Pricing a Motor Extended Warranty With Limited Usage Cover

By
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(ASTIN Colloquium)

Outline

1.Introduction to motor warranties.

2.Research Problem

3.The Model

4.Case Study

5.Concluding Remarks

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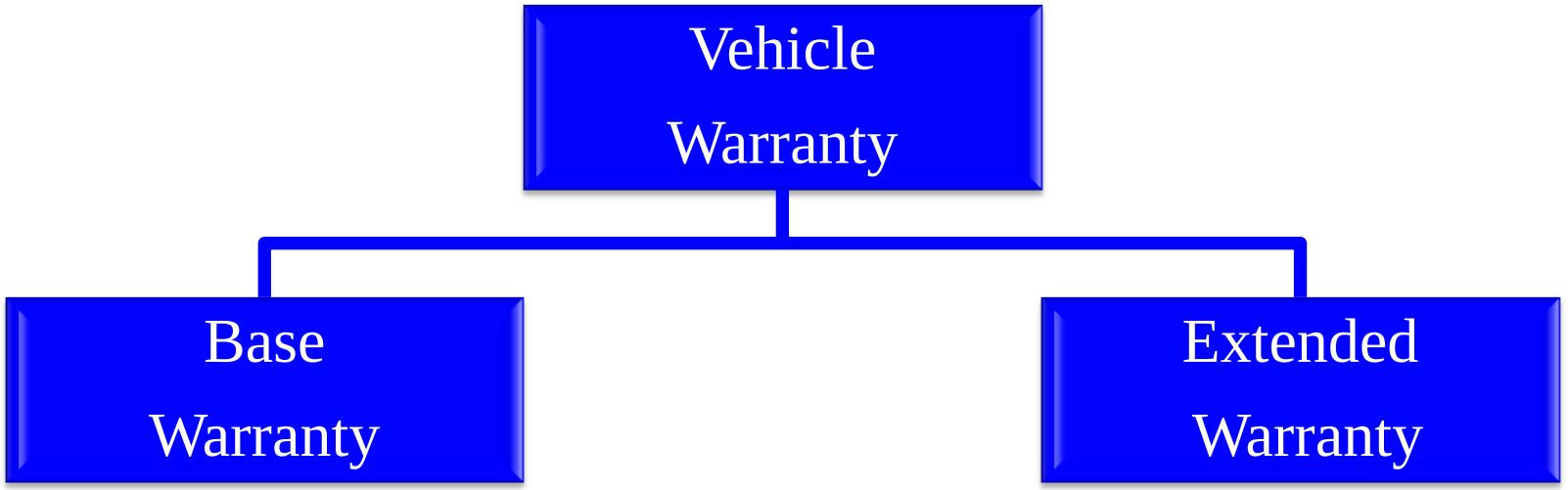
Introduction to Warranties

- Vehicle warranties compensate customers on covered parts that fail during the warranty term.
- Mechanical breakdown is the major peril.
- For mechanical breakdown, compensation is typically for parts and labour cost.
- Other secondary benefits include: roadside assistance, hotel accommodation and car rental.
- Service items are typically excluded from cover: e.g., oil filter, battery, brake pads and fuel filter.

