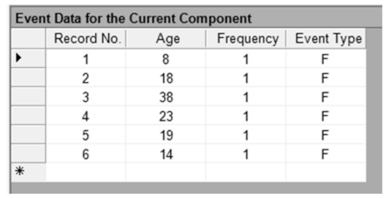
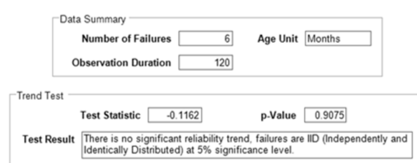
Input event data



5

Perform Trend Analysis

1


3


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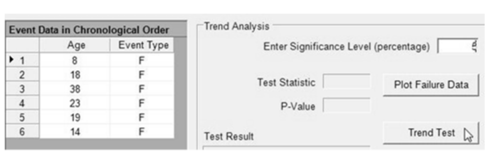

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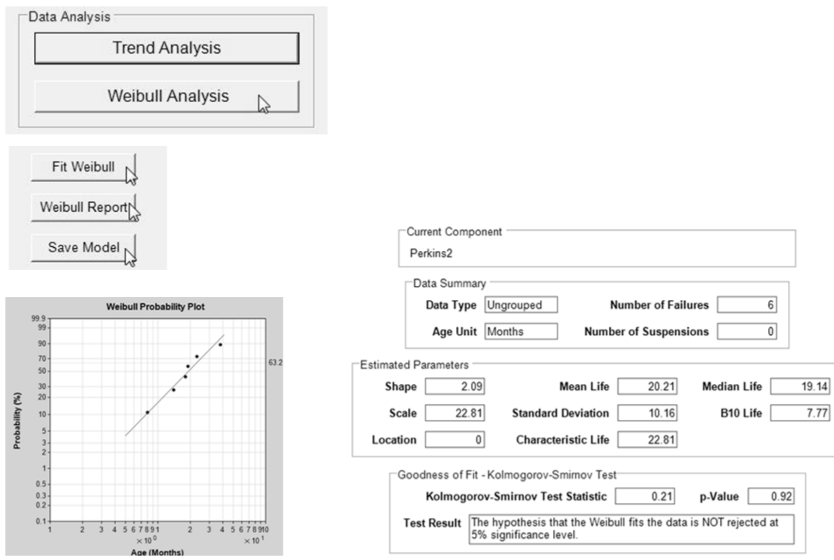
Perform Weibull analysis



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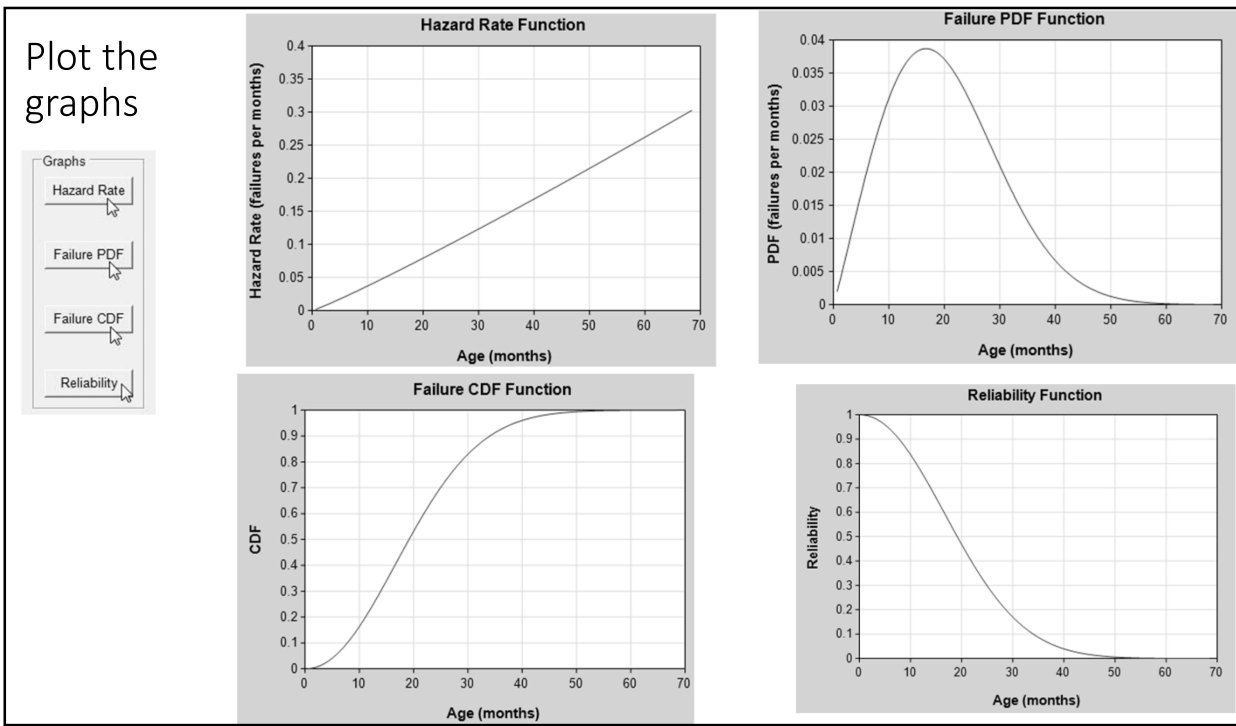
Plot the graphs



