Institution: Liverpool John Moores University (LJMU)		
Unit of Assessment: 17		
Title of case study: Transport logistics systems: resilience and sustainability		
Period when the underpinning research was undertaken: 2012-2018		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Zhuohua Qu (ZQ) Zaili Yang (ZY)	Senior Lecturer Professor	2012-date 2003-date
Period when the claimed impact occurred: 2014-date		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

A holistic decision support framework has been developed, resulting in the improved safety and green performance of logistics and transport companies in the UK and internationally. It has also had a significant and direct impact on both regulatory and public policy targeting transport logistics resilience and sustainability. Specifically, the impact has been:

- Reduced logistics and transportation operational incidents (e.g. ship collisions) by an estimated 10% of incident-caused cost for COSCO Shipping (the third largest shipping line in the world).
- Influenced UN policy making on port adaptations to climate change and enabled the global premier infrastructure firm AECOM to provide effective climate adaptation consultation to its clients and generate circa. £100K additional revenue p.a.
- Advised Dublin Ferryport that an investment in automation will save more than 6 million Euros and eliminate all human related safety incidents in comparison to using manually-driven equipment. Following our research, in 2017 the terminal management decided to invest in automation technologies with Kalmar (cargo handling solutions provider), making it the most modern terminal in the region.

2. Underpinning research

Since the start of the current century, the world has experienced uncertainties as a result of climate change, security threats and a revolution in new technologies in the digital industrial era. For instance, the 2017 Atlantic hurricane season caused over $200 billion in damages from 17 storms (National Geographic, 2017). Cargo thefts have doubled in the EU in 2014-2016 with an annual rate of increase of 115% (Lloyd's Loading List, 2017), presenting a multi-billion-euro problem for the European transport sector (EC, 2017). These uncertainties have a huge impact on the transportation system (accounting for between 6% and 12% of the GDP in many developed countries (Rodrigue, 2017)) which stimulates this research on resilient and sustainable transport logistics systems. Management strategies are moving from cost saving and value orientation towards a resilience and sustainability focused regime concerned with climate adaptation, safe transportation, and integrated logistics resilience management. Decision making under such uncertainties presents a complex challenge in modern transportation and logistics. It requires stakeholders, policy makers and practitioners to make decisions in the face of multiple uncertainties. To address uncertainties in data relating to the transportation system (including incompleteness, fuzziness and ambiguity), an innovative methodology for decision making under uncertainty with supporting concepts, models and methods has been developed.

These risk based decision-making methods have contributed to the improvement of maritime activities at both strategic and operational levels, including risk based safety policy making and

practice and security analysis and operational (e.g. automation) management. The methods are generic in nature and have been tailored and applied in different transport modes and logistics contexts. Below are the selected illustrative examples.

Research output R1 for the first time tackled climate risk quantification for rational adaptation planning. The work was financially supported by an EU FP7 project (project G2 ENRICH) and its methodology was presented during the International Conference of the Asian Logistics Round Table (ALRT) 2015 and won the Best Paper Award (one out of over 100 papers).

Research output R2 pioneered the use of big data (ship inspection data in port) and Artificial Intelligence (AI) techniques to improve port inspection efficiency and hence port safety by utilising Bayesian networks together with game theory. The work was financially supported by an EU FP7 project (project G2 ENRICH), and it won the Maritime Policy and Management Best Paper Award (one out of over 250 papers), conferred by the International Maritime Economics Association (IAME) during the IAME 2018 conference.

Research output R3 analysed the impact of climate change on UK road transportation by using Fuzzy Bayesian networks to address the uncertainty in climate-related risk analysis. It also evaluated the corresponding adaptation plans and employs the evidential reasoning approach to realise their cost benefit analysis by taking into account both climate risk and adaptation cost simultaneously. It was financially supported by an AECOM funded project (Project G3 CAT) and an EU H2020 project (Project G4 GOLF). It contributed to the Best Young Researcher Award, conferred during the 4th International Project Logistics Conference 2018.