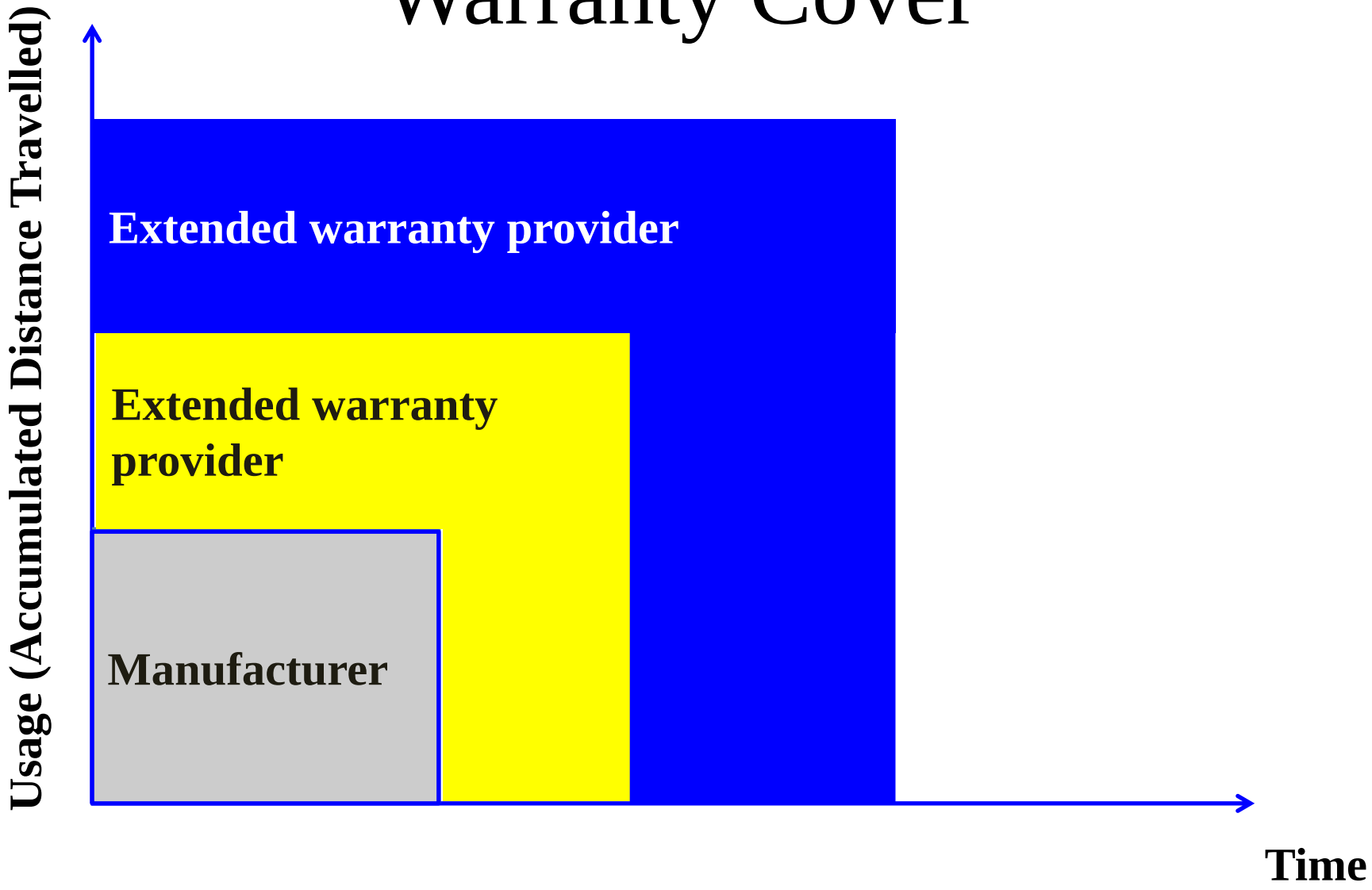
Types of Vehicle Warranties



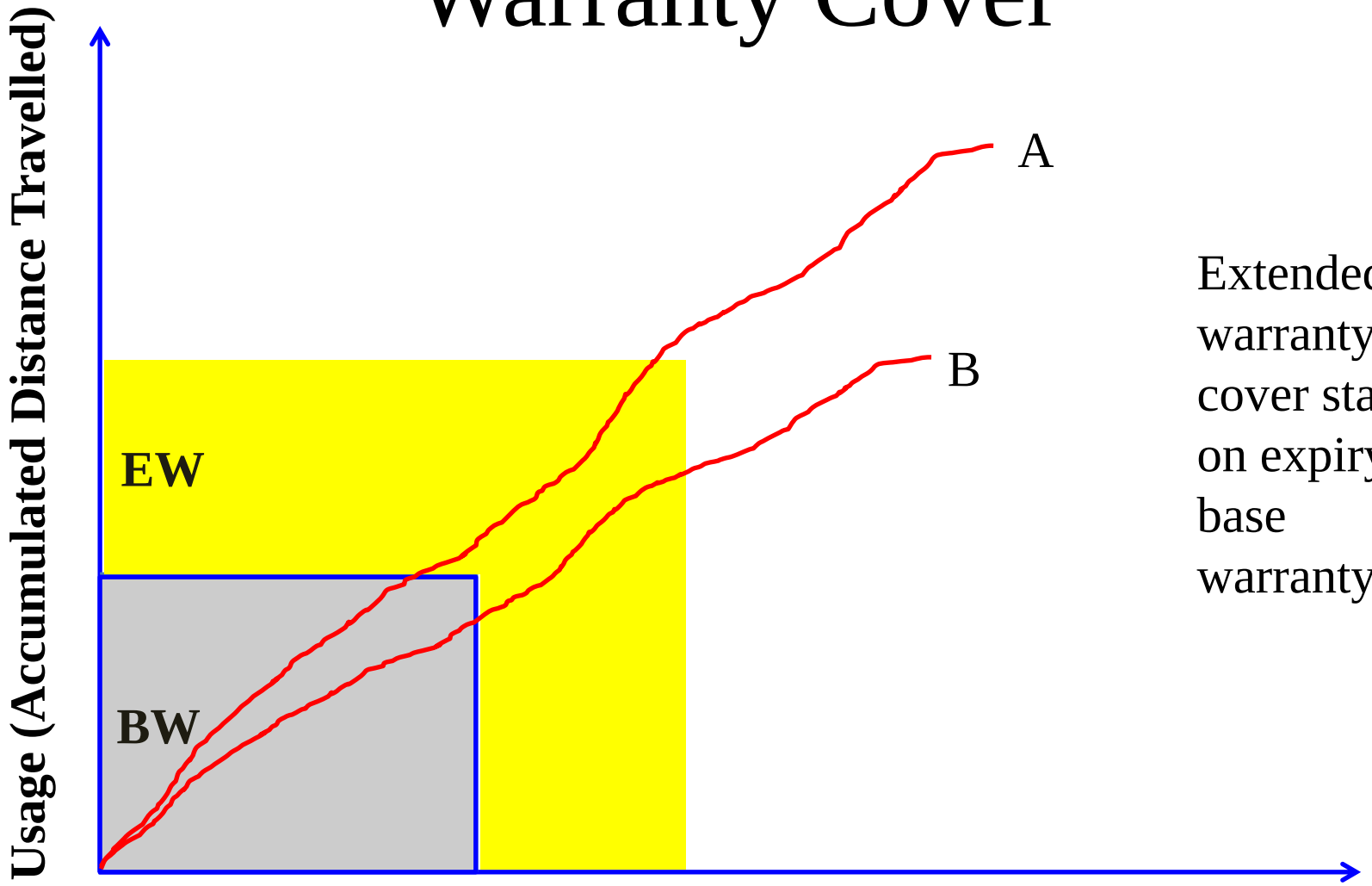
- Issued by manufacturer
- Tied to sale of new product
- Deemed as Non-insurance in most territories

- Issued by manufacturer and other third parties
- Customer has option to buy extended warranty
- Deemed as Insurance in most territories

Warranty Cover



Warranty Cover



Extended warranty cover starts on expiry of base warranty.

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Vehicle Exposure at Risk

- Exposure is unitised either as time or usage.
- The appropriateness of an exposure unit depends on the warranty cover.
- Usage limit allowed for by projecting the vehicle population at risk via a usage rate distribution (Cheng and Bruce (1993); Rai and Singh (2005); Majeske (2007); Alam and Suzuki (2009); Su and Shen (2012); Wu (2012); Shahanaghi et al. (2013)).
- These studies rely on the **premise** that usage rate is **constant** on a vehicle but varies across vehicles.

Research Questions

- If cover period is set on time and usage, how can a warranty provider estimate the probability of being on risk at a specific time in service?
- How does variation of vehicle age and accumulated usage, at point of extended warranty sale, influence the provider's exposure to risk?
- Can a usage rate distribution be reliably used to forecast the number of vehicles on risk?
- **Above all**, how do answers to the foregoing questions influence the 'fair' price of a motor extended warranty?

Research Contribution

- Developing an estimator of the probability that a warranty provider is on risk at a specific time in service.
- Employing a non-parametric interval-censored survival model to directly measure the probability distribution of time to accumulate a specific usage.
- Case study results suggest that employing a usage rate distribution to forecast the number of vehicles on risk can be misleading, especially on an extended warranty with a relatively high usage limit. This is despite observing that some positively skewed statistical distributions fit well to usage rate data.