8

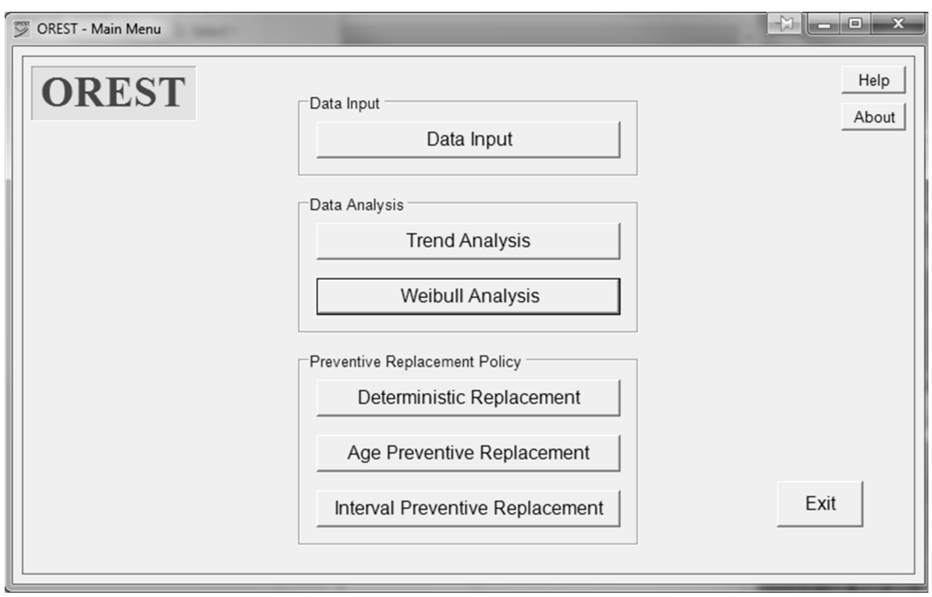
Clutch failures

For the following truck clutch assembly failure data, use Weibull analysis to determine the parameters of the distribution. Also determine the mean life of the assembly.

