CASE 2

MAINTENANCE SERVICE CONTRACTS [CASE: PHOTO-COPIER]

CASE STUDIES IN RELIABILITY

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CASE 2

MAINTENANCE SERVICE CONTRACTS
[CASE: PHOTO-COPIER]

MAINTENANCE

- Maintenance are actions (or activities) needed to (i) control equipment degradation and failures and (ii) to restore a failed equipment to operational state.
- The former is termed Preventive Maintenance (PM) and the latter as Corrective Maintenance (CM)

APPROACHES TO MAINTENANCE

- Changed significantly over the last fifty years.
- Pre 1950: Maintenance was regarded simply as an unavoidable cost
- Post 1950: Scientific approach to maintenance (mainly OR models - dealing with operational and economic issues)

APPROACHES TO MAINTENANCE

- Post 1970: Maintenance management
  - Integral to business performance
  - Part of strategic management
  - More integrated and pro-active approach
  - Many approaches (e.g., TPM, RCM, Tero-technology, ILS) have evolved

IMPACT OF TECHNOLOGY

- Systems are getting more complex
- Maintenance requires specialist skills and equipment
- It is often not economical for businesses to carry out in-house maintenance.
- Out-sourcing of maintenance is an option

OUT-SOURCING OF MAINTENANCE

IMPORTANT ISSUES

- Two different parties
  - Service Agent (providing the maintenance service)
  - Customer (owner of the system and recipient of the maintenance service)
- Different objectives or goals
- Decision problems for both parties

SERVICE AGENT PROBLEMS

- Terms of service contract (response time, penalties)
- Pricing of service contract
- Number of customers to service
- Spare parts to be stocked
- Repair crew – size, location, scheduling of jobs (PM and CM) etc

RELIABILITY MODELLING

- Modelling failures at the system and component levels
- Choice depends on the objective
- System level: For deciding on repair crew (strategic decision)
- Component level: For deciding on stock level (operational decision)

CASE: PHOTO-COPIER

DATA FOR MODELLING

Count	Day	Component
60152	29	Cleaning Web
60152	29	Toner Filter
60152	29	Feed Rollers
132079	128	Cleaning Web
132079	128	Drum Cleaning Blade
132079	128	Toner Guide
220832	227	Toner Filter
220832	227	Cleaning Blade
220832	227	Dust Filter
220832	227	Drum Claws
252491	276	Drum Cleaning Blade
252491	276	Cleaning Blade
252491	276	Drum
252491	276	Toner Guide
365075	397	Cleaning Web
365075	397	Toner Filter

- Supplied by the service agent
- Single machine: Failures over a 5 year period
- Part of the data is shown on the left side

MODELLING

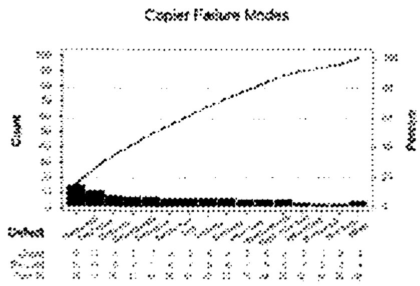
- **One can either use number of copies (count) or time (age) as the variable in modelling at both component and system level**
- **The count and time between failures are correlated (correlation coefficient 0.753)**

COMPONENT FAILURES

Failed Component	Frequency
Cleaning web	15
Toner filter	6
Feed rollers	11
Drum blade	2
Toner guide	7
Cleaning blade	7
Dust filter	6
Drum claws	5
Crum	6
Ozone filter	8
Upper fuser roller	5
Upper roller claws	5
TS block front	2
Charging wire	6
Lower roller	2
Optics PS felt	3
Drive gear D	2

- **Photocopier has several components**
- **Frequency distribution of component failures is given on the left**