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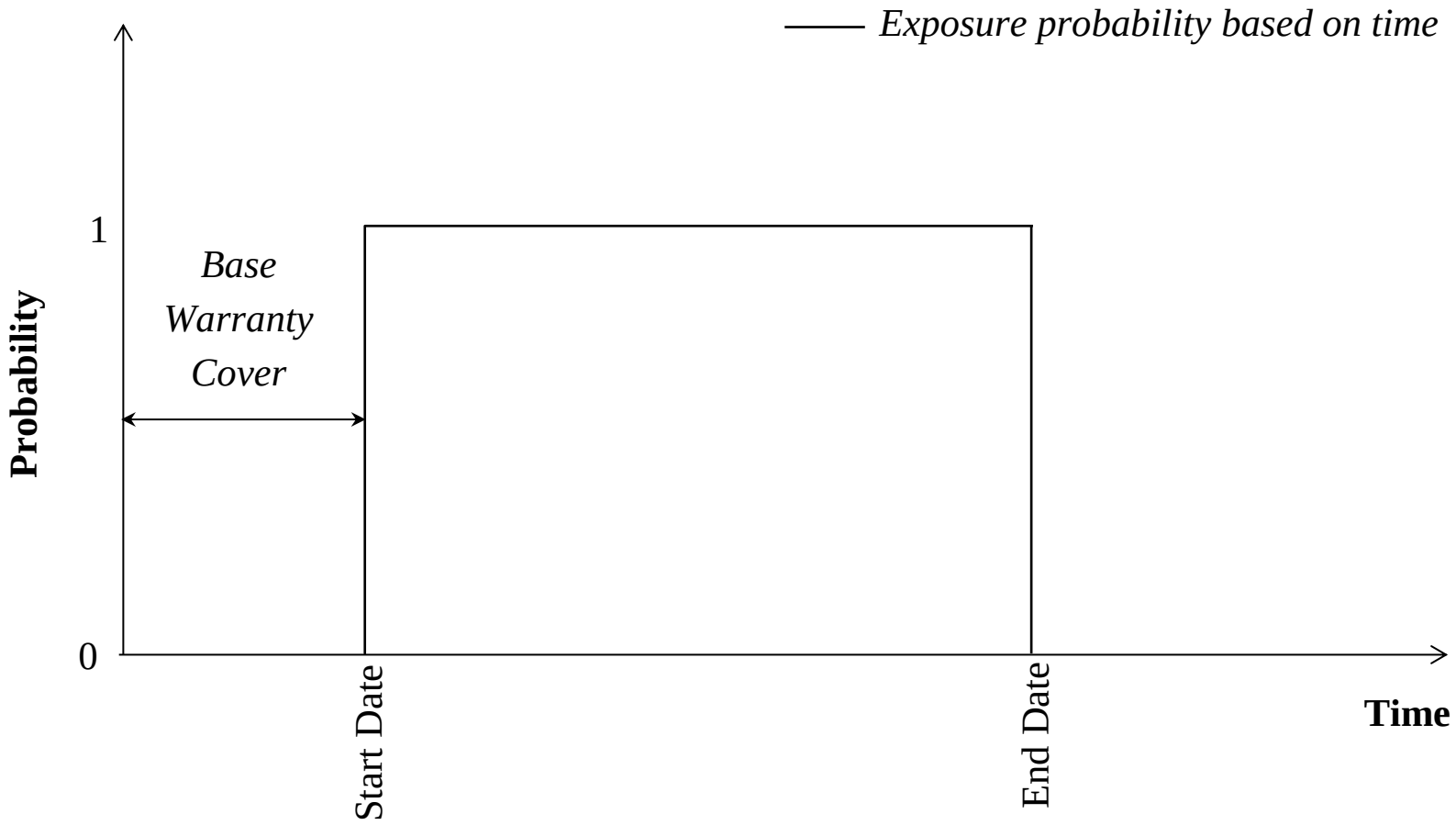
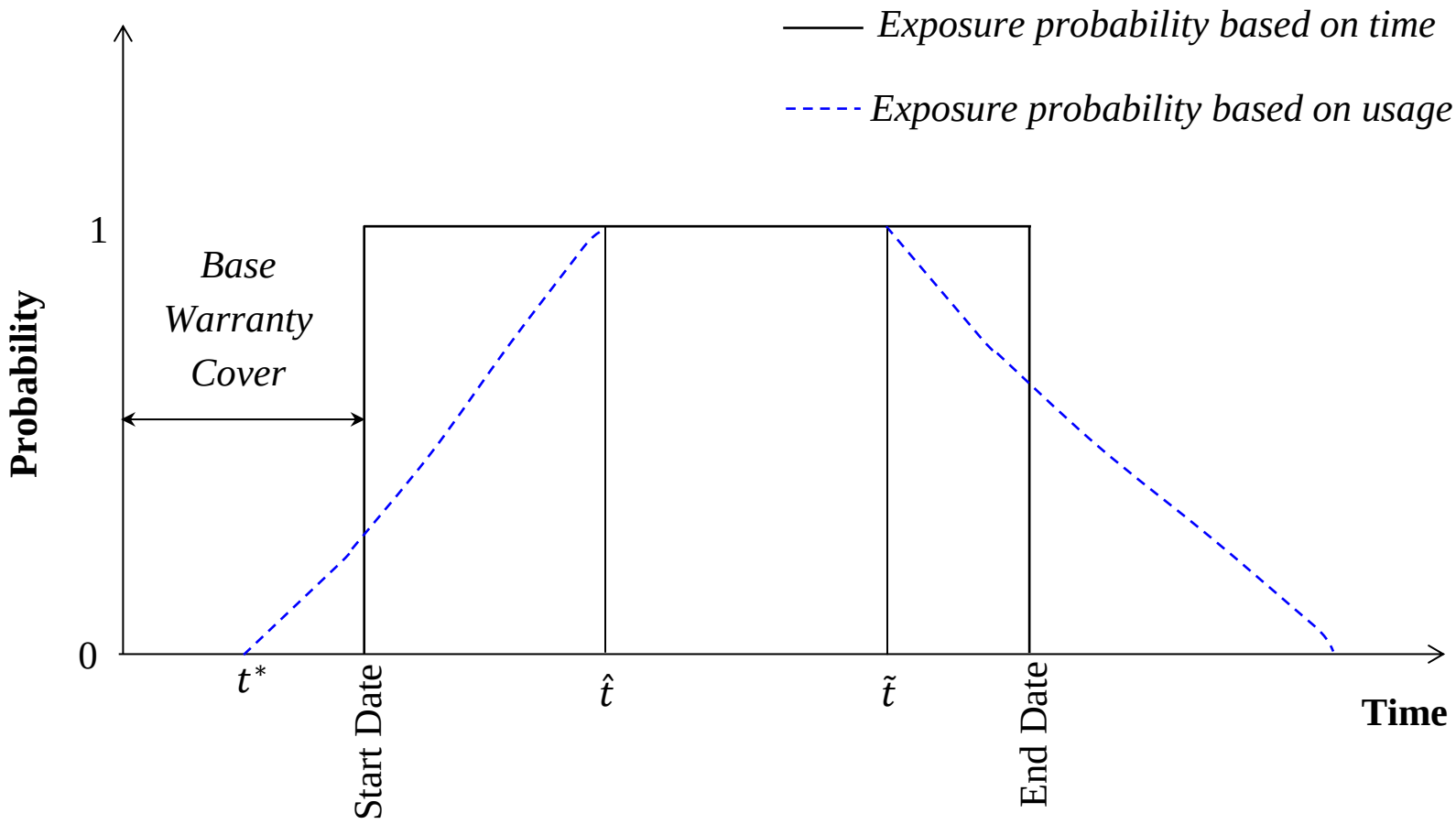
EW Provider Exposure Probability



EW Provider Exposure Probability



Survival Time To Accumulate Specific Usage

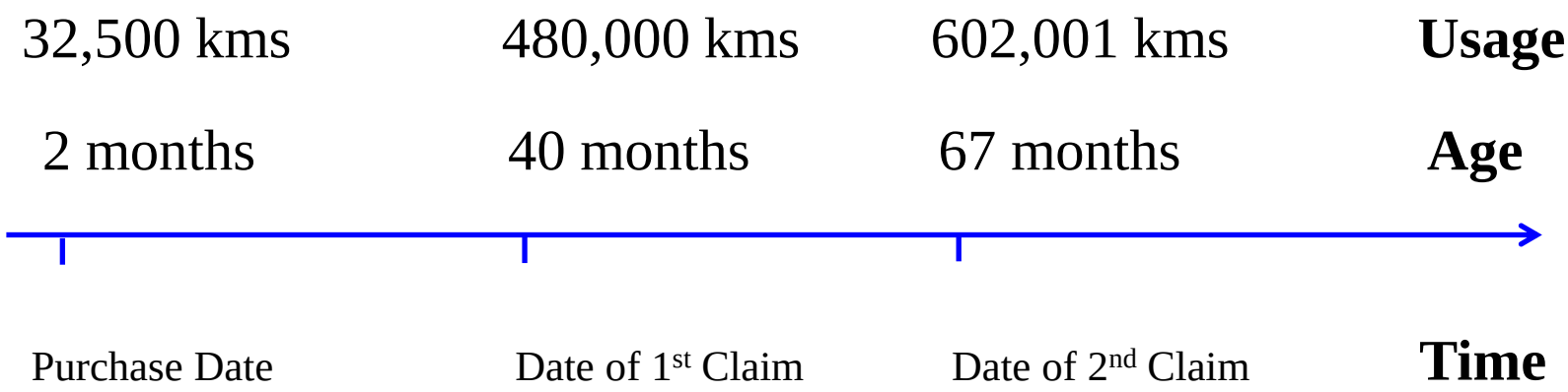
- Nonparametric interval-censored survival model.

$$S(t) = \Pr(T_U > t) = \Pr(U_t < U)$$

- Observed: $(L_i, R_i]$

$$\{T_U : L_i < T_U \leq R_i\}$$

Examples of Time Intervals



Interval for time to 400,000 kms: (L, R] = (2 months, 40 months].

Interval for time to 600,000 kms: (L, R] = (40 months, 67 months].

