Case 1

OPERATION OF UNRELIABLE SYSTEM [CASE: DRAGLINE]

CASE STUDIES IN RELIABILITY

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Case 1

OPERATION OF UNRELIABLE SYSTEM
[CASE: DRAGLINE]

PRODUCT RELIABILITY

- **Inherent reliability depends on decisions made during design and manufacture**
- **Reliability degrades with age and production rate (or usage level/intensity)**
- **System design based on some nominal production rate**
- **Actual production rate can differ - depends on commercial considerations**

PRODUCT RELIABILITY

Examples of increased production rate:

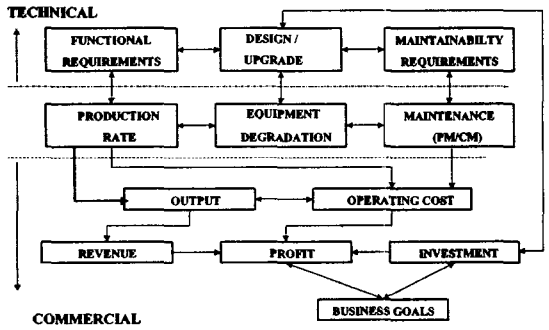
- **Machines running at higher speeds**
- **Trains carrying more load or running faster**
- **Flow rate in pipes (water, gas, oil etc) being higher**

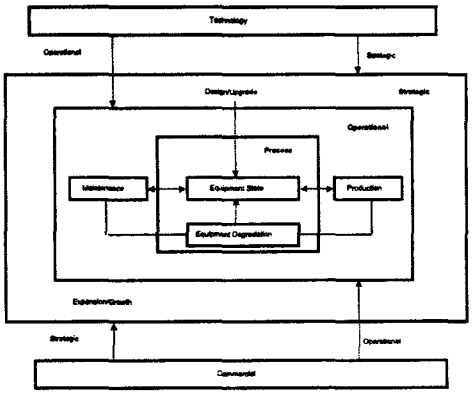
PRODUCT RELIABILITY

- **Production rate determines the load (electrical, mechanical, thermal etc) on the various components and affects degradation**
- **Higher production rate implies more output when the system is in operational state**
- **However, it also leads to higher failures and as a result higher corrective and preventive maintenance costs**

BUSINESS PERSPECTIVE

- **Businesses need to take into account the effect of higher load in making decisions with regards the operation of complex unreliable systems**
- **Need to take into account the link between technical and commercial considerations from an overall business perspective**





RELIABILITY PROBLEMS

- Process Level: Determining system state
- Operational Level: Optimal load, maintenance etc (Technical / Commercial interaction)
- Strategic Level: Design changes, Upgrades etc

PROBLEM SOLUTION

Requires a good understanding of

- Reliability science
- Reliability modelling
- Reliability engineering
- Reliability management

Decisions need to be made from an overall business perspective

CHALLENGE

- Need to model the different elements (technical, commercial, operational)
- Need to understand the underlying degradation processes involved (Reliability science)
- Adequate data to build and validate models

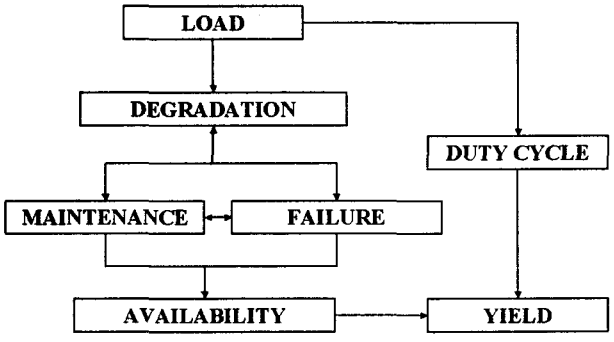
CASE: DRAGLINE

DRAGLINE

- Cost: 100 million dollars
- Moving surface dirt to expose coal in open cut mining
- Runs 24 hours per day and 365 days per year
- Revenue loss of 1 million dollar for every day out of action

