Book Review: "Survival Analysis Using SAS", 2nd Edition, by Paul D. Allison

Reviewed by
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Highly Regarded Reference

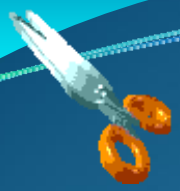
- "Allison gives, in my opinion, the best discussion I have seen of the tests done by the STRATA and TEST statements in PROC LIFETEST." Paul T. Savarese, Sr. Technical Support Statistician, SAS Institute

- Many references to the Allison book in the University of Michigan CSCAR course, “Applied Survival Analysis and Reliability Analysis” by Brenda Gillespie and Ananda Sen.

- Supplementary text book for BioStat 675 (Survival Analysis) at the UM School of Public Health.

Syllabus for BioStat 675

- Introduction to survival data; Censoring and Truncation (Ch 1, 2)
- Distributional characteristics of survival times (Ch 2)
- Cure models, residual survival function (not in Allison book)
- Life table, the Kaplan Meier, and Nelson-Aalen estimates (Ch 3)
- Two- and k-sample hypothesis tests (Ch 3)
- Parametric survival models (Ch 4)
- Cox regression model, partial likelihood (Ch 5)
- Time-dependent covariates, model diagnostics (Ch 5)
- Counting processes (some discussion in Allison, but not at theoretical level of BioStat 675)
- Competing risks (Ch 6)
- Additional topic in Allison (Ch 8: Heterogeneity of Variance, Repeated Events). This was on the advanced topics (if time available) for my course.



Ch 2: Basic Concepts of Survival Analysis

- **Good examples of censoring.**
- Right censoring: T > c.
- Example: Age of death ≥ 50; c = 50.

- Left censoring: T < c.
- Example: Age of onset of disease. If exact age of onset is unknown, set c = age of entry into study and consider the observation to be left censored.

- Interval censoring is another type of censoring, a < T < b..

- Procs LifeTest and LifeReg can handle right, left, or interval censoring.
- However, Proc PHReg can only handle right censoring.
- Right censoring is most common in survival analysis.

Ch 2: Fundamental Formulas

- F(t) = CDF (Cumulative Distribution Function) = Pr(T ≤ t)
- S(t) = Survival Function = 1 – F(t) = Pr (T > t).
- f(t) = pdf (probability density function) = -dS(t)/dt.
- h(t) – Hazard Function = f(t)/S(t) = -d(ln(S(t))/dt.
- Λ(t) = Cumulative Hazard Function

$$\Lambda(t) = \int_0^t \lambda(u)du = -\ln\left(S(t)\right)$$

$$S(t)=\exp\left(-\Lambda(t)\right)$$

Ch 3: Proc LifeTest

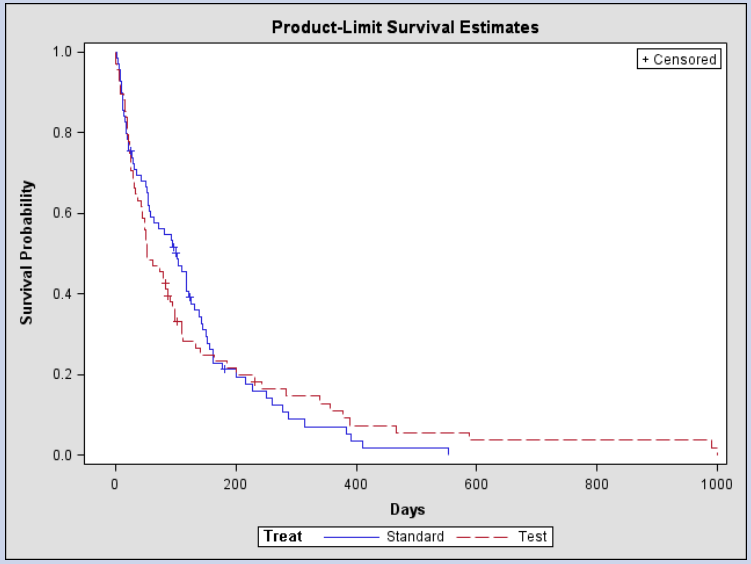
- Estimating and comparing survival curves
- Clear Presentation of formulas for survival functions.