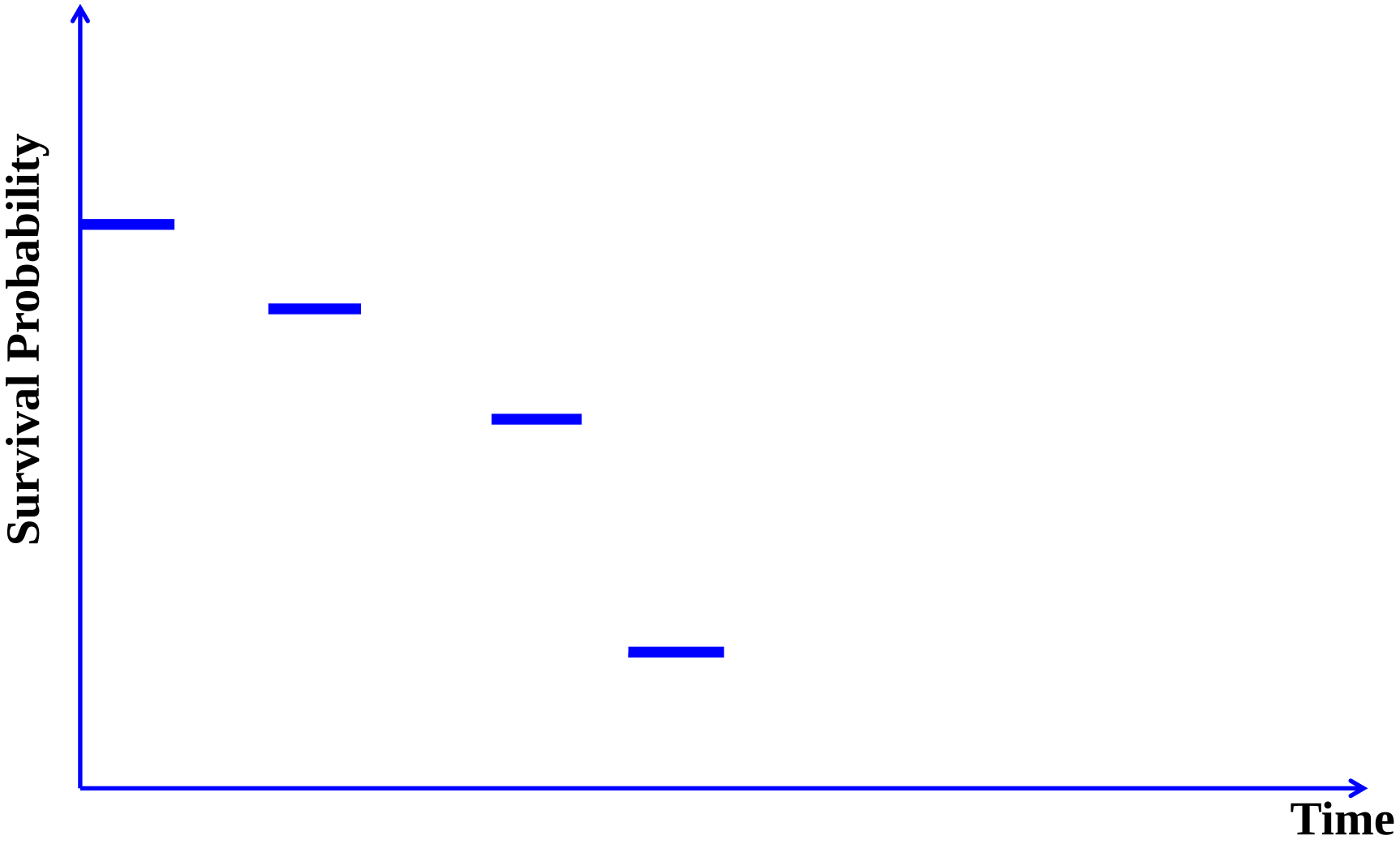
Interval for time to 800,000 kms: (L, R] = (67 months, ∞].

Nonparametric Maximum Likelihood Estimator

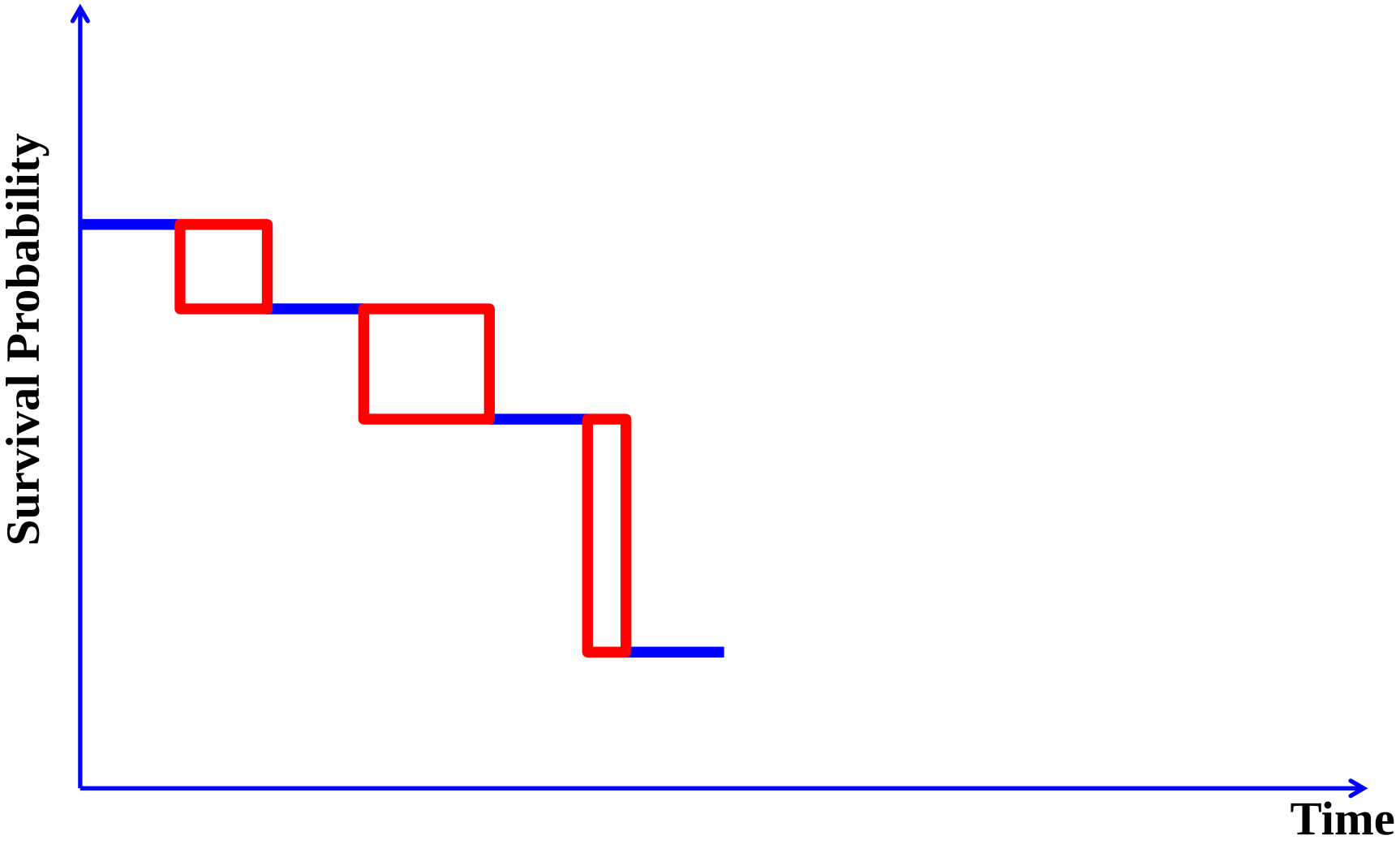
$$\text{Likelihood} = \prod_{i=1}^{n} \left[S\left(L_i\right) - S\left(R_i\right) \right]$$

- Closed form solution non-existent. So, iterative methods are used to estimate the survival function.
- For example:
  - Self consistent algorithm (Turnbull, 1976)
  - Expectation maximisation (EM) algorithm (Dempster et al., 1976)
  - Iterative convex minorant (ICM) (Groeneboom and Wellner, 1992)
  - EM-ICM algorithm (Wellner and Zhan, 1997).