CASE: DRAGLINE

- Commercial considerations dictate an increase in output
- Idea: Increase bucket size (100 tons to 140?)
- Greater load on components
- Implications for reliability and maintenance

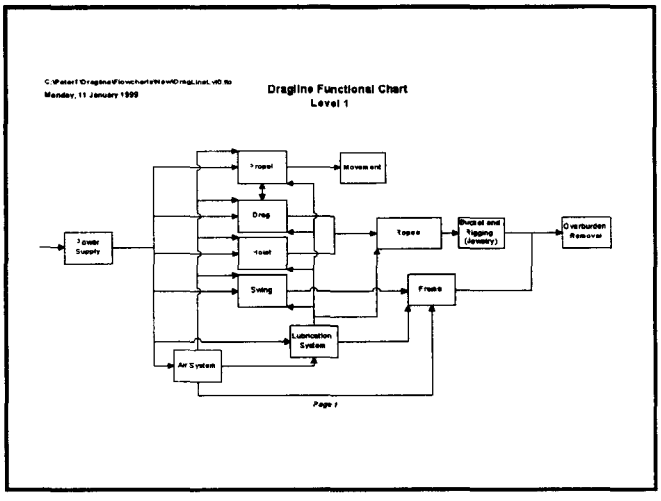


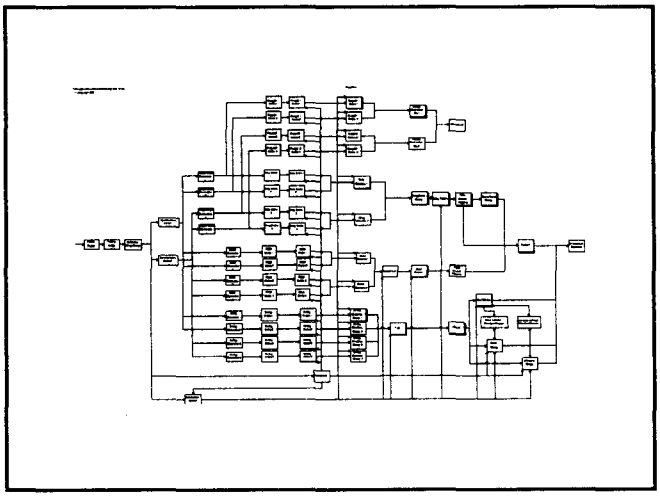
MODELLING

- Modelling system in terms of its major components [Decomposition]
- Modelling degradation of each component
- Modelling effect of bucket load on component and system performance
- Involves reliability science, engineering and mathematics

SYSTEM DECOMPOSITION

- Hierarchy: Systems, sub-systems, assemblies, sub-assemblies and so on down to part and material level
- Complexity versus tractability
- Data available determines the appropriate level to model -- Need adequate data for model building

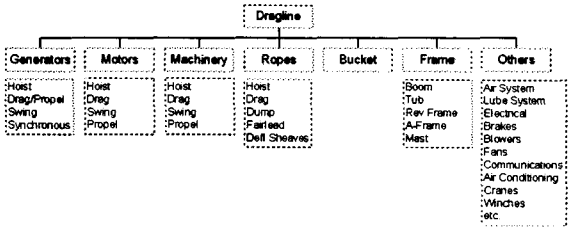




SYSTEM DECOMPOSITION

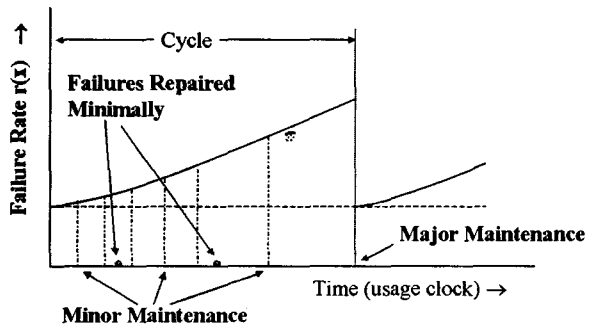
- **The dragline was decomposed into 7 major systems**
- **Some of them were further sub-divided resulting in 25 components**
- **Decision influenced by the data available for modelling**

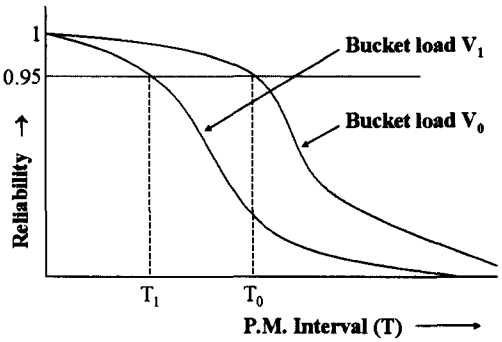
SYSTEM DECOMPOSITION



MODELLING

- **Component Failures**
- **System Failures**
- **Effect of Load on Failures**
- **Maintenance Actions**
  - **Major: Done every 5 years (Duration: 6 weeks)**
  - **Minor: Done once every 3 weeks (Duration: 8 hours)**
- **Availability: Fraction of the time working**
- **Yield: Dirt moved per unit time**





COMPONENT FAILURES

- Black box approach
- Weibull Distribution
  - Two parameter Weibull distribution
  - Scale (β) and shape (α) parameters
- Effect of bucket load (Accelerated Life)
  - No effect on shape parameter
  - Scale parameter is affected

EFFECT OF LOAD

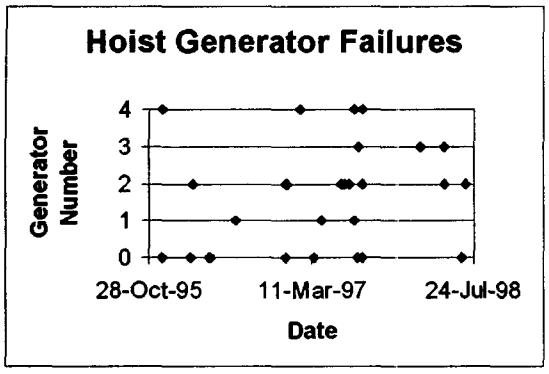
- Define $v = V / V_0$
- V_0 - Base dragline load (bucket + rigging + dirt)
- V - Dragline load

$$F_{vi}(t,\alpha_i,\beta_{vi}) = F(t,\alpha_i,\frac{\beta_i}{\psi_i(v)})$$

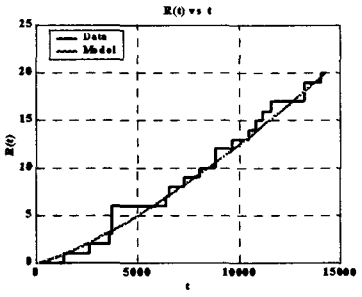
where $\psi_i(v)$ is the scaling factor

FAILURE DATA

- Taken from FMMS maintenance database
- From end of Major Shutdown in March/April 1996 to July 1998
- Machine was assumed to be as "Good as New" at end of Major Shutdown
- Estimation of parameters using maximum likelihood method and least squares method



DRAG GENERATOR



SYSTEM PERFORMANCE

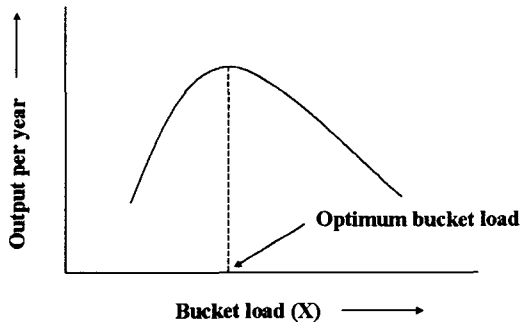
- **Availability: Depends on up and down times**
- **Down times: To rectify minor failures and preventive maintenance to avoid major failures**
- **Up time: Productive time**
- **Cycle: Time between major maintenance**

