Risk Planning with Discrete Distribution Analysis Applied to Petroleum Spills

Roy L. Nersesian, Monmouth University, West Long Branch, NJ, USA & Columbia University, New York, NY, USA
Kenneth David Strang, School of Business and Economics, State University of New York (SUNY), Plattsburgh, NY, USA & University of Phoenix, USA & APPC Research, Australia

ABSTRACT

This study discussed the theoretical literature related to developing and probability distributions for estimating uncertainty. A theoretically selected ten-year empirical sample was collected and evaluated for the Albany NY area (N=942). A discrete probability distribution model was developed and applied for part of the sample, to illustrate the likelihood of petroleum spills by industry and day of week. The benefit of this paper for the community of practice was to demonstrate how to select, develop, test and apply a probability distribution to analyze the patterns in disaster events, using inferential parametric and nonparametric statistical techniques. The method, not the model, was intended to be generalized to other researchers and populations. An interesting side benefit from this study was that it revealed significant findings about where and when most of the human-attributed petroleum leaks had occurred in the Albany NY area over the last ten years (ending in 2013). The researchers demonstrated how to develop and apply distribution models in low cost spreadsheet software (Excel).

Keywords: Discrete Probability Distributions, Emergency Management, Oil and Gas Industry, Petroleum Spills, Risk, Risk Mitigation, Risk Planning, Uncertainty Quantification

INTRODUCTION

Petroleum spills happen more often than we may think in larger cities (Liang, Ryvak, Sayeed, & Zhao, 2012; Mendelssohn et al., 2010). There were over 1000 petroleum spills observed in Albany NY over a ten year period which averaged 100 per year. The researchers hypothesized there were patterns when petroleum leaks were likely to occur in certain industries or on particular days of the week. The day of week is important for humans and therefore it is a criterion for investigating man-made disasters.

The researchers tried to quantify these uncertainties into a probability distribution which could predict future spills. Knowing the methodologies to predict petroleum disasters could help emergency management agencies, insurance companies, and other stakeholders, to plan their operational strategies, human resources and schedules (Liang et al., 2012).

Awareness of risk analysis methods for disaster planning will help emergency

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management stakeholders avoid the loss of lives as well as to reduce the costs of mitigation (Taleb, 2007; Vanasselt & Renn, 2011). Unfortunately though one of the major limitations with existing disaster planning models and tools is that they are too complex for most managers to apply (Ellram, 1996; Mangan, Lalwani, & Gardner, 2004; Sproull & Keisler, 1991; Worthington, 2009). Several researchers recommended that scholars ought to develop new models or migrate existing tools into easy-to-use low cost spreadsheet software (Krajewski, Ritzman, & Malhotra, 2010; Nersesian, 2012; Strang, 2012).

Our current world is uncertain. Disasters are not necessarily normal in the statistical sense. Black swan events are seen everywhere such as in weather patterns when two supposedly 100-year hurricanes - Sandy and Isaac - occurred back to back (Tang, 2006). The sea wall protecting the Fukushima nuclear power plants in Japan against tsunamis was built to withstand any that had occurred in recorded history, but unfortunately the one that struck in 2012 was twice that height (Nersesian, 2012).

Man-made disasters may illustrate different probabilities as compared to natural catastrophes. Petroleum spills are generally caused by humans although some may be triggered after a natural disaster (Adams & Berry, 2012; Wagner et al., 2009). Therefore, natural and man-made disasters cannot be expected to approximate normal probabilities. Nassim Taleb provided salient advice: “only a fool would base his expectations on a normal probability distribution” (Taleb, 2007, p. 12).

This may be especially pertinent when developing disaster-related models where humans are involved with highly corrosive, toxic petroleum spills. Therefore, disaster planning models for petroleum spills should be developed using empirical data and not just simulations. “Mathematical models cannot totally replace human logic, and mistakes can be made, so it is essential to apply quality assurance when using software tools to assist with disaster planning” (Strang, 2013, p. 2). “Logistical models should not [totally] rely on simulated data – they should be tested with empirical quantitative and qualitative data (such as using the case study or experiment methodology) […] so that business managers can readily understand, interpret and apply them to their problems” (Strang, 2011, p. 13).

This study discussed the theoretical literature related to analyzing and applying probability distributions for risk analysis. A case study was used to develop and apply a discrete distribution model for risk analysis using spreadsheet software. Petroleum spill data was collected from the New York State Department of Environmental Conversation. A theoretically-selected ten-year empirical sample was evaluated for the Albany NY area to demonstrate the probability distribution model (N=1005).

LITERATURE REVIEW

Uncertainty Quantification and Risk Analysis

Disasters are risk events or crises (Taleb, 2007). Disaster planning means to plan for mitigating against disasters (Simonovi, 2010). Since disasters are uncertain until they occur, risk management theories can be applied to estimate uncertainty and to develop strategic mitigation plans (Ginn, 1989). Man-made disasters are more uncertain due to the nature of human socio-cultural behavior (Adams & Berry, 2012; Goodwin & Strang, 2012; Wagner et al., 2009).

Uncertainty quantification is done in the assessment phase of risk management generally by applying probability theory and statistical techniques (Goodwin & Strang, 2012), to estimate the likelihood each event could occur (Taleb, 2007). The most difficult aspect of risk analysis is developing a probability distribution model, which can be easily applied to actual practice when needed (Nersesian, 2012).

Probability theory can be applied to historical data to quantify uncertainty... by dividing the number of occurrences of an event by the total possibilities in the event space (Goodwin & Strang, 2012, p. 3).
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