Kaplan – Meier Method	Life Table/ Actuarial Method
$\hat{S}(t) = \prod_{j:tj \le t} \left[1 - \frac{d_j}{n_j} \right]$	$\hat{s}(t) = \prod_{j:tj \le t} \left[1 - \frac{d_j}{\left(n_j - \frac{c_j}{2} \right)} \right]$

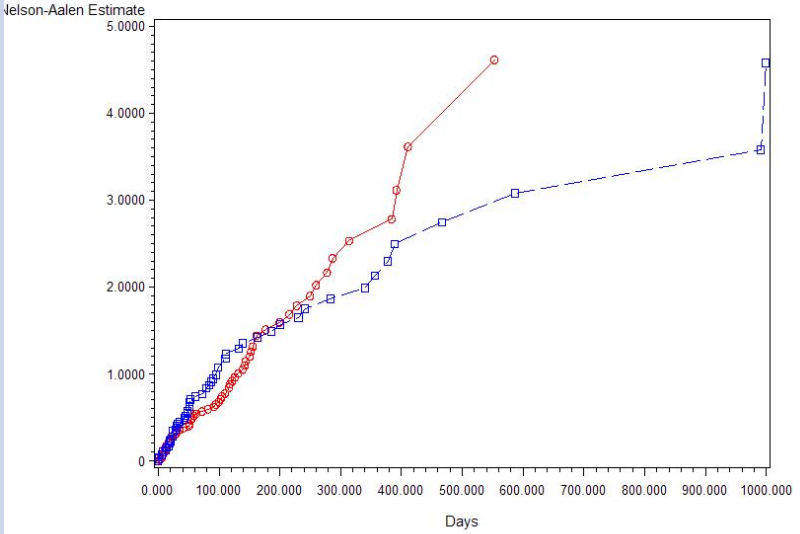
- Wilcoxon and Log Rank tests for equality of survival curves.
- Graphics options in Proc LifeTest.

