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Selection of Inspection Intervals Based on Multi-attribute Utility Theory

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Outline

- Introduction
- Problem Description and Assumptions
- Case Study
- Conclusions

Maintenance Management

- Uncertainty
  - Time to Failure
  - Time to Repair
  - Consequences (Availability and Cost)
- Inspection Policies
  - Complex systems faults
- Delay Time Concept
  - Two step failure process

Maintenance Management

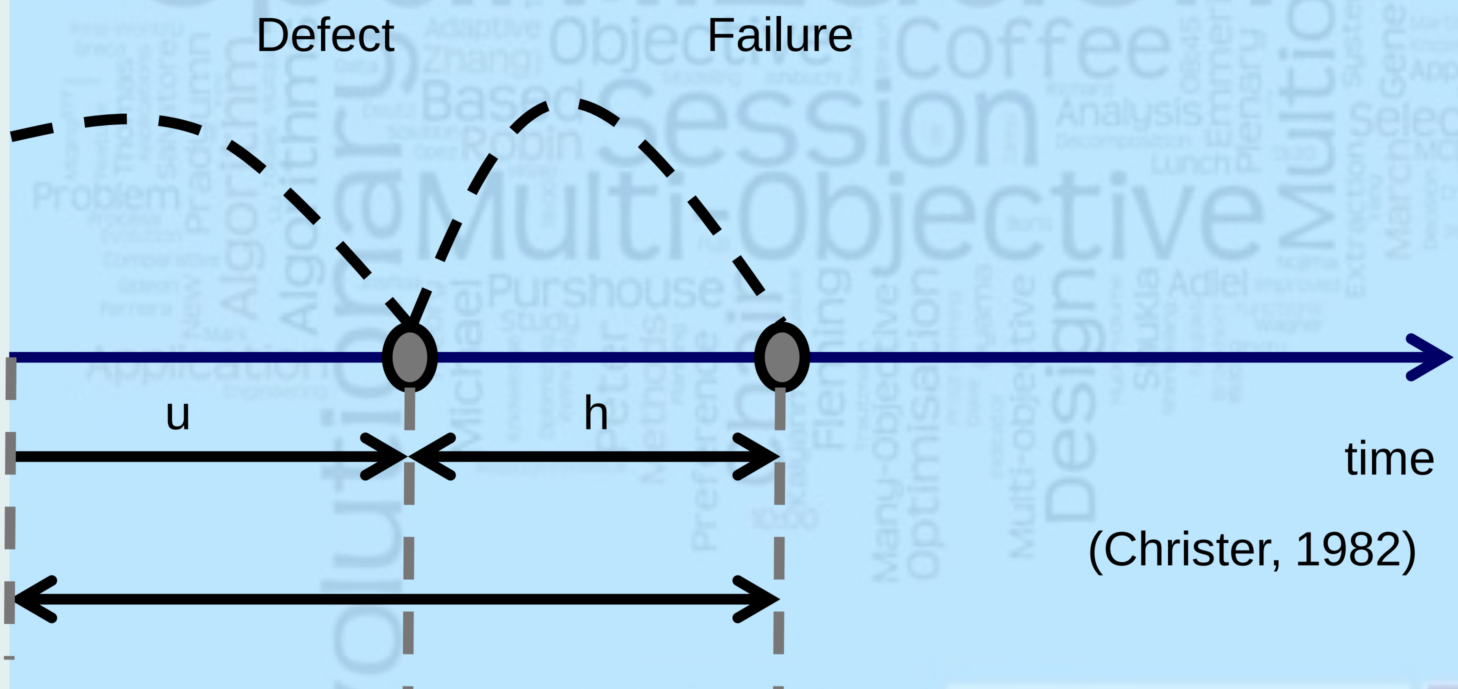
- Majority of inspection models considers only one objective
- Main contribution of this paper is to put forward a multicriteria decision model in order to aid maintenance planning
- Decision maker's preferences
- Inspection intervals
- Periodic condition monitoring
- Cost and Availability of inspection policy

Inspection policy

- The standard inspection policy consists of checks on a unit that operates for an infinite span at successive times T
- Any failure is detected at the time of the next check and a replacement is immediately made
- Delay time is the time lapse from when a system defect could first have been noticed until the time when its repair can no longer be delayed (Christer, 1999)

Delay time

- Failures are consequences of two different stochastic mechanisms: the delay in itself and the initial point of identifying defects



(Christer, 1982)

if an inspection is carried out during the delay time of the failure, the defect present might well be detected, and consequently the failure could be avoided.