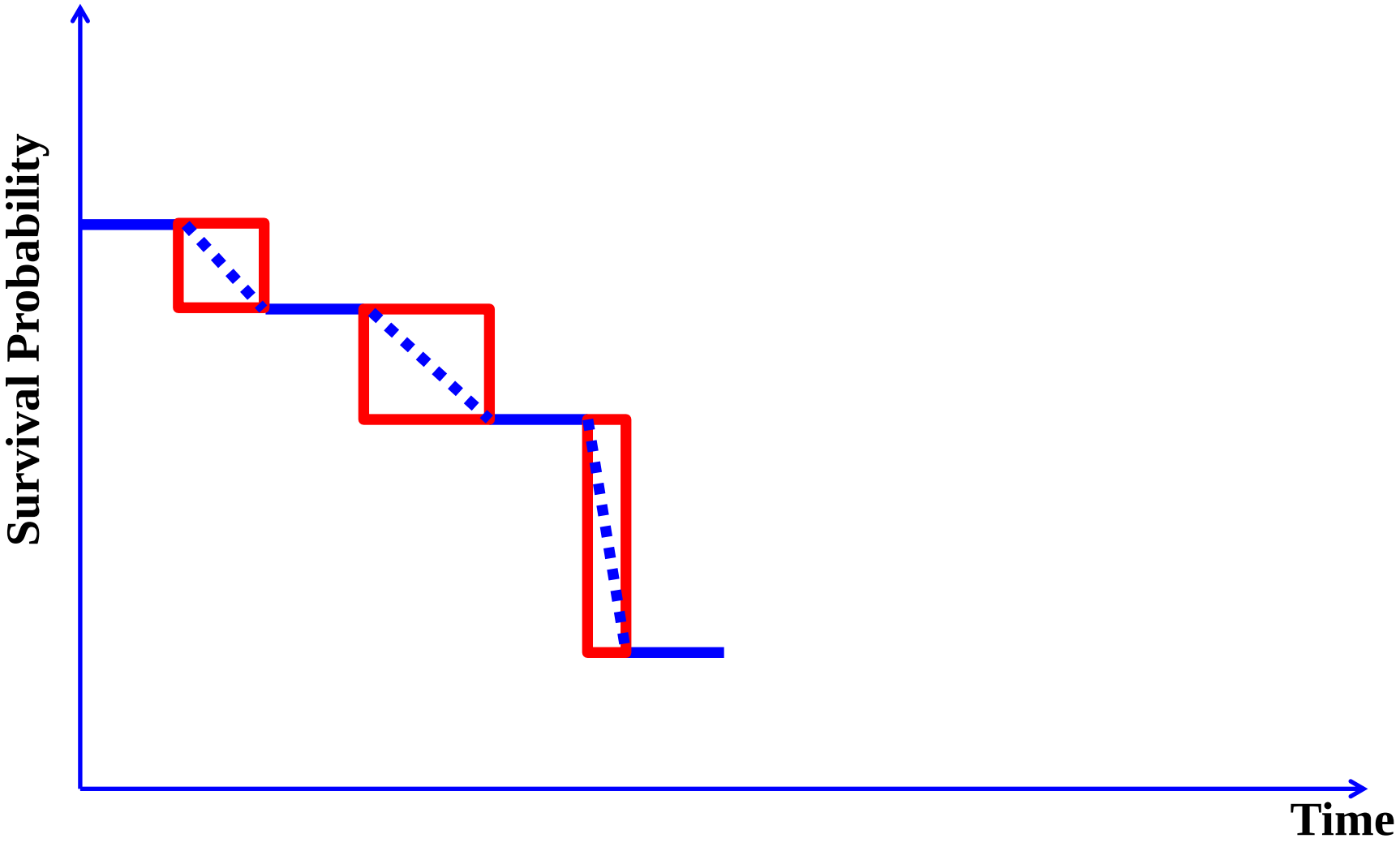
Interval-censored Survival Function



Interval-censored Survival Function



Interval-censored Survival Function



Warranty Risk Premium

$$\text{Risk premium} = \sum_{t} \left\{ \text{Cost per Exposure}(t) \times \text{Probability of Exposure}(t) \right\}$$

- Simulation can be employed to account for varied age and usage at extended warranty start date.