Research output R4 proposed a new method capable of modelling the risks of maritime supply chains (MSCs) in a situation where historical failure data is not available or is incomplete. It analyses the risks of MSCs from different perspectives, develops an advanced risk analysis method to tackle the uncertainty in risk data, compares risk analysis results by using different methods to demonstrate the advantages of that which is proposed, and conducts an empirical study to provide useful insights for the identification and control of high risks. It was financially supported by an EU H2020 project (Project G4 GOLF). It led to the success of an EU Research Council Consolidator Grant (Project G6 TRUST)

Research output R5 conducted a novel study on Key Green Performance Indicators (KGPIs) to allow the combination of different green vehicle performance related factors for a single unique value to present vehicle cleanliness, which can guide buyers to choose cleaner vehicles and aid transport policy makers (e.g. DfT) to develop more efficient decarbonisation policies. The work was financially supported by a UK research council project (Project G5 PVC).

Research output R6 offered the first insights into how different advanced optimisation and simulation methods can be combined to improve the performance of ports. It also provides the first detailed cost model for a new type of automated equipment in ports, verified by real port data. It is financially supported by an EU Interreg project (Project G1 IntraDE). It led to a Runner Up and Highly Commended credit in the 2017 Newton Prize.

3. References to the research

Cited outputs (all papers have been through a rigorous peer-review process):

R1: Yang Z.L., Ng A., Lee P.T.W., Wang T., Qu Z., Rodrigues V.S., Pettit S., Harris I., Zhang D. and Lau Y.T. (2018). "Risk and cost evaluation of port adaptation measures to climate change impacts", *Transportation Research Part D: Transport and Environment*, vol. 61, p. 444 - 458.

R2: Yang Z.S., Yang Z.L., Qu Z.H. and Yin J.B. (2018), "A risk-based game model for rational inspections in port state control", *Transportation Research Part E: Logistics and Transportation Review*, vol. 118, p. 477-495

R3: Wang T.N., Qu Z., Yang Z.L., Nichol T., Dimitriu T, Clarke G., Bowden D. (2019) "How can the UK Road System be Adapted to the Impacts Posed by Climate Change? By Creating a Climate Adaptation Framework", *Transportation Research Part D: Transport and Environment*, vol, 77, pp. 403-424.

R4: Wan C., Yan X., Zhang D., Qu Z. and Yang Z. (2019) "An advanced fuzzy Bayesian-based FMEA approach for assessing maritime supply chain risks", *Transportation Research Part E: Logistics and Transportation Review*, vol. 125, p.222-240.

R5: Yang Z., Poo M.C.P., Galatioto F., Dimitriu D., Qu Z., Rushton C., Lee P.T.W. and Guan B. (2020), "Key Green Performance Indicators (KGPIs) for vehicle cleanliness evaluation: A buyer choice", *Transportation Research Part D: Transport and Environment*, Vol. 87, pp. 102505.

R6: S. Kavakeb, T. T. Nguyen, K. McGinley, Z. Yang, I. Jenkinson, R. Murray (2015). "Green vehicle technology to enhance the performance of a European port: a simulation model with a cost-benefit approach". *Transportation Research, Part C: Emerging Technology*, vol. 60, pp. 169-188.

Cited research projects/grants

No	PI	Sponsor	Year	Value	Title
G1	Yang Z.	EU Interreg	2009-14	€516K (out of €3.5M)	InTraDE – Intelligent Transport for Dynamic Environment
G2	Yang Z.	EU RISE	2013-17	€592K	ENRICH – EU China Research Network on Integrated Supply Chains
G3	QU Z.	AECOM	2015-17	£30K	CAT - Climate Adaptation in Transportation
G4	Qu Z.	EU RISE	2018-21	€59,800 (out of €1m)	GOLF – Food Supply Chains.
G5	Yang Z.	UK EPSRC	2018-20	£50K	PVC – Prioritising Vehicle Cleanliness for better air quality
G6	Yang Z.	EU ERC (Consolidator Grant)	2020-2025	€1.99m	TRUST Towards Resilient and Sustainable Container Transport

