Available online at www.sciencedirect.com
SCIENCE DIRECT
Int. J. Production Economics 91 (2004) 149–164
international journal of production economics
www.elsevier.com/locate/dsw

Cost-optimization heuristic algorithm in safety engineering

Ben-Yair Avner*

Safety Engineering and Management Unit, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel

Received 22 August 2001; accepted 19 August 2003

Abstract

A hierarchical fault tree, on the basis of the system branch tree, is considered. Each basic element at the bottom level may relate to a set of possible primary failures, some of which, in turn, may have an essential influence on critical failures at the top level. We suggest several optimization models with cost objectives which enable diminishing the probability of a critical failure via reducing the probabilities of primary failures to occur. The objective to be minimized is the entire cost of required technical alterations, subject to the pregiven upper permissible level of the critical failure's probability.
© 2003 Elsevier B.V. All rights reserved.

Keywords: Fault tree simulation; Cost-reliability problem; Cost-optimization; Top critical failure; Primary failure

1. Introduction

A hierarchical technical system which in the course of its functioning can be the source of large-scale accidents, e.g. nuclear power facilities, is considered. In the last four decades a large number of scientists (see, e.g. Barlow and Lambert, 1975; Fussell, 1975; Golenko-Ginzburg and Papic, 1998; Haasl, 1981; Schneeweiss, 1985; Weber, 1982; Young, 1975, etc.) undertook extensive research in the area of *fault tree analysis* (FTA) in order to develop effective techniques to predict and to prevent various failures of high risk safety technology. Fault tree analysis is mainly based on simulation models, and it can be well-recognized via simulation (Barlow and Lambert, 1975; Ben-Yair, 2001; Golenko-Ginzburg and Gonik, 1998a, b; Golenko-Ginzburg and Gonik, 2002; Golenko-Ginzburg and Papic, 1998; Fussell, 1975) that the probability of a critical failure P_{cr} at the top level depends mainly on certain primary failures' probabilities at the bottom level. Thus, increasing the reliability of the corresponding elements at the bottom level results in increasing the overall system's technical reliability. Note that most primary failure probabilities can be decreased by introducing corresponding technical alterations which require the lay out of expenditure. The latter may be calculated in advance, either by using experts, or on the basis of statistical analysis of similar technical systems.

Since the required budget to undertake technical alterations and refinements is usually restricted, various trade-off problems of "cost-reliability" type become highly important. However, despite the prevalence of

*Tel.: +9-728-623-8322.
E-mail address: benyaira@bgumail.bgu.ac.il (B.-Y. Avner)

0925-5273/$ - see front matter © 2003 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpe.2003.08.007

FTA, publications on cost-optimization problems in Safety Engineering within the last decades are very scanty (see, e.g. Kuo and Prasad, 2000). They practically do not cover cases of complicated hierarchical technical systems with primary failures at the lower levels and top critical failures at the upper level. Few publications on reliability optimization problems with cost parameters for large-scale systems boil down to the study of various network communications problems (Li and Haimes, 1992), as well as problems of determining optimal levels of component reliabilities and redundancies with respect to multiple objectives (Sakawa, 1981). The results obtained in the area of cost-reliability models for stochastic projects (Golenko-Ginzburg and Gonik, 1998a, b; Golenko-Ginzburg and Gonik, 2002), cannot be applied to engineering systems with hierarchical structure, as well as to hierarchical fault trees.

Consider, that all primary failures at the system's bottom level are enumerated by F_ξ, $1 \leqslant \xi \leqslant Q$. Denote the corresponding primary failure probability by P_ξ. Assume that, by introducing possible technical improvements, value P_ξ can be decreased but cannot become less than its lower bound $P_{\xi\,\min}$ which is usually obtained by using expert systems.

Determine the corresponding "probability step" ΔP_ξ, i.e., a constant reduction, in order to undertake a whole number of steps to reduce the probability of primary failure F_ξ from P_ξ to $P_{\xi\,\min}$. Denote the corresponding number of steps by N_ξ. Thus, relation $N_\xi \cdot (\Delta P_\xi) = P_\xi - P_{\xi\,\min}$ holds. Introducing technical improvements to diminish the primary failure probability by one step requires cost expenditures which are pregiven as well. Denote a top critical failure by F_{cr} with its corresponding probability P_{cr}. Assume that value P_{cr} is high enough and has to be reduced in order not to exceed the prescribed upper level P^*_{cr}. The newly developed cost-optimization problem (the direct problem) is to determine improved primary failures probabilities $P_{\xi f_\xi}$ of F_ξ after undertaking f_ξ consecutive steps (f_ξ being the step index), $1 \leqslant \xi \leqslant Q$, $0 \leqslant f_\xi \leqslant N_\xi$, which require the minimal accumulated costs to undertake all technical improvements, subject to reliability constraint, i.e., the top level critical probability not to exceed the pregiven upper level P^*_{cr}. Another cost-optimization problem—the dual one—centers on minimizing the failure probability subject to the cost constraint, i.e., to the restricted budget to carry out the technical improvements.

Both problems have been solved by using a heuristic cost-optimization algorithm via simulation. A numerical example to check the fitness of the algorithm is presented.

2. Notation

Let us introduce the following terms:

FT	the fault tree comprising n hierarchical levels with its logical and probabilistic structure (Barlow and Lambert, 1975; Ben-Yair, 2001; Golenko-Ginzburg and Gonik, 1998a, b; Golenko-Ginzburg and Gonik, 2002; Golenko-Ginzburg and Papic, 1998; Fussell, 1975), which enables calculating top critical failure probabilities on the basis of primary failure probabilities;
SM	the simulation model with incoming primary failures at the bottom level and outcome top level failures;
F_ξ	primary failure, $1 \leqslant \xi \leqslant Q$ (Q–number of primary failures);
P_ξ	the probability of F_ξ (pregiven);
$P_{\xi\,\min}$	the minimal possible probability value P_ξ which, due to technical conditions, cannot be diminished (pregiven);
$C(P_\xi, P_{\xi\,\min})$	the cost of technical improvements in order to reduce the primary failure F_ξ by diminishing its probability up to $P_{\xi\,\min}$ (pregiven);
ΔP_ξ	the "probability step" for value P_ξ in order to implement a technical improvement and diminish value P_ξ by ΔP_ξ (pregiven);

دریافت فوری ← متن کامل مقاله

ISIArticles
مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات