

機率推理在環境風險分析應用之初探

呂哲帆、劉豐瑞

E-mail: 9701136@mail.dyu.edu.tw

摘要

環境風險評估(Environmental risk assessment, ERA)是指評估人類活動所造成環境或生態負面效應之程度與機率的過程，大致可分為「健康風險評估」(Health risk assessment)與「生態風險評估」(Ecological risk assessment)等兩類。由於風險隱含了機率的概念，因此，以機率推理方法來進行風險評估，以預測可能危害的發生機率，是值得探討的議題。本研究嘗試以著名的機率推理工具-貝式信賴網路(Bayesian Belief Network, BBN)來進行環境風險評估。在BBN應用於健康風險評估方面，相較於傳統非致癌物質的健康風險評估，只提供是否對健康造成危害的簡單訊息，BBN方法則提供更多的資訊，包含可以羅列各種可能引致的疾病與致病率，甚至推論出致死率，使得風險管理的不確定性可以降低。本研究是以道路工程施工階段的健康風險為例來探討其適用性，並以降低致死率為目標來進行健康風險管理。在BBN應用於生態風險評估方面，以BBN來預測工程施工對於特定動物族群未來狀態之風險，來作為施工規劃的參考依據。本研究是以台灣高鐵工程施工階段對水雉未來族群狀態的風險為例來探討其適用性，並以增強水雉未來族群狀態為目標來進行生態風險管理。

關鍵詞：環境風險評估；健康風險評估；生態風險評估；貝式信賴網路

目錄

第一章 緒論 1.1 研究背景 1.2 研究目的 1.3 貝氏信賴網路之文獻 1.3.1 我國研究貝氏信賴網路之碩博士論文 1.3.2 國外貝氏信賴網路應用於環境工程與科學之文獻 1.4 研究流程 第二章 環境風險評估 2.1 健康風險評估 2.1.1 風險評估之步驟 2.1.1.1 危害性鑑定 2.1.1.2 劑量反應評估 2.1.1.3 暴露評估 2.1.1.4 風險特性界定 2.1.2 風險評估的計算方式 2.1.2.1 攝取量的計算 2.1.2.2 危害指數的計算 2.1.2.3 致癌風險度的計算 2.2 生態風險評估 2.2.1 生態風險評估架構 2.2.1.1 問題形成 2.2.1.2 分析 2.2.1.3 風險特性界定 第三章 以貝氏信賴網路進行機率推理 3.1 貝氏信賴網路 3.1.1 機率理論 3.1.2 類圖理論 3.1.3 可信度的傳遞方式 3.2 貝氏信賴網路的四種基本類型 3.2.1 鏈型網路 3.2.2 樹型網路 3.2.3 複樹型網路 3.2.4 環型網路 第四章 健康風險評估：以道路工程為例 4.1 以貝式信賴網路進行健康風險評估 4.1.1 危害性鑑定 4.1.2 劑量反應評估 4.1.3 暴露評估 4.1.4 風險特性界定 4.1.4.1 流行病學與空氣污染統計資料的收集 4.1.4.2 機率值的制定 4.1.4.3 機率值的融合 4.1.4.4 以最後之死亡率進行驗證 4.2 道路工程健康風險管理 4.3 貝氏信賴網路與傳統健康風險評估之比較 第五章 生態風險評估：以營建工程為例 5.1 問題形成 5.1.1 本研究生態風險評估指標性物種-水雉 5.1.2 水雉之棲息環境及生活狀況 5.2 分析階段 5.2.1 水雉之棲息地與其影響因子 5.2.2 生態反應分析 5.2.3 暴露度分析 5.3 風險特性確認階段 5.3.1 機率值的制定 5.3.2 營建工程生態風險管理 第六章 結論與建議 參考文獻 附錄A 附錄B 附錄C 附錄D 附錄E 195