SYSTEM PERFORMANCE

- **Bucket load (X) affects both these variables**
- **Need to take into account preventive maintenance schedules for different components [Different time scales]**
- **Multiple objectives: Study different alternatives**

OBJECTIVES

- **Probability of major failure for a component during operation < some pre-specified value [0.05%]**
- **Maximise total output per year**
- **Maximise revenue per year**
- **Minimise total cost per year**
- **Yield: Dirt moved per unit time**



MODELLING THE SYSTEM

- **System consists of 25 components (K= 25)**
- **The reliability of the system is modelled as a series system**
- **System only in working state if all components are working**

$$S(T)=1-F(T)=\prod_{i=1}^{K}(1-F_i(T))$$

AVAILABILITY

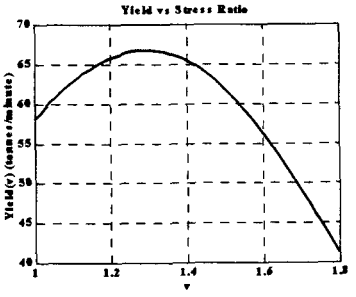
- **Cycle Time: Depends on load v the ratio of load to the base load**
- **Up time: T_v**
- **Expected downtime (for minor and major preventive maintenance)**
- **From this we can obtain availability**

AVAILABILITY

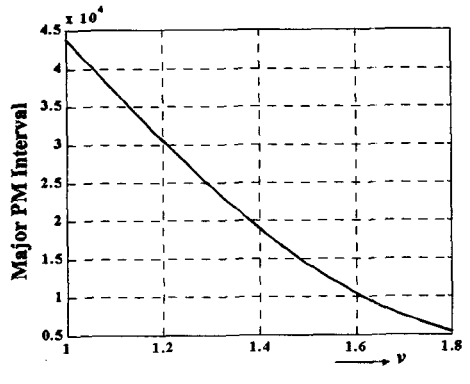
$$A(T,v) = \frac{T_v}{ECL(v)}$$

$$ECL(v) = T_v + [\sum_{i=1}^{K} \{ \int_0^{T_v} r_{vi}(x)dx \} \tau_{ri}] + \tau_{pm} + \tau_p$$

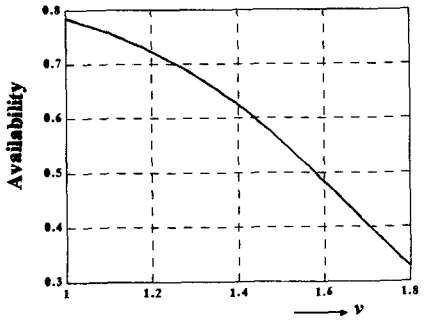
YIELD - BUCKET LOAD



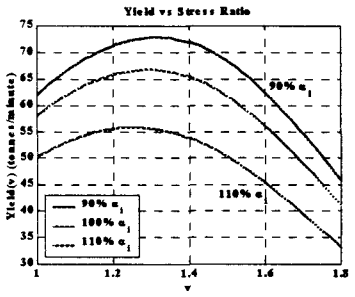
MAJOR PM INTERVAL vs v



AVAILABILITY vs v



SENSITIVITY STUDY (α)



CONCLUSIONS

- Study reveals that the bucket load can be increased to maximise the output yield
- Maximum yield corresponds to $v \approx 1.3$ (dragline load = 182 tonnes or payload of 116 tonnes) as opposed to current payload of 74 tonnes
- Major PM interval will need to be reduced from 43680 usage hours to 25000 usage hours

REFERENCE

- For more details, see Townson, P. Murthy, D.N.P. and Gurgenci, H. (2002), Optimisation of Dragline Load, in Case Studies in *Reliability and Maintenance*, WR Blischke and DNP Murthy [Editors], Wiley, New York.