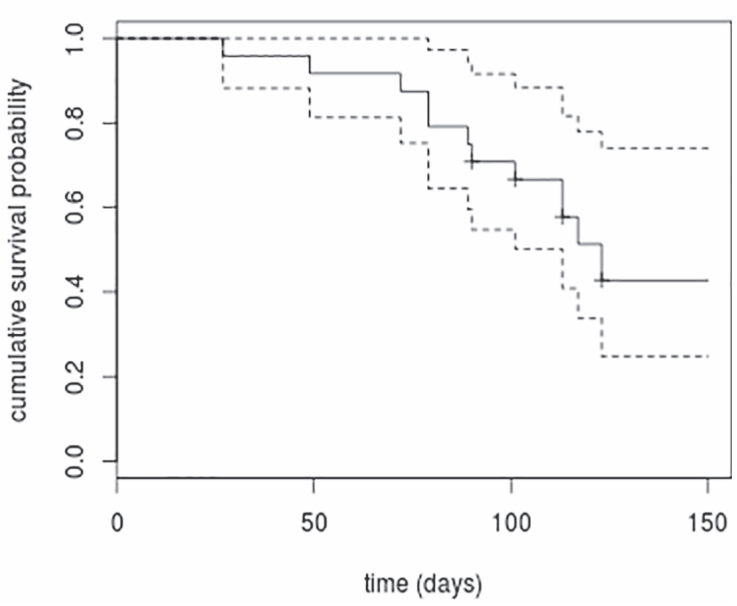
History of survival analysis

LIBERATO CAMILLERI

The term 'survival analysis' has been used for data involving time to a certain event such as death, onset of a disease or relapse of a condition. The development of survival analysis dates back to the 17th century with the first life table ever produced by John Graunt in 1662.

Throughout the centuries, survival analysis was solely linked to the investigation of mortality rates; however, in the last few decades, applications of the statistical methods for survival data analysis have been extended beyond biomedical research to other fields such as criminology, sociology, marketing, institutional research and health insurance practice.

Survival analysis plays an important role when analysing data on events observed over time, such as death, cardiac arrest, relapse of drug addiction or failure of an electronic device. Besides identifying the significant risk factors, the survival model ranks these hazards by their importance in predicting survival durations. This information is essential to surgeons, psychologists and manufacturers to address these risk factors optimally.



Kaplan Meier survival probability curves. PHOTO: HTTPS://WWW.R-BLOGGERS.COM/VETERINARY-EPIDEMIOLOGIC-RESEARCH-MODELLING-SURVIVAL-DATA-NON-PARAMETRIC-ANALYSES

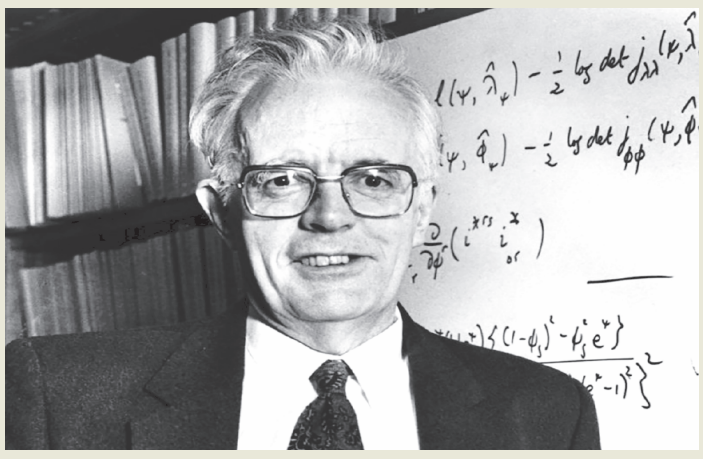
The contributions of Kaplan and Meier in 1958 in estimating survival probabilities and hazard rates led to ground-breaking improvements in survival analysis. The Nelson-Aalen estimator is an alternative non-parametric estimator of the cumulative hazard rate. The proportional hazard model proposed by Cox in 1972 was another significant contribution to survival analysis. This semi-parametric model consists of two parts. The first component is the baseline hazard, which is a function of time and describes how risk varies over time. The second component is an exponential function of a linear combination of the predictors and is independent of time.

In essence, the Cox model can be used to compare the relative forces of mortality of two lives or two homogeneous groups of lives. These non-parametric and semi-parametric survival models assume that the members in a population are similar and so are inappropriate in the presence of unobserved diversity.

Further developments in survival analysis include the shared and unshared frailty models introduced by Vaupel in 1979 and extended by Hougaard in 1984. These models are more appropriate in accommodating heterogeneity and random effects as they eliminate biases in estimation.

Liberato Camilleri is an associate professor at the Department of Statistics and Operations Research at the Faculty of Science of the University of Malta.