Ch 3: Proc LifeTest Survival and Cumulative Hazard Plots

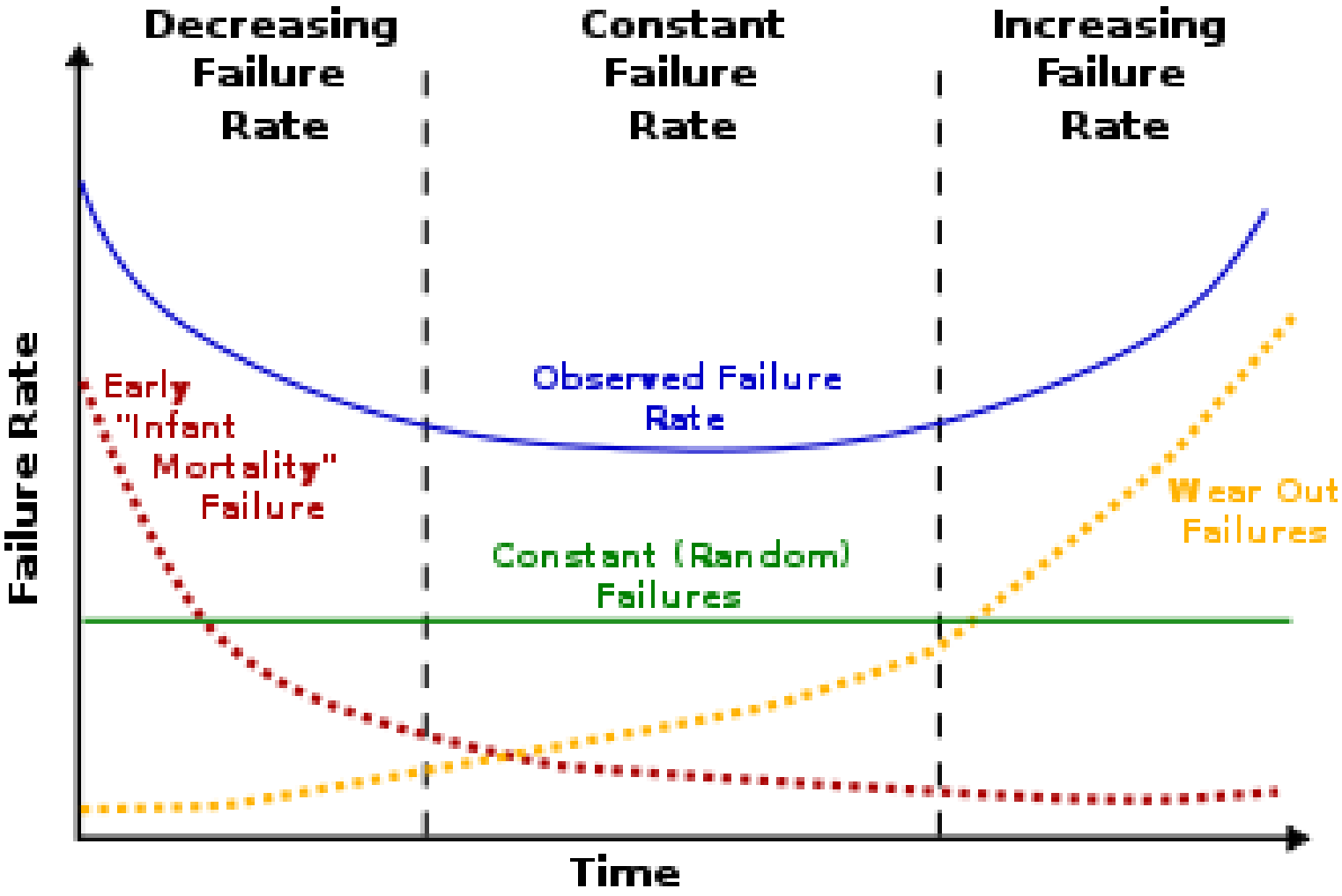
Kaplan-Meier Survival Plot



Cumulative Hazard Plot



Weibull Regression – Bathtub Curve

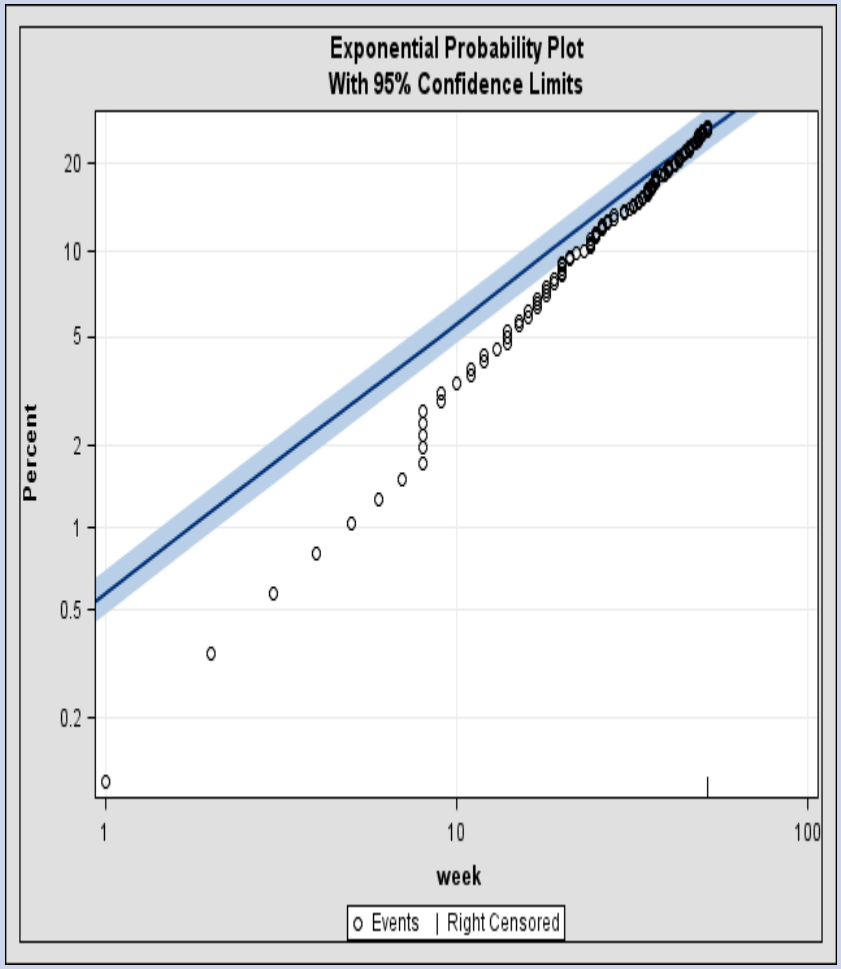


Ch 4: Parametric Regression (Proc LifeReg)