The problem

- Managers are interested in balancing the costs of the inspection policy with savings arising from improving the performance of the system
- A very short interruption due to a failure can cause a substantial financial loss
- In the contexts of maintaining medical equipment, the protection of a country by military means and an oil distribution system, a failure could lead to disastrous consequences, and therefore such contexts should not be constrained only by the monetary dimension

The problem

- The failure process is assumed to be a non-homogeneous Poisson process
  - An inspection takes place every T time units and lasts d_i, where $d_i << T$;
  - Inspections are perfect in that any defect present within the system will be identified. Once the defects are identified, the repairs are made immediately after the inspection, the repair for each defects lasts d_d;
  - The defects arise at a constant rate per unit of time (λ).
  - The delay time (h) is independent of the initial point u;
  - The distribution of the delay time is known, and its probability density function $f_h(h)$ is known.

The problem

- Using these assumptions, the probability of a fault arising as a breakdown is:

$$b(T) = \int_0^T \frac{(T-h)}{T} f_h(h)\,dh$$

- Cost of a complex system can be modelled by the following expression:

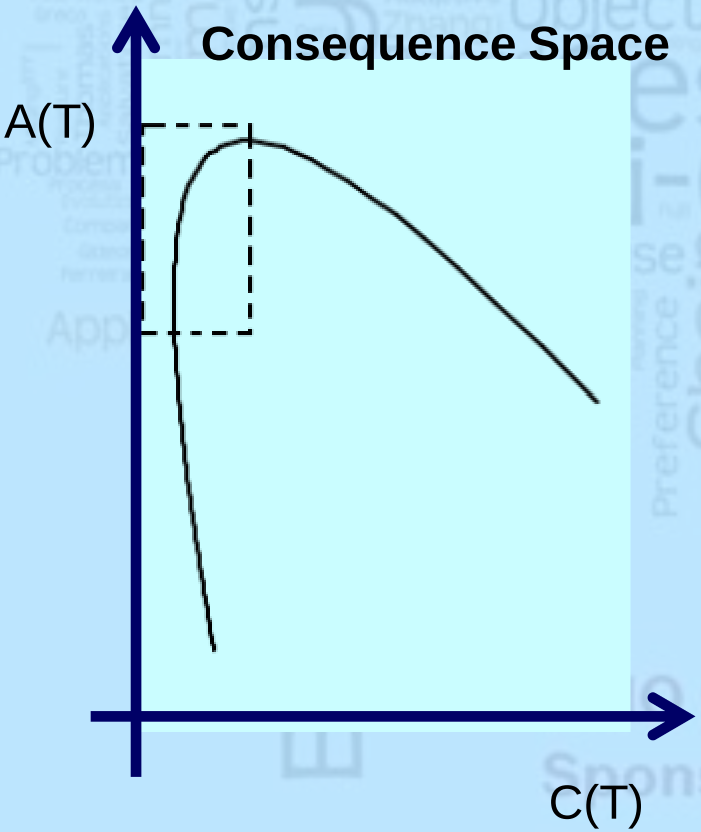
$$C(T) = \frac{c_i + (c_f)\lambda T b(T) + c_d \lambda T\left[1 - b(T)\right]}{T + d_i + d_d \lambda T\left[1 - b(T)\right]}$$

- Availability of a complex system can be modelled by the following expression:

$$A(T) = \frac{T - d_f \lambda T b(T)}{T + d_i + d_D \lambda T\left[1 - b(T)\right]}$$

The Multi-attribute Utility Theory Model

- A multi-attribute utility theory model is proposed considering that attributes of cost and availability are additive independent if and only if the two-attribute utility function is additive.