PHOTO OF THE WEEK



Sir David Cox was born in Birmingham in 1924. He studied mathematics at St John's College, Cambridge, and obtained his PhD from Leeds University in 1949. In 1955, Cox published his seminal work on the Cox process, where the time-dependent intensity is considered a stochastic process. In 1956 he moved to Birkbeck College as a reader in statistics and in 1961 was appointed a professor. In 1966 he took up the chair position in Statistics at Imperial College and later became head of the mathematics department. In 1972, Cox proposed the proportional hazards model, which separates the time-dependent hazard function from time-independent predictors. The analysis of medical data was greatly eased by this contribution, and this model is still used extensively in the analysis of survival data. In 1973, he was elected fellow of the Royal Society of London and was knighted by Queen Elizabeth in 1985. In 1988 he became warden of Nuffield College and a member of the Department of Statistics at Oxford University. In 1990 Cox was awarded the Kettering Prize for his contributions to cancer treatment and in 2010 was awarded the Copley medal of the Royal Society for his contributions to the theory and applications of statistics. After his retirement in 1994, he served as president of the Bernoulli Society, the Royal Statistical society, and the International Statistical institute. PHOTO: HTTPS://EN.WIKIPEDIA.ORG/WIKI/DAVID_COX_(STATISTICIAN)

SOUND BITES

- **From the international scene:**

Survival analysis is a useful statistical technique for answering questions that deal with the duration of events. The Kaplan-Meier and Nelson-Aalen estimators are the traditional statistical techniques for estimating hazard rates and survival probabilities; while the Cox proportional hazard model assumes that the effect of each predictor is multiplicative with respect to the hazard rate. A recent development in survival analysis includes the accelerated failure time models, which assume a Weibull, Log-normal or Log-Logistic distribution. Unlike the Cox model, these parametric models do not exhibit proportional hazards.

Another recent development was the introduction of unshared and shared frailty models, which address the unobserved diversity in the data. To address the impact of frailty, these models incorporate a multiplicative term in the survival distribution, where in the unshared case, each individual is assigned a unique frailty effect, while in the shared case, groups of individuals are assigned the same frailty effect.

- **From the local scene:**

The author of this page (Liberato Camilleri), together with other researchers, has applied these statistical models in several research fields including health, cardiology and medicine, and the results were reported in the following publications:

- Modelling survival durations using frailty models. *Proceedings of the 2017 ESM Conference* p.428-432.

- Does Aortic Valve Replacement Restore Normal Life Expectancy? A 20-year relative survival study. *International Cardiovascular Forum Journal*, Volume 6, p.46-53.

- Long-term survival following aortic valve replacement: the influence of age, prosthesis-patient mismatch and indexed effective orifice area. *International Cardiovascular Forum Journal*, Volume 11, p.31-36.

- Estimation of ejection fraction with ventri-culography versus echo-cardiography in patients referred for cardiac surgery. *Journal of Cardiology and Therapeutics*, Volume 4, p.3-7.

For more sound bites, listen to Radio Mocha: Mondays at 7pm on Radju Malta and Thursdays at 4pm on Radju Malta 2 (https://www.fb.com/RadioMochaMalta).

DID YOU KNOW?

- Smoking increases the hazard of death from coronary heart disease by four times, but reduces the hazard of developing Parkinson's disease by 30 per cent.
- The risk for men of experiencing a sudden cardiac arrest is two to three times higher, compared to women. Moreover, this hazard increases with age, particularly for those suffering from heart disease and other cardiovascular conditions.
- Compared to women, men are three to four times more likely to be diagnosed with attention deficit disorder; four to five times more likely to be diagnosed with autism; and two to three times more likely to be dyslexic.
- Moderate alcohol drinking (one drink a day) decreases the risk of death by 20 per cent, but excessive alcohol drinking raises the hazard by 50 per cent, compared to non-alcohol drinking.
- Men are more likely than women to use illicit drugs; while women are more likely than men to crave for drugs and relapse. Moreover, the hazard of a fatal drug overdose is larger when a relapse occurs.
- Compared to non-smokers, the risk for smokers to die from lung, throat and mouth cancer are 14 times higher; and two times larger to die from bladder cancer.

For more trivia, see: www.um.edu.mt/think

MYTH DEBUNKED

Hazardous survival myths

There are several misconceptions about specific survival situations, some of which have been articulated for decades and ingrained in our culture.

Although it can be difficult to discriminate between facts and myths, it is possible, through well-designed research studies and appropriate statistical analysis, to confirm facts and debunk myths.

These are some misconceptions related to survival:

One of the popular myths recommends drinking your urine if you are lost in a desert. Urine is full of sodium and impurities, and if it doesn't make you vomit, it will surely increase the risk of diarrhoea and more dehydration.

Another myth recommends sucking out poison after being bitten by a venomous snake. By biting and sucking out the poison you would be increasing the risk of infection and poisoning your mouth.

Another myth is that a weapon as the best survival tool if you get lost in the wilderness. In such conditions most people die of hypothermia and dehydration rather than due to predators. So it is more important to wear proper clothing and have sufficient water supply when travelling in wild territory.

Another myth recommends eating snow to quench your thirst when travelling across a frozen landscape. Eating snow drastically reduces your body temperature and it only contains 10 per cent water, while the rest is air. It would be better to carry sufficient fuel to melt some ice for drinking water.

Another myth recommends finding shelter in a cave and lighting a fire to keep yourself warm if you get lost in a cold, desolate region. By lighting a fire in an enclosed space you risk inhaling a dangerous level of carbon monoxide. This odourless gas will replace the oxygen in your red blood cells, which will lull you to sleep and kill you.

CONTRIBUTORS
EDWARD DUCA
JEAN-PAUL EBEJER
PETER BORG
DANIELLE MARTINE FARRUGIA
JOSEF BORG
CLAUDIA BORG

E-MAIL
SCI-SUNDAY@UM.EDU.MT