Interval 1000 km	Failures
0-5	8
5-10	12
10-15	15
15-20	15
20-25	12
25-70	38

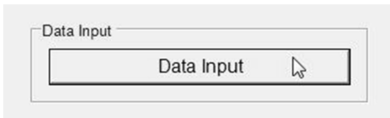
9

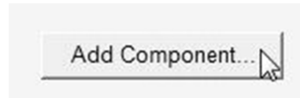
Open OREST

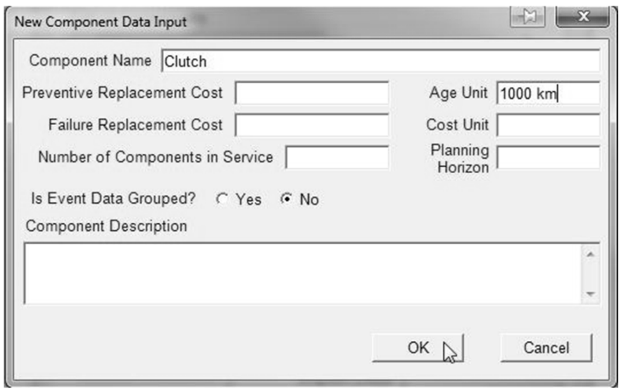


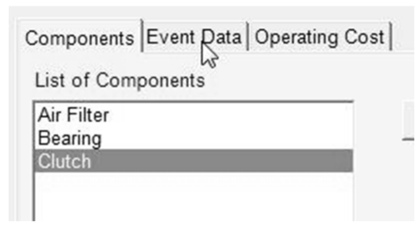
10

Start new analysis

1 

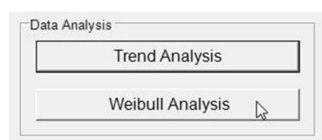
2 

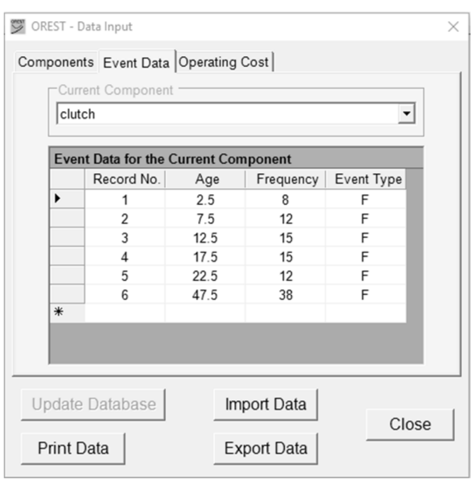
3 

4 

11

Enter event data





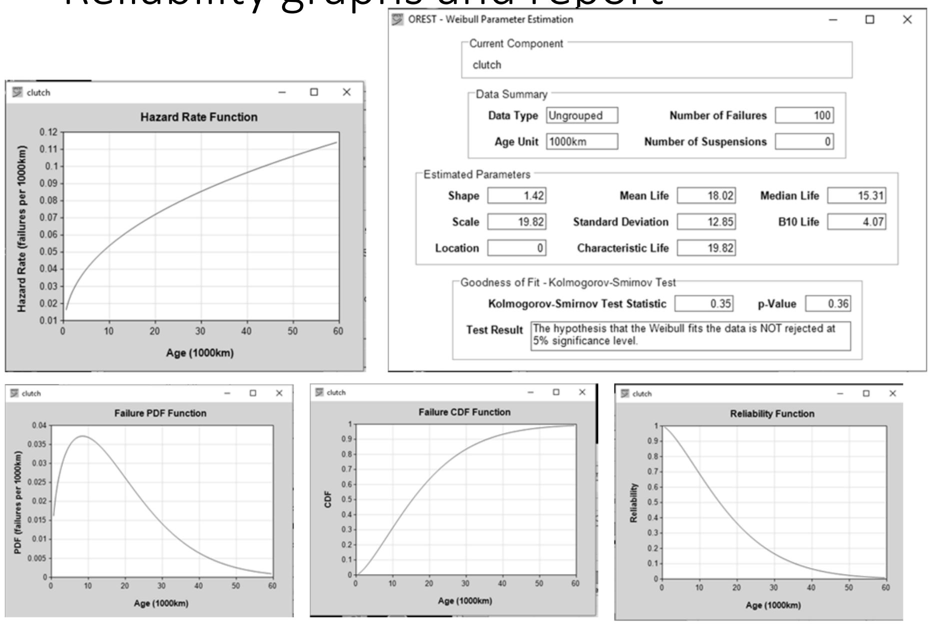
Record No.	Age	Frequency	Event Type
1	2.5	8	F
2	7.5	12	F
3	12.5	15	F
4	17.5	15	F
5	22.5	12	F
6	47.5	38	F

NB: Do not perform Trend Analysis. The purpose of Trend Analysis is to determine whether, over time as a result of changes in operating context there has been significant reliability growth or deterioration.

In this example, the data is “grouped”. We do not know the chronological order of the failure events. In the maintenance department data from the EAM will be from individual work orders and will not be grouped in this way.

12

Reliability graphs and report



13

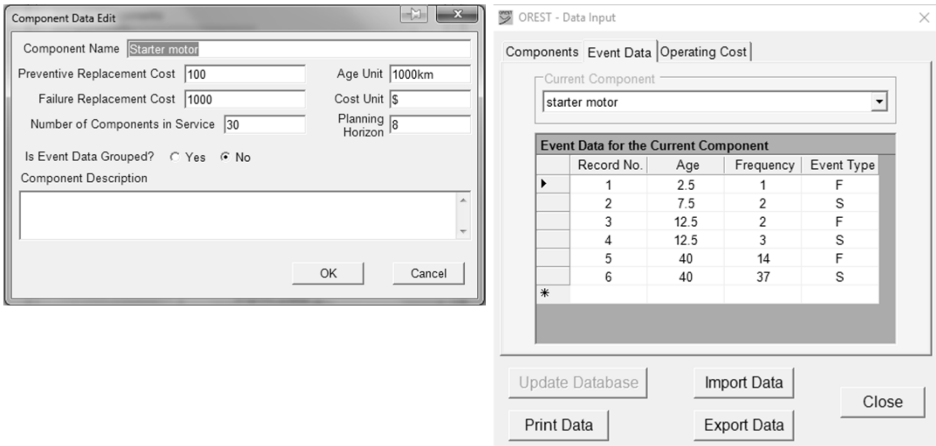
Starter motor (includes suspensions)

The following starter motor failure data includes suspensions. Determine the reliability characterisitcs of the motor.