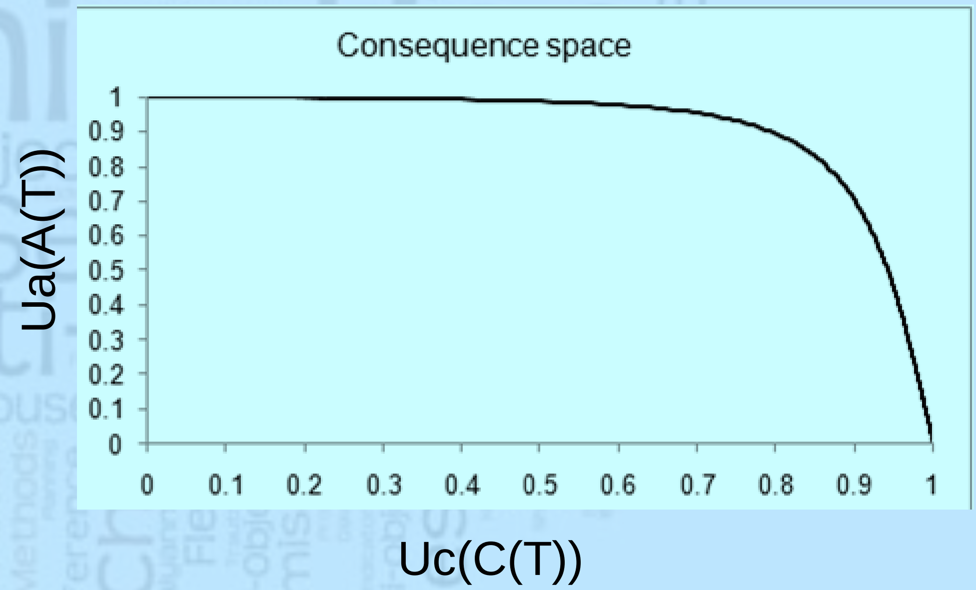


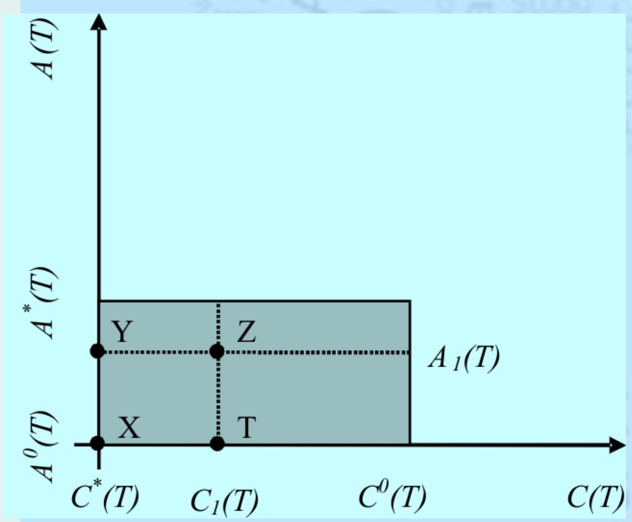
Are these two attribute additive independent?

Utility and additive independences should be checked

The Multi-attribute Utility Theory Model

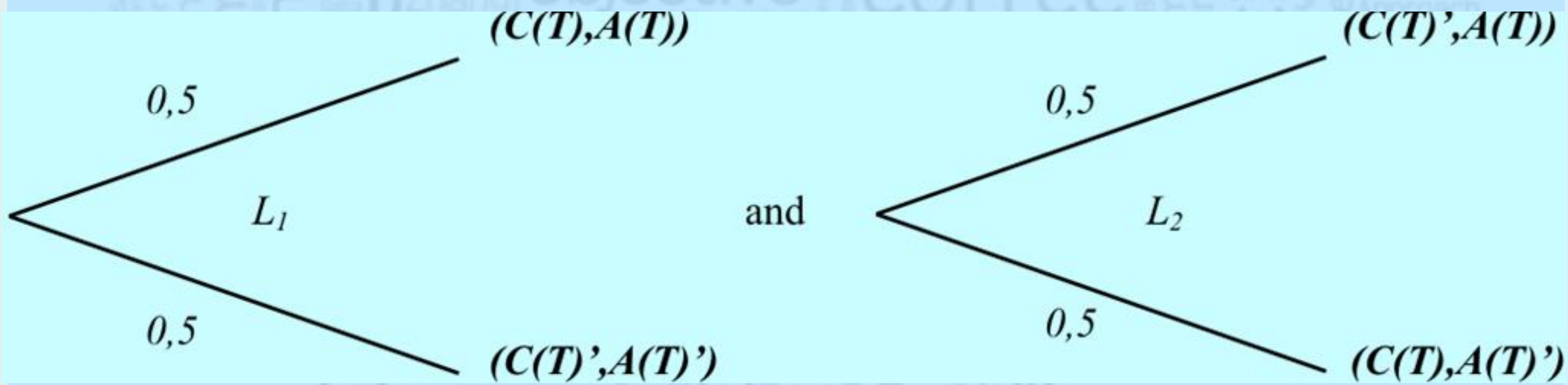
- Assessing the utility independence property to estimate the function *u(C(T),A(T))* when cost and downtime are





