新一代劇烈天氣監測系統（QPEPlus）之社會經濟效益評估

Socioeconomic Benefit Assessment of the Quantitative Precipitation Estimation and Segregation Using Multiple Sensors Plus (QPEPlus)

陳注維[1] (Chen C.-W.) 溫芳宜[1] (Wen F.-I.) 林桓億[1] (Lin H.-I.) 張郁婕[1] (Chang Y.-C.) 吳炫慶[2] (Wu S.-C.)

[1]中華經濟研究院 [2]中央氣象署綜合規劃組

[1] Chung-Hua Institution for Economic Research

[2] Planning Division, Central Weather Administration

摘　要

隨著極端天氣事件日益頻繁，高時空解析度的氣象資訊已成為政府防災與決策鏈的核心驅動力。本研究從服務價值鏈的視角切入，系統性評估中央氣象署「新一代劇烈天氣監測系統（QPEPlus）」於我國運輸與防災預警等公共部門的實務應用效益。面對多數氣象服務缺乏市場價格之挑戰，本研究採用事後分析法與假設情境條件評估法，整合國際減災成效係數、專家調查之氣象貢獻率及政府運輸部門之統計生命價值（VSL），將多元的防災質性貢獻轉化為具體的貨幣化社會經濟效益。

成本效益分析（Cost-Benefit Analysis, CBA）結果顯示，QPEPlus 投入之年營運成本，在各應用部門皆轉化為極大的社會經濟效益。在實務防災應用上，航港局藉由QPEPlus提供的海域風浪網格預警資訊，大幅縮短處置反應時間並啟動預先避險，有效降低船舶擱淺與沉沒之實質風險；公路局則透過逐公里降雨監測資訊，即時觸發預警性封路封橋與機具疏散，保障用路人生命安全；民航局則利用高時空解析度降雨資訊、閃電監測與預報資料，優化航線規劃並降低地勤作業風險。在全國層級的警消與縣市政府防災應用而言，透過QPEPlus所提供的雷達回波與閃電監測功能，即時掌握降雨趨勢，作為人力調度與防災通報及人員預警疏散的判斷依據，降低民眾因土石流、洪水或溪水暴漲而造成的傷亡風險。

以成本效益比（BCR）檢視，各運輸部門之避險投資報酬率介於 1.29 至 26.60 之間。而在結合警消與縣市政府的全國防災應用上，因其能顯著縮短通報時效並落實超前部署，BCR最高可達 247.81。從交通運輸到全國層級的預警效益，各單位的效益比普遍介於數倍至數百倍之間，不僅與國際成熟預警系統的評估結果相符，更證明此類氣象科技投資能有效轉化為具體可量化的社會價值，亦證明此類氣象科技投資是支撐我國災害風險管理的重要基礎。

關鍵字：新一代劇烈天氣監測系統（QPEPlus）、統計生命價值、成本效益分析、減災效益

Abstract

With the increasing frequency of extreme weather events, high-spatiotemporal-resolution meteorological information has emerged as a core driver of government disaster prevention and decision-making chains. This study adopts a service-value-chain perspective to systematically evaluate the practical application benefits of the Central Weather Administration's "Quantitative Precipitation Estimation and Segregation Using Multiple Sensors Plus" (QPEPlus) system across Taiwan's public transportation and disaster warning sectors. Addressing the challenge that most meteorological services lack explicit market prices, we employ ex-post evaluation and hypothetical scenario contingent valuation methods. By integrating an international disaster-mitigation efficiency coefficient, an expert-surveyed meteorological contribution rate, and the Value of Statistical Life (VSL) derived from government transportation authorities, we convert diverse qualitative disaster prevention contributions into concrete, monetized socioeconomic benefits.

The cost-benefit analysis (CBA) indicates that the annualized resources allocated to sustain QPEPlus operation and maintenance costs are efficiently translated into substantial socioeconomic benefits across various application sectors. In practical disaster prevention applications, the Maritime and Port Bureau leverages the marine wind and wave gridded warning information provided by QPEPlus to significantly shorten operational response time and initiate early risk-evading measures, thereby effectively reducing the empirical risks of vessel grounding and sinking. The Bureau of Highways utilizes kilometer-by-kilometer rainfall monitoring data to instantly trigger precautionary road and bridge closures as well as equipment evacuation, ensuring the safety of road users. The Civil Aeronautics Administration implements high-spatiotemporal-resolution precipitation data alongside lightning monitoring and forecasting resources to optimize flight route planning and mitigate ground handling operational hazards. Regarding national-level disaster prevention applications executed by police, firefighters, and local governments, the real-time rainfall trend insights gained from the radar echo and lightning monitoring functions of QPEPlus serve as crucial determinants for manpower deployment, disaster hazard notifications, and precautionary community evacuations, consequently lowering public casualty risks associated with debris flows, floods, or sudden river surges. Evaluated by the benefit-cost ratio (BCR), the return on risk-evading investments across various transportation sectors ranges from 1.29 to 26.60. Furthermore, within the national disaster prevention framework combining police, firefighters, and local governments, the maximum BCR reaches as high as 247.81 due to its prominent capability to accelerate alert dissemination and implement preemptive deployments.

Spanning from transportation to national-level warning benefits, the benefit-cost ratios across various agencies generally range from several-fold to several-hundred-fold. These empirical findings not only align with the evaluation results of mature international early warning systems but also substantiate that public investments in meteorological technologies can be effectively converted into tangible, quantifiable social value, thereby proving that such investments serve as an essential cornerstone supporting disaster risk management.

Key words : QPEPlus, Value of Statistical Life (VSL), Cost-Benefit Analysis (CBA), Disaster Mitigation Benefits