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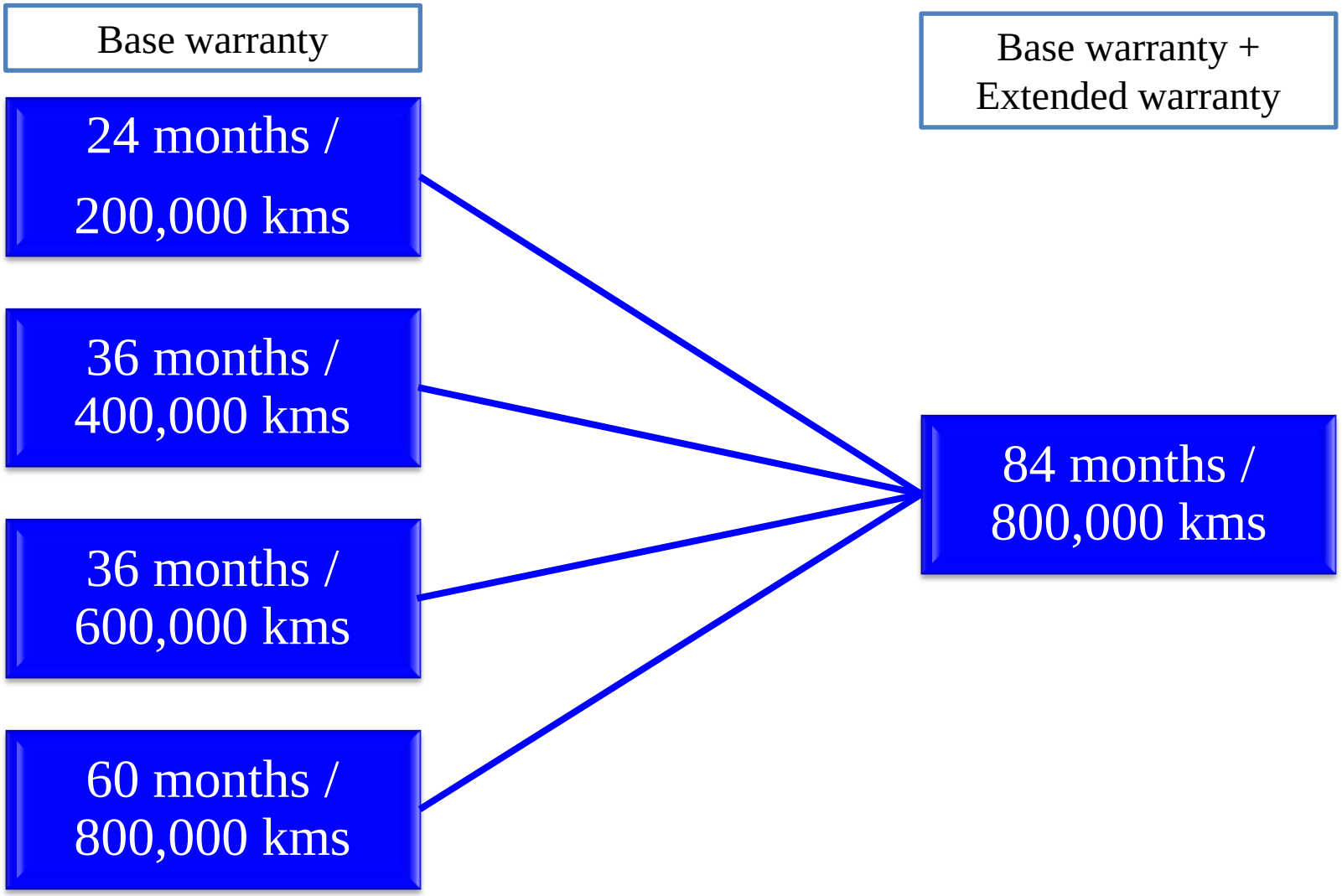
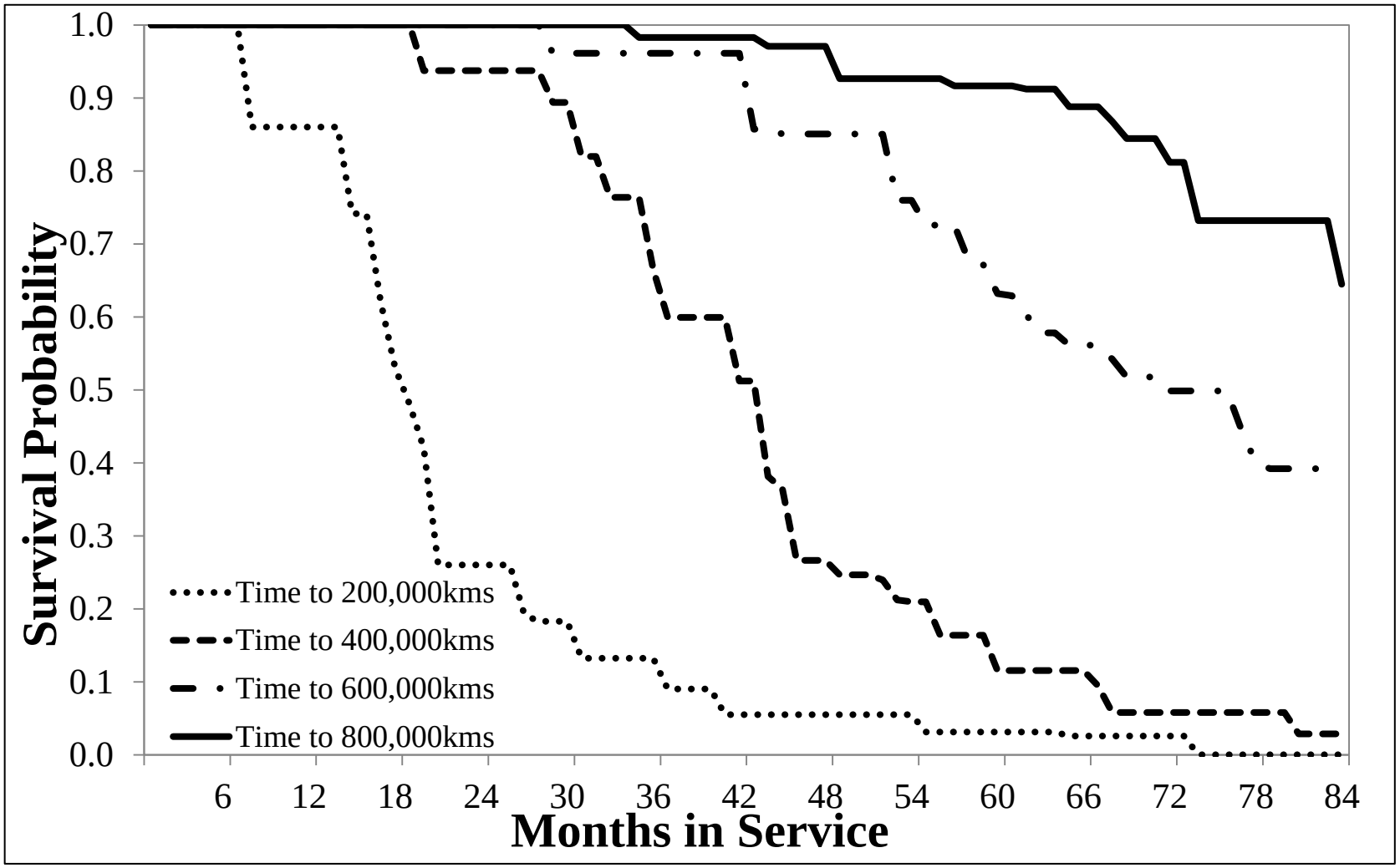
Data

- Proprietary data of insurer located in South Africa
- Eligibility: heavy commercial truck involved in medium or long-haul operations.
- Usage data source: Withdrawals, claims, policy inception and maintenance records. Total: 857 trucks.
- Claims data source: only warranty data used to estimate claim severity and frequency.