The Multi-attribute Utility Theory Model

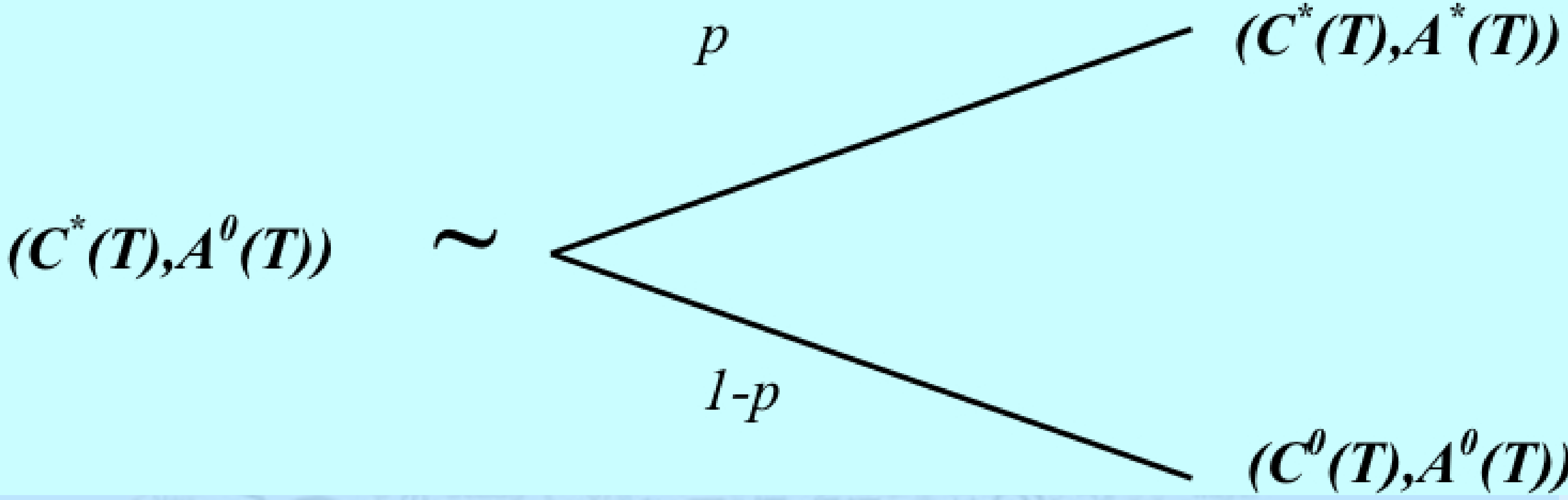
- Lotteries to check the property of additive independence



Criteria could not be independent preferentially for a given decision maker. In this case, specific procedures should be applied for deal with this situation, see Keeney & Raiffa (1976).

The Multi-attribute Utility Theory Model

- Lottery to find the scaling constant k_c



$$\max u(C(T), A(T)) = k_c u_c(C(T)) + k_a u_a(A(T))$$

A five steps procedure defined by Ferreira et al. (2009) is indicated to evaluate the consistency of multi-attribute utility function proposed in this paper

Case Study

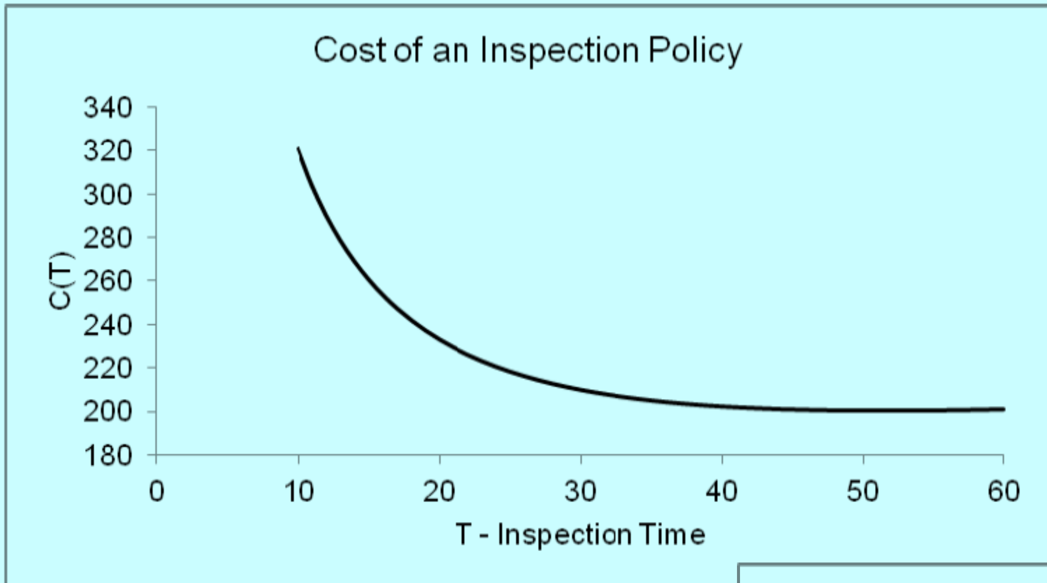
- Maintenance of pipelines
- Inspection of safety valves
- Complex system that has to be inspected in order to mitigate a consequence of failure
- T – inspection interval
- d_i – inspection duration
- d_d – minimal repair time
- d_f – corrective action time