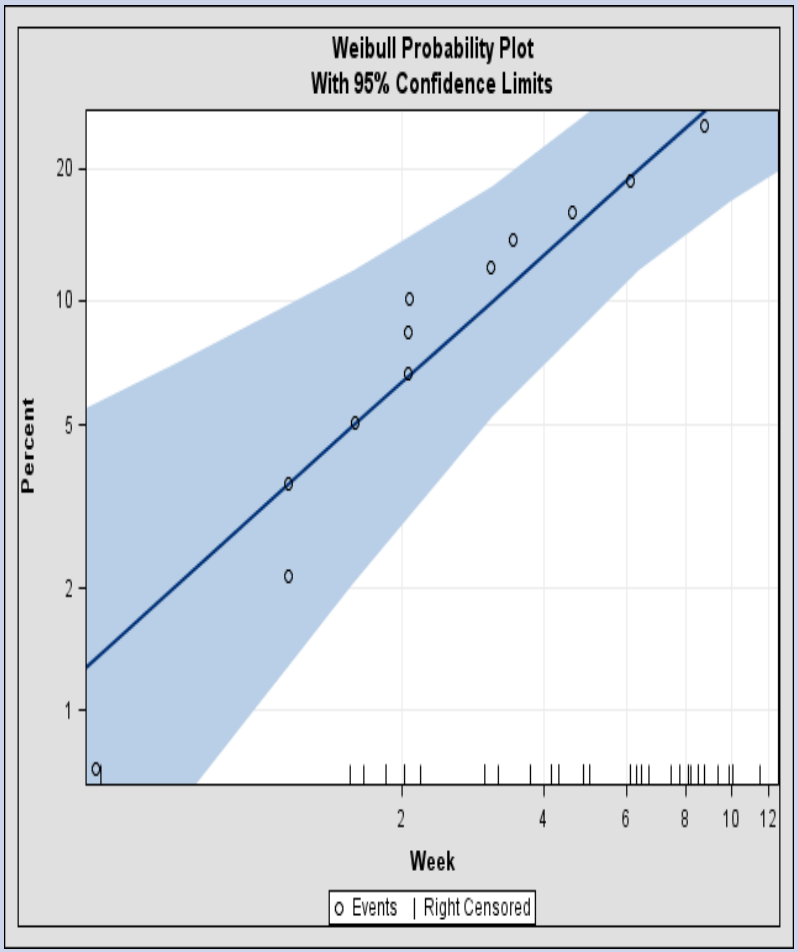
- Clear presentation of the theory.
- Accelerated Failure Time Model. Example: 1 dog-year = 7 human years. $S_{human}(t) = S_{dog}(\Phi t)$, $\Phi = 7$.
- Clear Presentation of formulas, especially liked the table on page 77 of the distribution of residuals, depending on the distribution of time.
- Good examples of SAS code, including the ProbPlot statement for checking the fit of the model. Model Y = X1 X2 X3; ProbPlot;
- Derivation of maximum likelihood equations.
- Conversion of model coefficients between Weibull and Proportional Hazards models, p. 80.

Ch 4 Proc LifeReg Diagnostic Plots Using "ProbPlot," From Allison's Book, pp. 101 - 103

Exponential Model



Weibull Model



Ch 5: Proportional Hazards Reg (Proc PHReg)