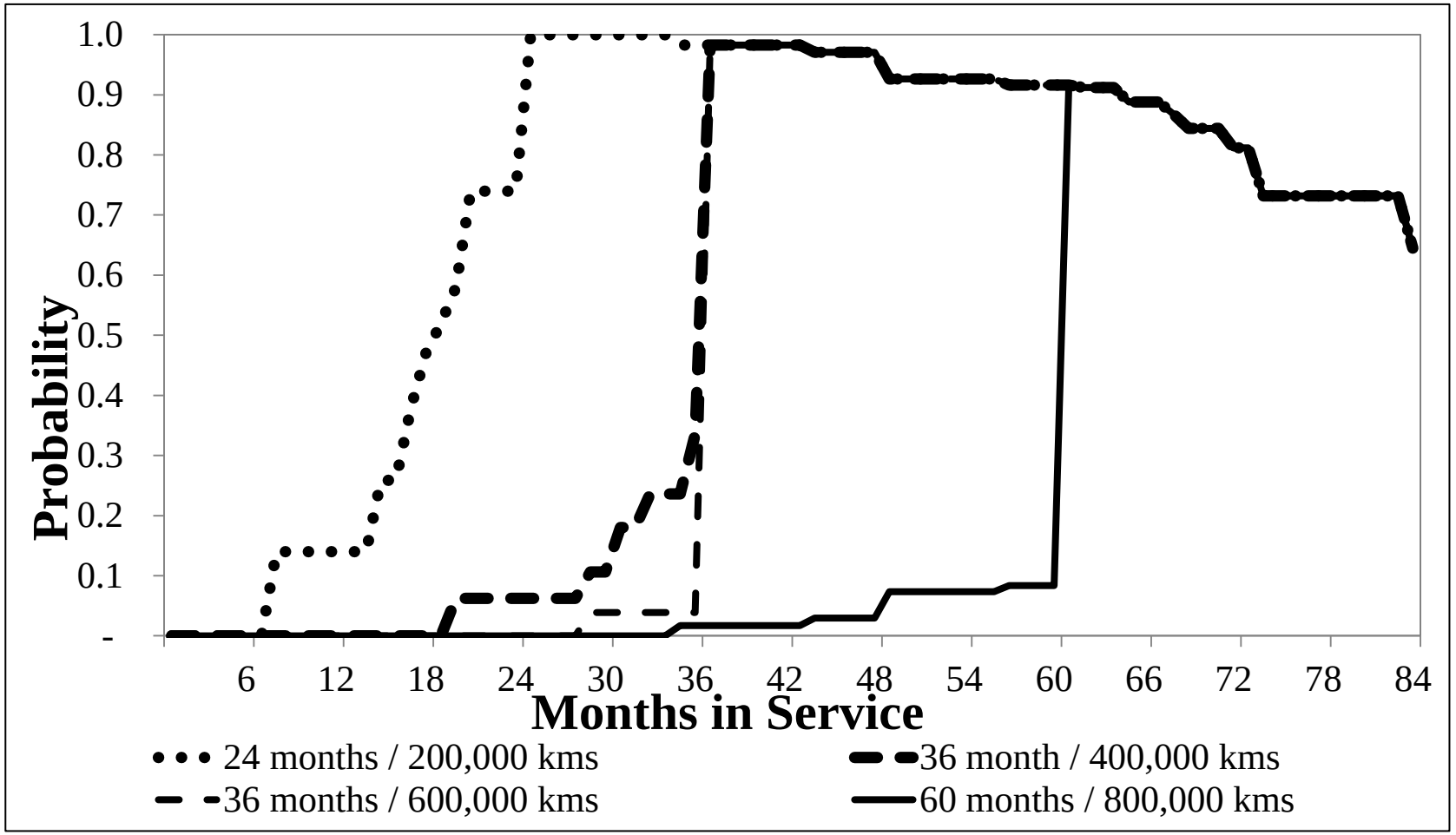
Pricing Objectives



Time to Reach a Specific Usage



Pr. of EW Provider Being on Risk



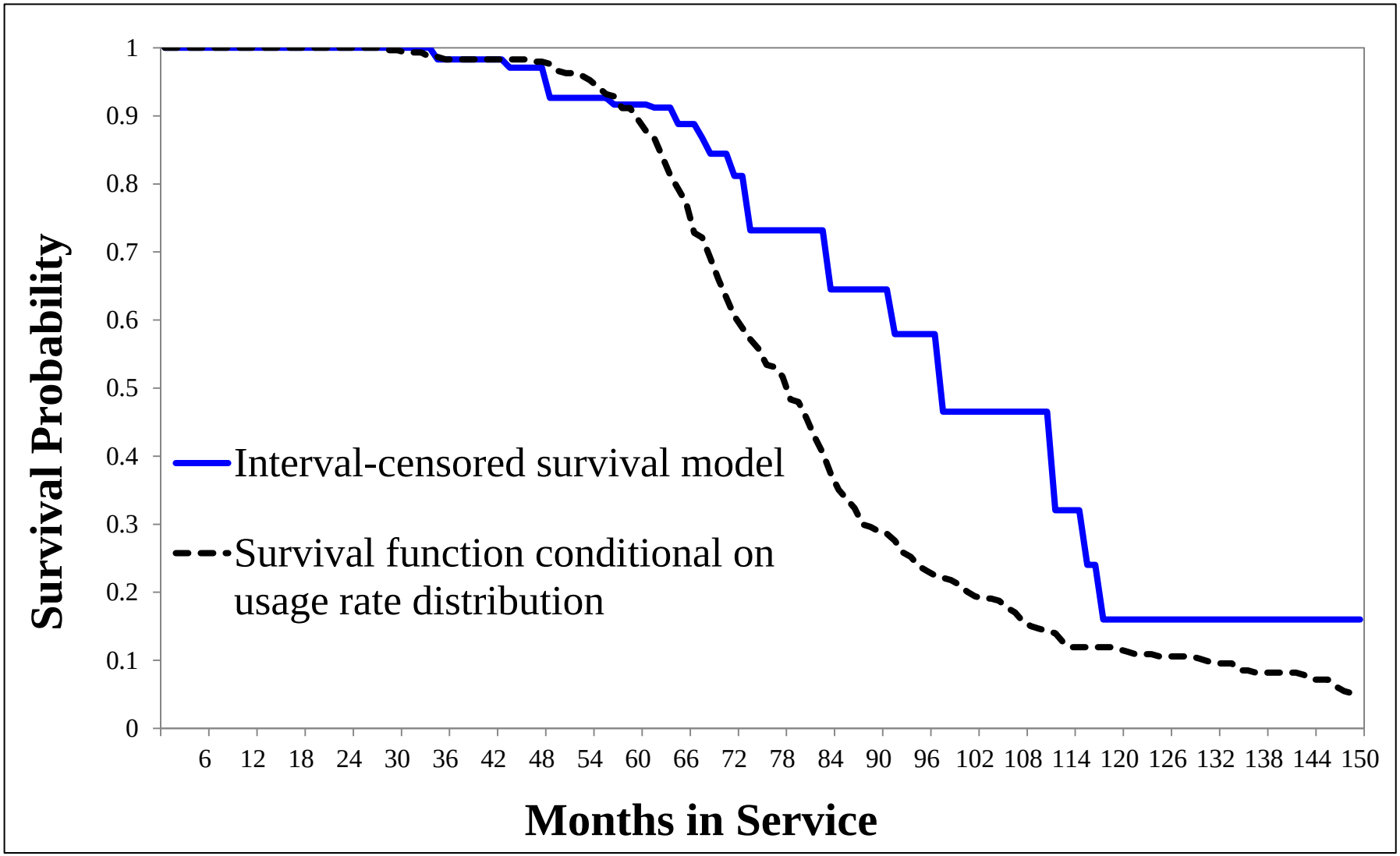
Weighted Log-rank Test Results

$$H_0 : S_{NPMLE}(t) = S\left(t \middle| g(u)\right) \quad \forall t$$

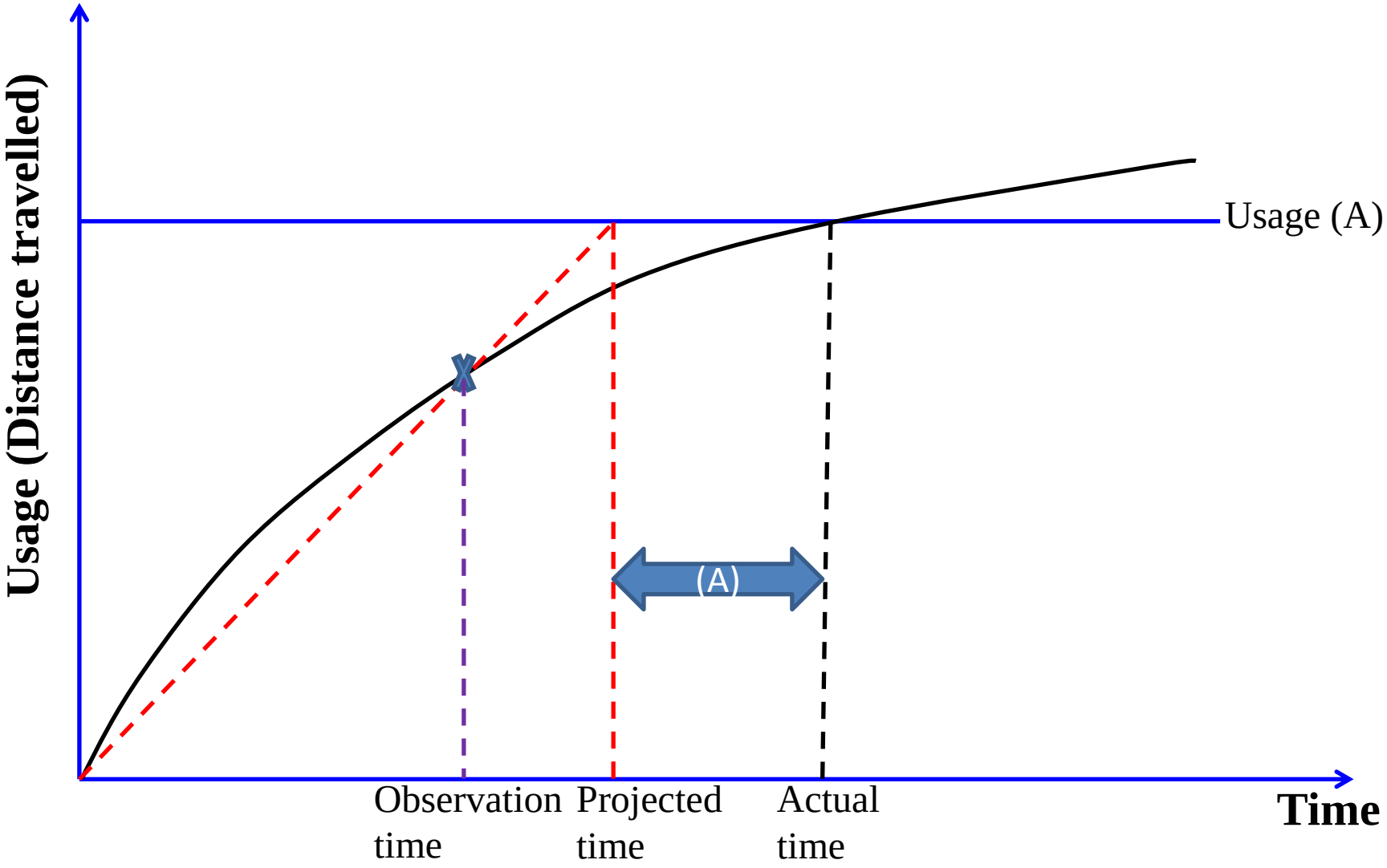
$$H_{alt} : S_{NPMLE}(t) \neq S\left(t \middle| g(u)\right) \quad \forall t$$