Case Study

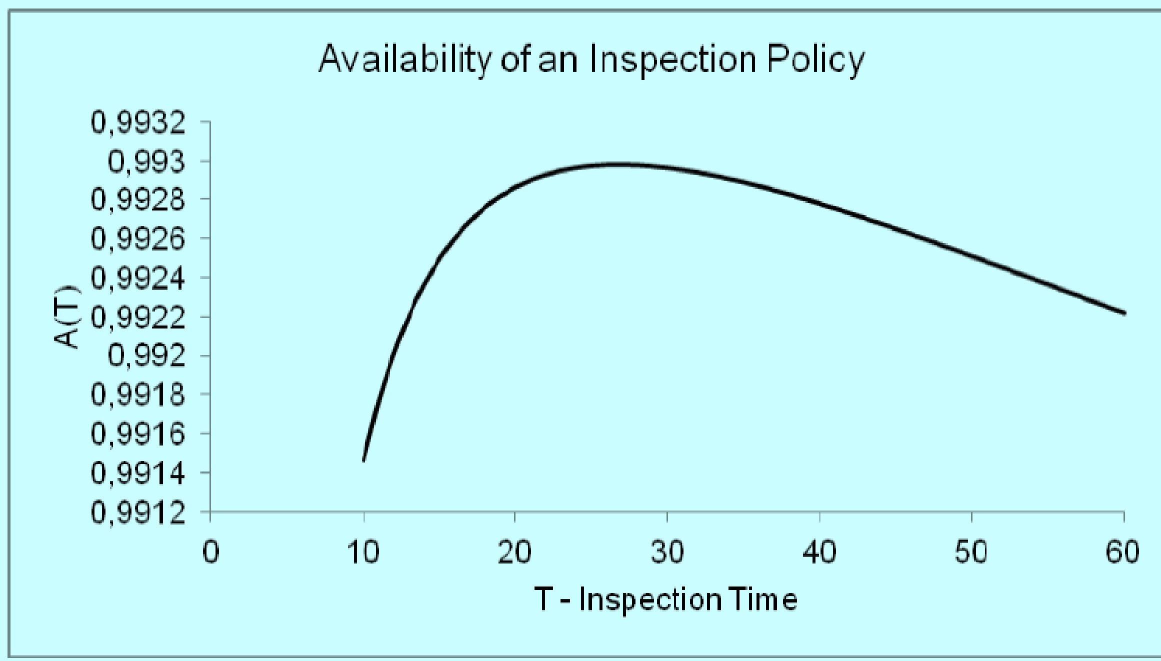
- cf – cost of failure
- cd – cost of minimal repair
- ci – cost of inspection

λ	0.022 faults per day
$h(\text{mean delay time})$	Exponential 60 days
d_i	1 hour
d_d	4 hours
d_f	14 hours
c_f	US$ 1,200.00
c_d	US$ 500.00
c_i	US$ 200.00

Case Study



- The minimum cost is US$ 200,43 for T=52 days and the maximum availability is 0,99298 for T=27 days.



Case Study

- MAUT was the approach chosen to deal with the uncertainty and the conflicting criteria, as well as to take into account the decision maker's preferences.
- The sequence of steps is as follows:
  - (1) introducing the terminology and idea;
  - (2) identifying relevant independence assumptions
  - (3) assessing conditional utility functions;
  - (4) assessing scaling constants;
  - (5) checking for consistency and reiterating.

Conclusion

- Multi-attribute utility theory to support the planning of an inspection policy.
- The concept of delay time was used to model the failure process of the valves
- Availability and Cost of inspection policy was analyzed


Thank you