4. Details of the impact

Systematic research on transport logistics resilience and sustainability (e.g. adaptation to climate change) has developed since 2015 (output R1), but the incorporation of risk models and uncertainty methods into this body of research has been scarce, with only a limited number of studies available. Dr Qu and her collaborators have significantly extended this body of work and have made important contributions to advancing practical understanding in industry through joint research projects, workshop events for output dissemination and regular communications involving the senior managers from COSCO, AECOM and Dublin Ferryport. The holistic decision support framework and its associated supporting methods, developed by Dr Qu and colleagues, provide an effective tool for decision making and have benefited numerous stakeholders in transportation and logistics. The research has resulted in significant political, environmental and cultural impact. The framework and the associated methods have been adopted by industry and evidence of the impact is listed as below.

1. Usage by the shipping industry to improve transport resilience

   COSCO, the third largest container shipping line in the world, is a Chinese state-owned shipping and logistics services supplier. In 2018/19, through two EU funded projects (projects G2 and G4), and by incorporating a new shipping resilience risk concept (output R4) into COSCO's global shipping network configuration, the new concept has helped reduce its incident-caused logistics costs by an estimated 10% (Source S1). The new shipping resilience risk concept has led to a paradigm shift in COSCO shipping logistics practice, moving to a new mechanism that incorporates risk assessment from a global shipping network perspective. This new approach was proven successful when it was implemented as a case study on COSCO's Asia-Africa logistics network. This success promoted the concept's implementation by other COSCO logistics networks. [dates of impact: 2018-19]

2. The provision of cost-effective adaptation measures for road, rail and ports to form useful recommendations for regional and global climate adaptation policymaking

   Through a project (project G3), AECOM has used the research findings (output R1 and R3) and incorporated climate risk analysis into its commercial consultancy programme on transport (*i.e.*, road and rail) network planning. It has directly generated an additional estimated £100k revenue per year in 2018-2020 (Source S2). [Impact period: 2018-20].

   Output (R1) received support of a large scientific consortium of over 50 scholars from more than 30 countries. Some of them are working in/for the UN branches relating to climate change. The identification of climate threat to major transport infrastructure via large international (30 countries) and UK national surveys (Source S2 and S3) has benefited transport stakeholders (*e.g.*, operators and authorities) to improve service climate resilience. It has directly shaped UN policy making on "Climate Change Impact and Adaptation for International Transport Networks" (*i.e.,* Section 4.3.4 "Technical adaptation measures for seaports").

   http://www.unece.org/fileadmin/DAM/trans/main/wp5/publications/climate_change_2014.pdf . Specifically, our work has directly led UN policymakers to develop guidelines and approaches to climate adaptation planning in ports and transportation infrastructures, particularly in terms of methods for how climate risks should be identified and how adaptation measures can be evaluated (Source S3). [Impact period: 2014].

3. Application of cutting-edge techniques in the port industry for transport sustainability

   To be sustained in the highly competitive transport logistics market, services suppliers need to constantly improve efficiency, reduce cost and decrease emissions and pollution. The

requirement to optimise the use of cutting-edge technologies, such as automated vehicles and automated gates led us to devise new mathematical/optimisation techniques that had not been proposed before, simply because the existing methods did not work well. Through an EU project (project G1), our new models have been utilised by the port industry. For example, research output (R1) offered the first insights into how different advanced optimisation and simulation methods can be combined to improve the performance of ports. It also provides the first detailed cost model for a new type of automated equipment in ports, and informs Dublin Ferryport that an investment in automation would save more than €6m in comparison to using manually-driven equipment. In 2017 the terminal management invested in automation technologies with Kalmar, making it the most modern terminal in the region (Source S4). [dates: 2015-2017]

5. Sources to corroborate the impact

S1. Logistics Division Manager, COSCO Shipping Logistics COSCO Shipping Logistics Co. Ltd)

S2. Transport Consultant, Logistics Division of AECOM UK

S3. UN climate adaptation working group expert member Professor and Director of Transport Institute, University of Manitoba, Canada

S4. Director, Dublin Ferryport Terminals, Dublin