COMPONENT FAILURES



SYSTEM LEVEL MODELLING

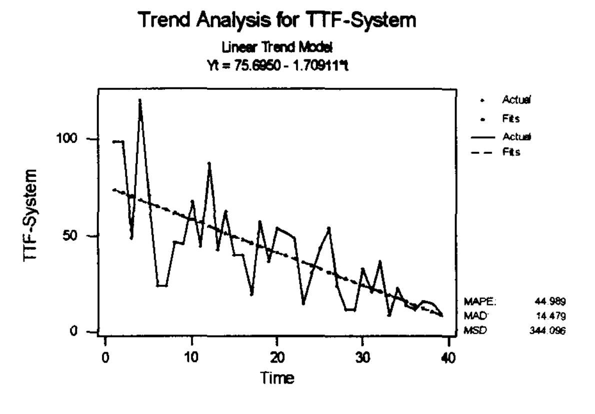
SERVICE CALLS

- Service calls modelled as a point process through rate of occurrence of failure (ROCOF) which defines probability of service call in a short interval as a function of age (time)
- ROCOF: Weibull intensity function
- η : Scale parameter
- β: Shape parameter

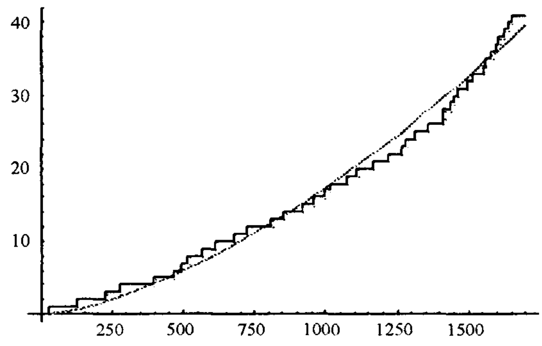
$$\lambda(t) = (t/\eta)^{\beta}$$

SERVICE CALLS

- The shape parameter β > 1 implies that service call frequency increases (due to reliability decreasing) with time (age)
- Data indicates that this is indeed the case. The next slide verifies this where TTF denotes the time between service calls.



MODELLING ROCOF



MODELLING ROCOF

- **Time used as the variable in the modelling**
- **η = 157.5 days, β = 1.55**
- **Estimated average number of service calls per year:**

Year	1	2	3	4	5	6	7	8	9	10
Estimated Service Calls	3.7	7.1	9.4	11.3	13.0	14.6	16.0	17.3	18.5	19.7

1.

COMPONENT LEVEL MODELLING

COMPONENT: CLEANING WEB

MODELLING

- **Failed components replaced by new ones**
- **Time to failure modelled by a failure distribution function *F*(t)**
- **The form of the distribution function determined using the failure data available (black-box modelling)**

MODELLING

Several distribution function were examined for modelling at the component level. Some of them were:

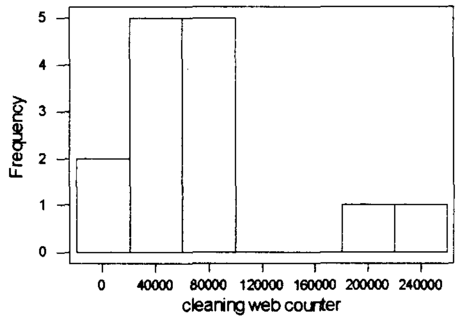
- **2- and 3-parameter (delayed) Weibull**
- **Mixture Weibull**
- **Competing risk Weibull**
- **Multiplicative Weibull**
- **Sectional Weibull**

COMPONENT LEVEL

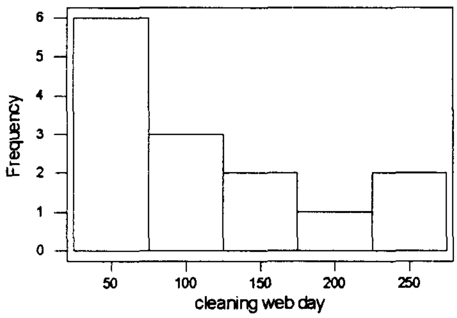
- **A list of the different distributions considered can in found in the following book:**