	Sun (1996) Score Test		Finkelstein (1986) Score Test		Fay and Shaw (2010) Monte Carlo Wilcoxon Test		
	Score Statistic	p-value	Score Statistic	p-value	Score Statistic	p-value	p-value 99% CI
Age at 200,000 kms	7.795	0.455	8.468	0.423	10.171	0.094	[0.093, 0.096]
Age at 400,000 kms	11.125	0.293	11.259	0.291	11.625	0.062	[0.061, 0.063]
Age at 600,000 kms	13.362	0.197	13.528	0.195	11.990	0.041	[0.040, 0.041]
Age at 800,000 kms	21.403	0.021	21.415	0.022	15.818	0.008	[0.007, 0.008]

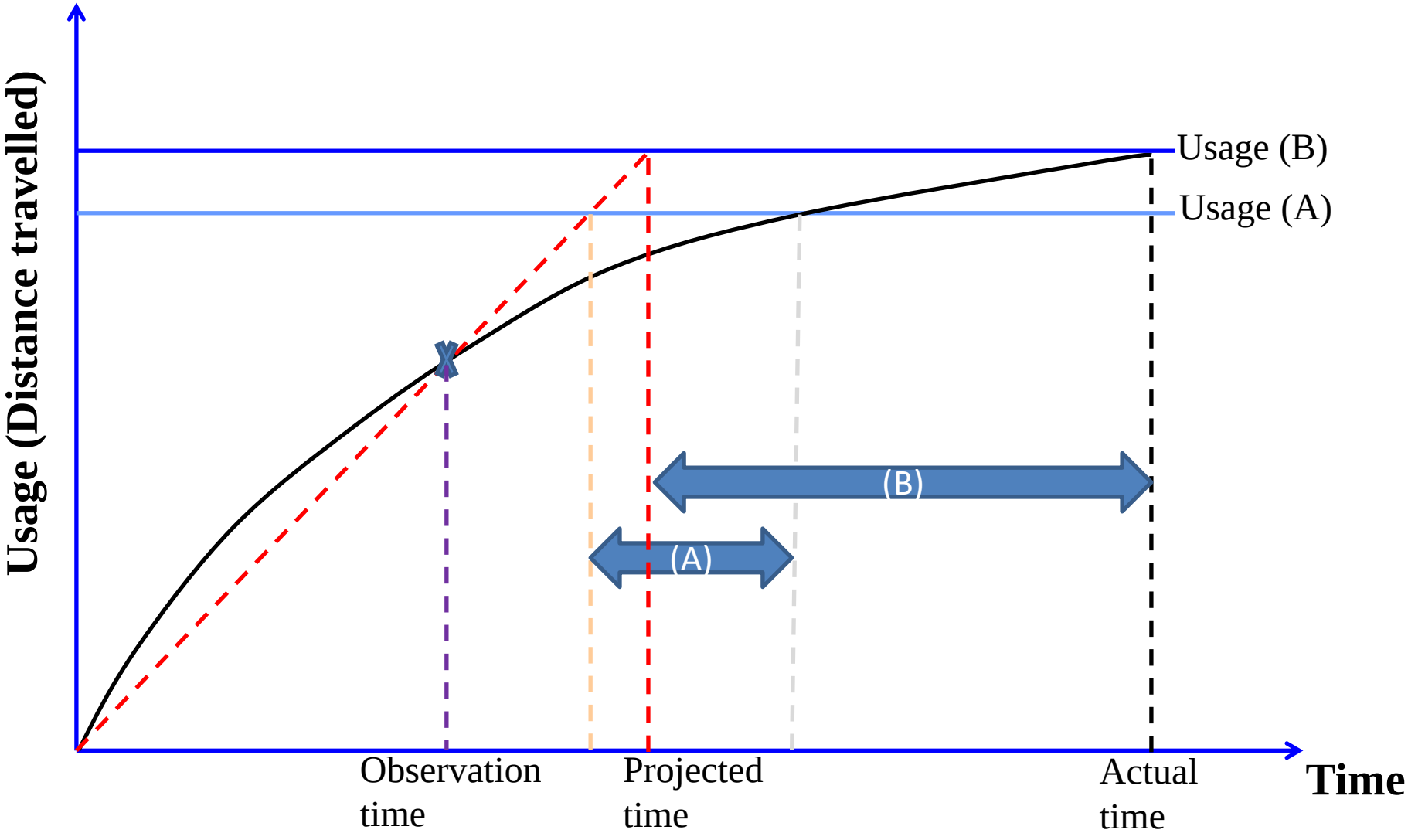
NPMLE vs Usage Rate Distribution (Time to 800,000 kms)



Plausible Explanation



Plausible Explanation



Goodness of Fit Test Results

Distribution	Parameter Estimates	Anderson-Darling Test Statistic	p-value
$Lognormal(\mu,\sigma)$	μ = 8.96; σ = 0.44	0.38	0.39
$Gamma(\alpha,\beta)$	α = 8.24; β = 0.98×10^{-3}	0.27	0.66
$Weibull(\alpha,\beta)$	α = 3.22; β = 9,614.29	0.25	0.73

- Results reaffirm that positively skewed statistical distributions fit well to usage rate data (Shahanaghi et al., 2013; Su and Shen, 2012; Jung and Bai, 2007; Kerper and Bowron, 2007; Majeske, 2007; Rai and Singh, 2005).
- This suggests that a parametric usage rate distribution is neither a necessary nor sufficient condition for knowledge about the survival time to accumulate a specific usage.

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Summary

- The effect of limiting usage on an extended warranty's risk premium can be captured through determining a provider's probability of being on risk at a specific time in service.
- Interval-censored survival models can suitably be employed to estimate exposure probabilities, especially given that extended warranty providers often have incomplete data on how usage accumulates with time.
- Employing a usage rate distribution can result in underestimating the risk premium.

Future Research

- Investigating if the distribution of time to a specific usage is stable over time.
- Accounting for other decrements when estimating exposure probabilities: For example:
  - Withdrawal
  - Accident
  - Theft.
- Incorporating factors to explain variations in the time to attain a specific usage, e.g. through an interval-censored proportional hazard model.