Interval 1000 km	Failures	Suspensions
0-5	1	0
5-10	0	2
10-15	2	3
15-65	14	37

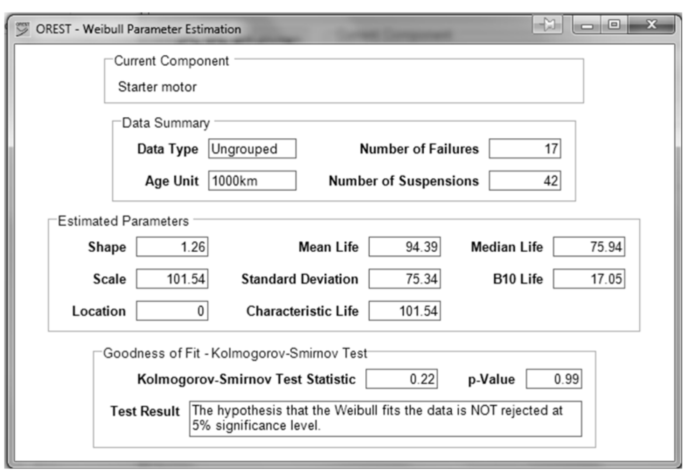
14

Enter general and data



15

Perform Weibull analysis



16

4.2.1 Quiz 1 Reliability Analysis in 2D Workshop

https://forms.gle/3cwReL6d2oBUmwc87

1. We should perform trend analysis to verify whether there has been reliability growth or reduction when: * 1 point

- The data sample of lifetimes extends over a long calendar time.
- In the sample period a fundamental change in the asset's design has occurred.
- There has been a significant shift in operating context over the sample period.
- There has been a significant change in the asset's age-reliability behavior pattern.
- all of the above
- none of the above

2. The following are ways in which we may express or approximate an item's reliability: * 1 point

- B10 life
- MTTF
- Characteristic life
- Median life
- The hazard, reliability, and probability density graphs.
- all of the above
- none of the above.

17

17

4.2.2 Optimal maintenance strategies

We will include "business factors" to the previous Weibull analyses for PM decision making.

Module 4.2 B

18

Age Preventive Replacement Policy

A policy called "Age Preventive Replacement" applies when the following is true:

1. When a failure occurs, the item is renewed at a fixed cost (called the "failure renewal cost").
2. When the item is renewed preventively the cost of renewal (called the "preventive renewal cost") is smaller than the failure renewal cost.

The optimal preventive renewal age balances the preventive and failure renewal costs so as to minimize the expected total renewal cost per unit of age.

19

For Perkins engine: Given that the Failure Renewal Cost is $1000 and the Preventive Renewal Cost is $100, use OREST's Age Preventive Replacement Policy calculation to discover:

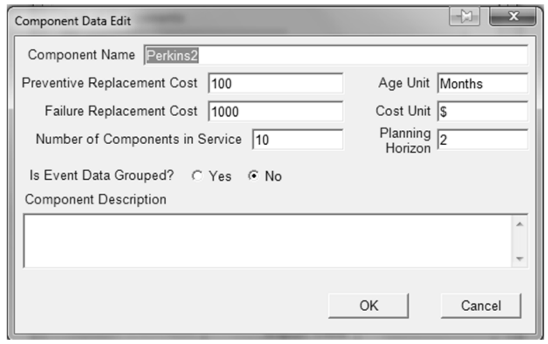
1. The optimal preventive replacement age that minimizes the average maintenance (failure and PM) cost.
2. The average monthly maintenance (failure and PM) cost.
3. The average PM monthly cost.
4. A plot of the average monthly cost versus the replacement age. Does the minimum on this plot correspond to your answers to questions 1 and 2?
5. If there are 10 engines in service and an engine can be rebuilt in 2 months (the "planning horizon“) what is the number of spare engines required?