  Murthy, D.N.P., Xie, M. and Jiang, R. (2003), *Weibull Models*, Wiley, New York
- **We consider modelling based on both "counts" and "age"**

HISTOGRAM (COUNTS)



HISTOGRAM (AGE)



WPP PLOT

- **WPP plot allows one to decide if one of the Weibull models is appropriate for modelling a given data set**
- **For 2-parameter Weibull: WPP is a straight line**
- **For more on WPP plot, see *Weibull Models* by Murthy et al (cited earlier)**

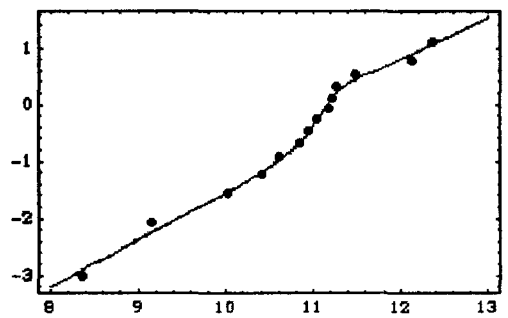
NOTATION

- Two sub-populations
- Scale parameters η_1, η_2
- Shape parameters β_1, β_2
- Location parameter γ
- Mixing parameter p
- *error:* (square of the error between model and data on the WPP)

MODEL FIT

Model	β_1	β_2	η_1	η_2	γ	t_0	p	error
Weibull(2)	1.060	.	80035	.	.	.	.	0.543
Delayed Weibull	1.060	.	80035	.	0	.	.	0.543
Mixture	*0.851*	*5.230*	*79377*	*67923*	.	.	*0.674*	*0.092*
Multiplicative	11.013	1.060	390693	80090	.	.	.	0.543
Competing Risk	0.630	1.266	1046923	96110	.	.	.	0.502
Sectional	0.926	1.199	107232	84078	3483.4	11832.9	.	0.484

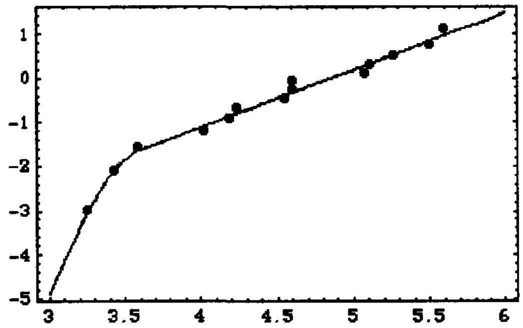
MIXTURE MODEL (COUNT)



MODEL FIT

Model	β_1	β_2	η_1	η_2	γ	t_0	p	error
Weibull(2)	1.481	.	129	.	.	.	.	0.752
Delayed Weibull	*0.851*	.	*100.3*	.	23.2	.	.	*0.365*
Mixture	2.404	2.199	55.0	184.0		.	0.390	0.424
Multiplicative	*6.618*	*1.286*	*29.0*	*128.0*	.	.	.	*0.173*
Competing Risk	1.480	1.482	203.0	210.0	.	.	.	0.752
Sectional	3.663	0.988	56.0	103.0	20.2	27.7	.	0.362

MULTPLICATIVE MODEL (AGE)



SPARES NEEDED

- **The average number of spares needed each year can be obtained by solving the renewal integral equation. Ssee, the book on *Reliability* by Blischke and Murthy (cited earlier) for details. It is as follows:**

Year	1	2	3	4	5	6	7	8	9	10
Estimated Cleaning Webs	2.83	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04

REFERENCE

- **For further details of this case study, see, Bulmer M. and Eccleston J.E. (1992), Photocopier Reliability Modeling Using Evolutionary Algorithms, Chapter 18 in Case Studies in *Reliability and Maintenance*, Blischke, W.R. and Murthy, D.N.P. (eds) (1992), Wiley, New York**