參考文獻

中文文獻：1.許惠悛(2006)，「風險評估與風險管理」，第二版，台北，新文京開發出版。2.郭憲文、吳昇光、梁文敏(2006)，「建立中部科學園區開發所致空氣污染之健康風險評估模組」，環保署/國科會空污防治科研合作計畫。3.蕭光明(2004)，「慢性阻塞性肺疾病與睡眠」，台北榮民總醫院記者會資料。 <http://www1.vghtpe.gov.tw/msg/> 4.謝挺蘊(2003)，「考量健康風險評估之室內空氣品質指標之研擬」，國立臺北科技大學環境規劃與管理研究所碩士論文。5.蘇慧貞、江哲銘、李俊璋(2003)，「室內/室外空氣污染物之國民健康風險評估及管制成本校益分析」，行政院環境保護署專題委託研究計畫。6.葛健群(2002)，「高屏溪水生生態風險評估」，國立高雄師範大學生物科學研究所碩士論文。7.陳宜清(2002)，「生態風險評估之內涵、方法及應用」，大葉學報，第十一卷第二期，pp.129-143。8.鄧伯齡(2002)，「水雉生態介紹」，水雉復育年刊 75，40-45。9.劉耀文(2001)，「以景觀生態探討官田水雉棲地之保育」，台灣大學農業工程研究所碩士論文。10.蘇慧貞、江哲銘、李俊璋(1999)，「室內空氣品質標準草案及管制策略探討」，行政院環境保護署研究計畫。11.葛應欽(1996)，「台灣空氣污染與社區居民健康效應」，高雄醫誌 12，657-669。12.交通部高速鐵路工程籌備處(1994)，「高速鐵路環境影響評估報告」，交通部高速鐵路工程籌備處。13.民國95年環境保護統計年報，行政院環境保護署。14.民國94年全民健康保險醫療統計年報，行政院衛生署。15.民國94年衛生署死因統計，行政院衛生署。16.行政院環境保護署，環境資料庫，空氣品質統計。http://edb.epa.gov.tw/index_air.htm 17.行政院環境保護署，環境影響評估書件查詢系統。 <http://ivy3.epa.gov.tw/eiadic/eiaweb/index.htm> 18.醫療大百科，呼吸系統疾病，肺癌。 <http://www.healthno1.com/cms/content/view/1555/142/> 英文文獻：1.Bacon, P. J., Cain, J. D., Howard, D. C., (2002). Belief network models of land manager decisions and land use change, Environment Management 65, 1-23. 2.Borsuk, M. E., Stow, C. A., Reckhow, K. H., (2003). Integrated Approach to Total Maximum Daily Load Development for Neuse River Estuary using Bayesian Probability Network Model (Neu-BERN), Water Resources Planning and Management 129(4), 271-282. 3.Borsuk, M. E., Stow, C. A.,

Reckhow, K. H., (2004). A Bayesian network of eutrophication models for synthesis, prediction, and uncertainty analysis, *Ecological Modelling* 173, 219-239.

4.Borsuk, M. E., Reichert, P., Peter, A., Schager, E., Burkhardt-Holm, P., (2006). Assessing the decline of brown trout (*Salmo trutta*) in Swiss rivers using a Bayesian probability network, *Ecological Modelling* 192, 224-244.

5.Bromley, J., Jackson, N. A., Clymer, O. J., Giacomello, A. M., Jensen, F. V., (2005). The use of Hugin to develop Bayesian networks as an aid to integrated water resource planning, *Environment Modelling & Software* 20, 231-242.

6.Castelletti, A., Soncini-Sessa, R., (2007). Bayesian Networks and participatory modelling in water resource management, *Environment Modelling & Software* 22, 1075-1088.

7.Dawsey, W. J., Minsker, B. S., VanBlaricum, V. L., (2006). Bayesian Belief Networks to Integrate Monitoring Evidence of Water Distribution System Contamination, *Water Resources Planning and Management* 132(4), 234-241.

8.Dockery DW, Pope Car., (1994). Acute respiratory effects of particulate air pollution, *Annual Review of Public Health* 15, 107-32.

9.Dorner, S., Shi, J., Swayne, D., (2007). Multi-objective modelling and decision support using a Bayesian network approximation to a non-point source pollution model, *Environment Modelling & Software* 22, 211-222.

10.Hammond, T. R., Ellis, J. R., (2002). A meta-assessment for elasmobranchs based on dietary data and Bayesian networks, *Ecological Indicators* 1, 197-211.

11.Henriksen, H. J., Rasmussen, P., Brandt, G., Bulow, D., Jensen, F. V., (2007). Public participation modelling using Bayesian networks in management of groundwater contamination, *Environment Modelling & Software* 22, 1101-1113.

12.Hoddinott, K. B., Lee, A. P., (2000). The use of environment risk assessment methodologies for an indoor air quality investigation, *Chemosphere* 41, 77-84.

13.Jørgensen, S.E., (2000). A systems approach to the environmental analysis of pollution minimization, CRC Press, New York.

14.MaCann, R. K., Marcot, B. G., Ellis, R., (2006). Bayesian belief networks: applications in ecology and natural resource management, *Can. J. For.* 36, 3053-3062.

15.Marcot, B. G., Steventon, J. D., Sutherland, G. D., MaCann R. K., (2006). Guidelines for developing and updating Bayesian belief networks applied to ecological modeling and conservation, *Can. J. For.* 36, 3063-3074.

16.Marcot, B. G., Holthausen, R. S., Raphael, M. G., Rowland, M. M., Wisdom, M. J., (2001). Using Bayesian belief networks to evaluate fish and wildlife population viability under land management alternatives from an environment impact statement, *Forest Ecology and Management* 153, 29-42.

17.Marcot, B. G., Hohenlohe, P. A., Morey, S., Holmes, R., Molina, R., Turley, M. C., Huff, M. H., Laurence, J. A., (2006). Characterizing Species at Risk II: Using Bayesian Belief Networks as Decision Support Tools to Determine Species Conservation Categories Under the Northwest Forest Plan, *Ecology and Society* 11(2), 12.

18.Martin de Santa Olalla, F., Dominguez, A., Ortega, F., Artigao, A., Fabeiro, C., (2007). Bayesian networks in planning a large aquifer in Eastern Mancha, Spain, *Environment Modelling & Software* 22, 1089-1100.