20

Verify the general data

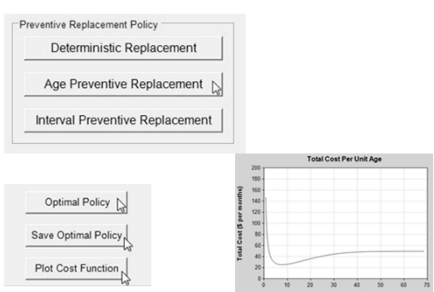
Information needed for spares calculation:

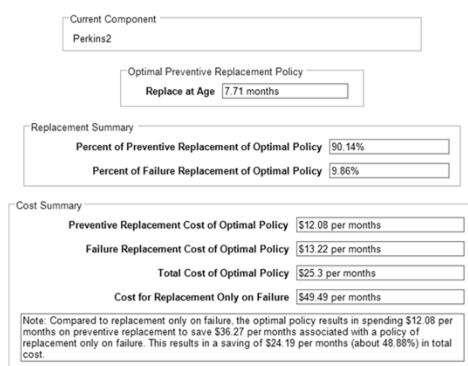
1. There are 10 operating engines in service, and
2. It takes two months (planning horizon) to rebuild and deliver an engine.



21

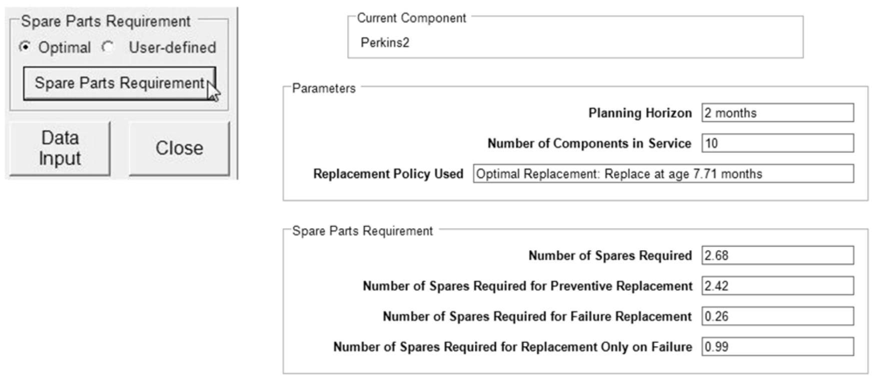
Conduct an Age Preventive Replacement calculation





22

Calculate spares requirement



The optimal policy resulting in lowest (PM and Failure) cost will require a capital investment of 3 spare engines. The organization will weigh that capital investment against the operational monthly savings of $24.19.

23

Interval Preventive Replacement Policy

Sometimes it is not practical to replace an item based on its individual age. For example, the street lights for an entire block might be replaced all at the same time, given the set up time required.

An "Interval Preventive Replacement" policy is also called "block" or "group" replacement.

The difference (from an age preventive maintenance policy) is that a constant calendar interval rather than an equipment age interval is used for scheduling preventive renewal. This means that an engine will be replaced preventively according to scheduled calendar intervals regardless of its actual “working” age.

So we are required to find the optimal calendar based preventive replacement interval that minimizes monthly (failure plus preventive) renewal costs.

24

Perkins Engine: Interval Preventive Replacement

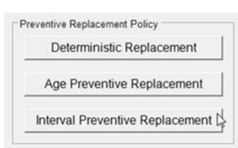
Assume, due to business factors, that preventive engine replacement can only be done on these engines at fixed calendar intervals.

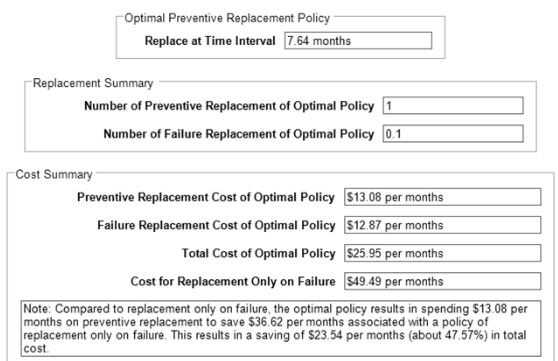
Using the same data, calculate as in the optimal calendar time replacement interval which will minimize total cost per unit of time?

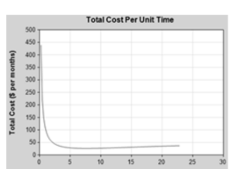
How does the total cost per unit of time compare with the total cost per unit of age? If the results appear similar, explain why.

25

Perform Interval Preventive Replacement calculation







The interval renewal results are not too different from those of the age renewal since the engines probably work more or less steadily with calendar time.