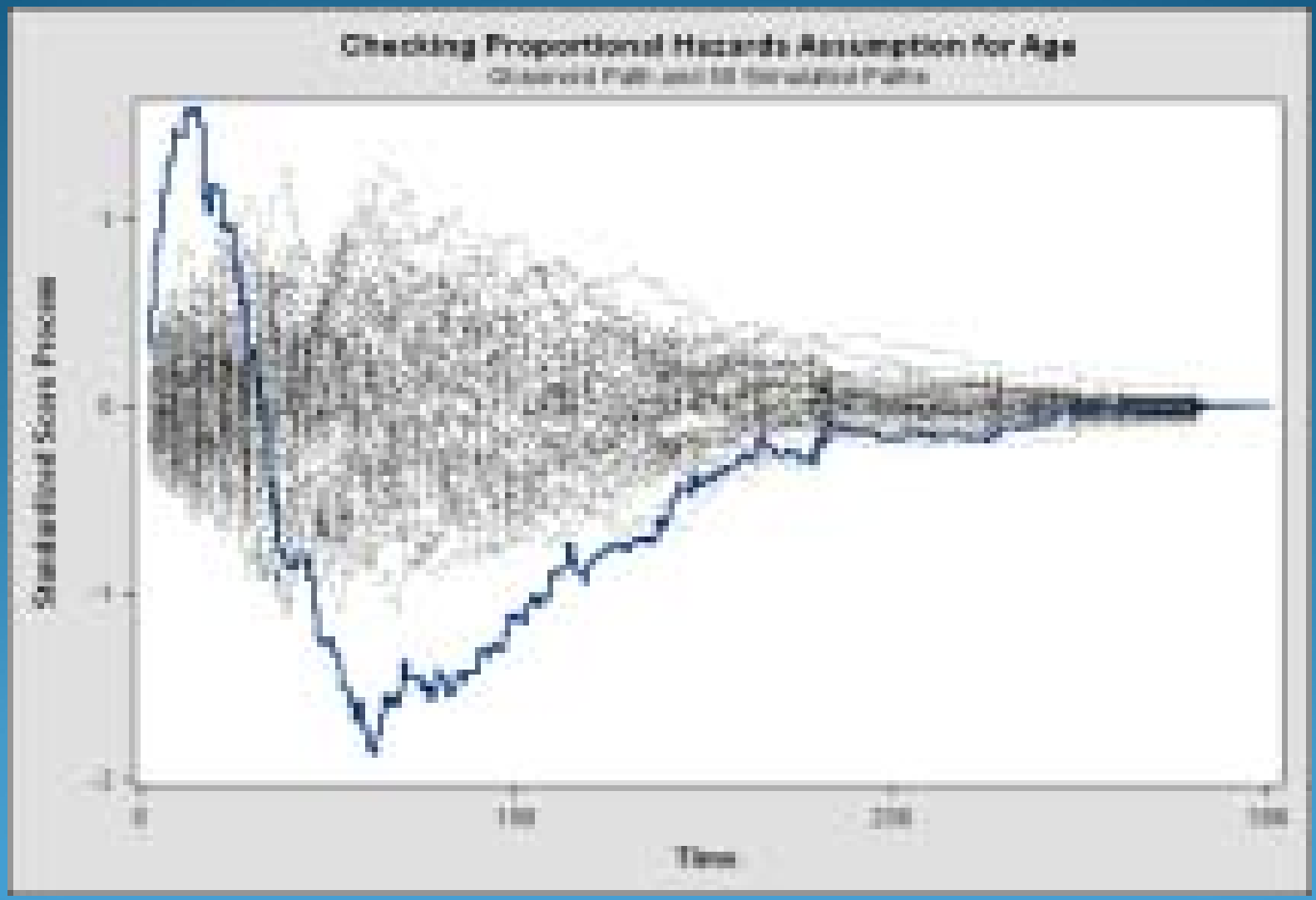
- Clear explanation of proportion hazards model. Made point that the model is popular because no assumption of the shape of the survival function is required and time-dependant covariates can be included in the model.

- $\lambda(t) = \lambda_0(t)\exp(\beta_1 X_1 + \beta_2 X_2 + .. + \beta_m X_m)$
- To compare the hazard ratio between X_2 at a+1 to a, the expression for the hazard ratio will be $\exp(\beta_2)$.

- Sections on partial likelihood, time dependent covariates, stratification.

- Discussion of checking residuals includes using the Assess statement for individual covariates.
- Although he mentioned checking the overall residuals for the model, no example of smoothed Martingale residuals.

Ch 5: Example of Diagnostic Plot for Covariate (Age)



Summary

- Allison's book closely, but does not exactly follow the syllabus for a masters level survival analysis course.
- The book provides material for more than a one-semester course and covers advanced topics, such as models with heterogenous variance and Bayesian methodology.
- The sections on theory are clear and concise, and useful for a text book supplement.
- Many excellent, practical examples of SAS code.
- Agree with SAS Institute and UM CSCAR that the book is a useful reference for anyone doing survival analysis with SAS, whether student, researcher, or applied statistician.

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