19.Martin de Santa Olalla, F. J., Dominguez, A., Artigao, A., Fabeiro, C., Ortega, J. F., (2005). Integrated water resources management of the Hydrogeological Unit ' ' Eastern Mancha ' ' using Bayesian Belief Networks, *Agricultural Water Management* 77, 21-36.

20.McNay, R. S., Marcot, B. G., Brumovsky, V., Ellis, R., (2006). A Bayesian approach to evaluating habitat for woodland caribou in north-central British Columbia, *Can. J. For.* 36, 3117-3133.

21.Nyberg, J. B., Marcot, B. G., Sulyma, R., (2006). Using Bayesian belief networks in adaptive management, *Can. J. For.* 36, 3104-3116.

22.Park, M. H., Stenstrom M. K., Using satellite imagery for stormwater pollution management with Bayesian networks, *Water Research* 40, 3429-3438.

23.Pearl, J., (1988). *Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Inference*, Morgan Kaufmann, California.

24.Pollino, C. A., White, A. K., Hart, B. T., (2007a). Examination of conflicts and improved strategies for the management of an endangered Eucalypt species using Bayesian networks, *Ecological Modelling* 201, 37-59.

25.Pollino, C. A., Woodberry, O., Nicholson, A., Korb, K., Hart, B. T., (2007b). Parameterisation and evaluation of a Bayesian network for use in an ecological risk assessment, *Environment Modelling & Software* 22, 1140-1152.

26.Raphael, M. G., Wisdom, M. J., Rowland, M. M., Holthausen, R. S., Wales, B. C., Marcot, B. G., Rich, T. D., (2001). Status and trends of habitats of terrestrial vertebrates in relation to land management in the interior Columbia river basin, *Forest Ecology and Management* 153, 63-88.

27.Rieman, B., Peterson, J. T., Clayton, J., Howell, P., Thurow, R., Thompson, W., Lee, D., (2001). Evaluation of potential effects of federal land management alternatives on trends of salmonids and their habitats in the interior Columbia River basin, *Forest Ecology and Management* 153, 43-62.

28.Sadoddin, A., Letcher, R. A., Jakeman, A. J., Newham, L. T. H., (2005). A Bayesian decision network approach for assessing the ecological impacts of salinity management, *Mathematics and Computers in Simulation* 69, 162-176.

29.Sahely, B. S. G. E., Bagley, D. M., (2001). Diagnosing upsets in anaerobic wastewater treatment using Bayesian belief networks, *Environment Engineering* 127(4), 302-310.

30.Smith C. S., Howes, A. L., Price, B., McAlpine, C. A., (2007). Using a Bayesian belief network to predict suitable habitat of an endangered mammal – The Julia Creek dunnart (*Sminthopsis douglasi*), *Biological Conservation* 139(3-4), 333-347.

31.Sonnemann, G., Castells, F., Schuhmacher, M., (2004). *Integrated life-cycle and risk assessment for industrial processes*, CRC Press, New York.

32.Steventon, J. D., Sutherland, G. D., Arcese, P., (2006). A population-viability-based risk assessment of Marbled Murrelet nesting habitat policy in British Columbia, *Can. J. For.* 36, 3075-3086.

33.Ticehurst, J. L., Newham, L. T. H., Rissik, D., Letcher, R. A., Jakeman, A.J., (2007). A Bayesian network approach for assessing the sustainability of coastal lakes in New South Wales, Australia, *Environment Modelling & Software* 22, 1129-1139.

34.Uusitalo, L., (2007). Advantages and challenges of Bayesian networks in environmental modeling, *Ecological Modelling* 203, 312-318.

35.Uusitalo, L., Kuikka, S., Romakkaniemi, A., (2005). Estimation of Atlantic salmon smolt carrying capacity of rivers using expert knowledge, *Marine Science* 62, 708-722.

36.Varis, O., (1997a). Bayesian decision analysis for environmental and resource management, *Environment Modelling & Software* 12(2-3), 177-185.

37.Varis, O., Kuikka, S., (1997b). Joint use of multiple environment assessment models by a Bayesian meta-model: the Baltic salmon case, *Ecological Modelling* 102, 341-351.

38.Varis, O., Kuikka, S., (1999). Learning Bayesian decision analysis by doing: lessons from environmental and natural resources management, *Ecological Modelling* 119, 177-195.

39.Varis, O., Keskinen, M., (2006). Policy Analysis for the Tonle Sap Lake, Cambodia: A Bayesian Network Model Approach, *Water Resources Development* 22(3), 417-431.

40.Wooldridge, S., Done, T., (2004). Learning to predict large-scale coral bleaching from past events: A Bayesian approach using remotely sensed

data, in-situ data, and environmental proxies, *Coral Reefs* 23, 96-108. 41. Walton, A., Meidinger, D., (2006). Capturing expert knowledge for ecosystem mapping using Bayesian networks, *Can. J. For.* 36, 3087-3103. 42. Zhu, Z. J. Y., McBean, E. A., (2007). Selection of water treatment processes using Bayesian decision network analyses, *Environ. Eng. Sci.* 6, 95-102.