26

Perform spares calculation

Spare Parts Requirement
(•) Optimal ( ) User-defined
[Spare Parts Requirement]

Parameters

Planning Horizon	2 months
Number of Components in Service	10
Replacement Policy Used	Optimal Replacement: Replace at interval 7.64 months

Spare Parts Requirement

Number of Spares Required	2.88
Number of Spares Required for Preventive Replacement	2.62
Number of Spares Required for Failure Replacement	0.26
Number of Spares Required for Replacement Only on Failure	0.06

27

Deterministic Replacement Policy

No age (failure and suspension) data available with which to perform reliability (Weibull) analysis)

A "Deterministic Replacement" (as opposed to a probabilistic) policy applies when:

1. The item's operating cost increases with age; (for example it runs less efficiently, requires more repair), and
2. Its renewal (replacement or overhaul) cost is fixed.
3. We do not have age data with which to build a Weibull data.
4. We have, from accounting records, the monthly (or yearly) costs of operating the item(s). The records indicate that the operating cost increases as the item gets older. From this we would surmise that:
   - The real cost (overall to the organization) of replacement (per unit of operational time) *decreases* as the item's service age increases.
   - The optimal replacement age (as a policy) should account for the increasing operating cost and the replacement cost per unit of time so as to minimize the total cost (operating + replacement) per unit time over the life cycle of the item.

28

Perkins engine – Deterministic Policy

Assume we do not have age data with which to build a Weibull model. But the operating costs during various age intervals are given below:

	Age Interval	Operating Cost
1	50	10
2	75	12
3	100	15
4	125	20

Renewal cost: 100

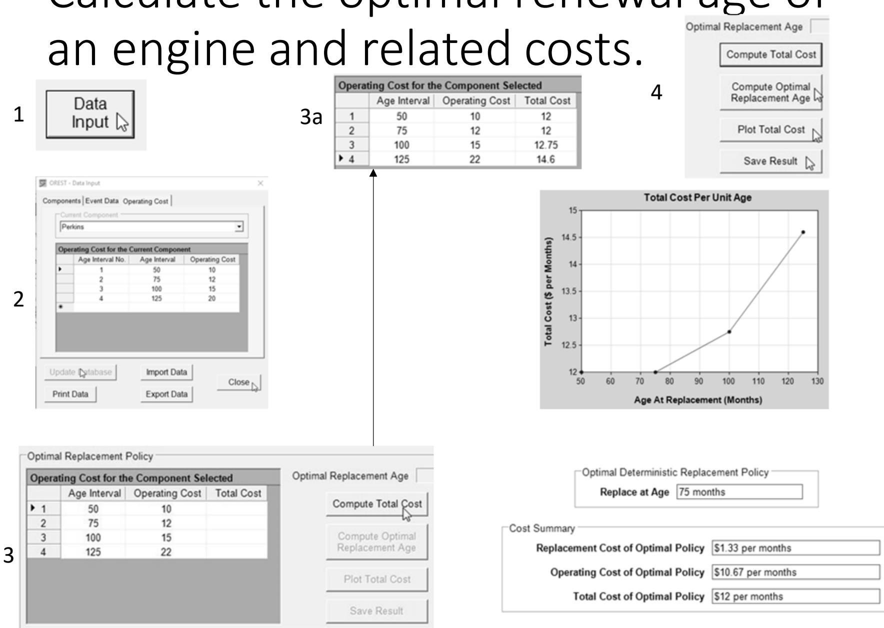
This analysis is independent of the Weibull model developed in the previous section for the Perkins engine. For this problem, we use only the above operating cost data.

Given the PM renewal cost is $100, find the optimal preventive renewal strategy based on the business data given in the table above.

We can say that for the first 50 weeks the average weekly cost is $10. For the next 75 weeks the operating cost is $12 per week. And so on.

29

Calculate the optimal renewal age of an engine and related costs.



30

4.2.1 Quiz 2 Reliability Analysis in 2D Workshop

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1. If a PM policy is based solely on an item's age we might schedule renewal at fixed intervals provided: * 1 point

- The Weibull shape parameter is greater than 1.
- Failure probability is age dependent.
- The hazard curve increases with age.
- The costs associated with a failure exceed the cost of a preventive task.
- all of the above
- none of the above.

2. The number of spares required to be kept in stock depends on: * 1 point

- The planning horizon.
- The number of operating units.
- The preventive replacement interval.
- all of the above
- none of the above.

31

31