Institution: Liverpool John Moores University (LJMU)		
Unit of Assessment: Sub-panel 12: Engineering		
Title of case study: A decision-support system for transportation and logistics		
Period when the underpinning research was undertaken: from 2006 to 2020		
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:**
Trung Thanh Nguyen (TTN)	TTN (Reader)	TTN (2011-date)
Zaili Yang (ZY)	ZY (Professor)	ZY (2003-date)
Zhuohua Qu (ZQ)	ZQ (Lecturer)	ZQ (2013-date)
Shayan Kavakeb (SK)	SK (Post-Doctoral Research Assistant)	SK (2011-2016)
Igor Deplano (ID)	ID (Post-Doctoral Research Assistant)	ID (2016-date)
Period when the claimed impact occurred: from August 2013 to December 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

The creation of a novel decision-support system, powered by new algorithms and models developed for the first time, is helping authorities and industry to make improved and more timely decisions, resulting in greener, more efficient and more sustainable transport and logistics:

1. Reducing costs up to 23%, emissions up to 19%, and accidents estimated at 10% in the port/maritime industry (VICONSHIP, the Ports of Liverpool, and COSCO Shipping Logistics).
2. Improving rail performance and passenger experience, monitoring four of Merseyrail's busiest stations (~24 million passengers annually) and directly servicing ~100,000 passengers/month at Liverpool South Parkway mainline interchange (10/10 score from station staff and 8/10 score from passengers).
3. Supporting active travel options (walking and cycling) in the Liverpool City Region (LCR) by providing data/analysis to both users and local authority operators, as part of the development/upgrade of 57.5km green cycling/walking routes, to reduce greenhouse gas (GHG) emissions by an estimated 334 tonnes in the period 2019-20.
4. Influencing UN policymaking on port adoption to climate change. Adoption of the safety assessment system by the Port of Dalian has led to a reduction of incidents by 8% and annual safety cost savings of £250k.
5. Assisting the region's COVID-19 response with a monitoring/evaluation system for 11 LCR popup emergency routes, supplying traffic data to the Department for Transport (DfT) (March-July 2020) and local authorities (March-December 2020), optimising people movement and social distancing measures in the LCR, and providing rail passengers with critical real-time travel information at Liverpool South Parkway station(56,000 passenger-journeys).

2. Underpinning research

Transport and logistics are essential drivers for economic growth and their sustainability is a challenge to UN, EU and UK government, targeting greener, more efficient and sustainable systems. These macro-level targets have informed the evolution of sustainable transportation and logistics research at LJMU, with a focus on maritime, rail, cycling, and walking applications.

A novel decision-support system has been developed in close collaboration with industry, comprising a set of tools applicable to different modes of transportation/logistics. Its impact has been validated by industrial partners. The body of the underpinning research (£5m in grant value to LJMU in total) that has directly led to the claimed impacts is described below:

A. Research on port operations

Funded by the EU [RPs 1, 2] and the Newton Fund [RP 3], we worked with various European and Far East ports to improve efficiency, reduce costs, 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, because existing methods did not work. These new models have been utilised by the port industry in all three

aspects of port operations: the seaside (berth planning and vessel stowage optimisation; *e.g.*, RP 3); the yard (yard simulation and container stacking optimisation; *e.g.*, RP 1); and the landside (truck appointment, vehicle routing, and bin packing optimisation; *e.g.*, RP 3). For example, the research output [RO 1] offered the first insights into how different advanced optimisation and simulation methods can be combined to improve the performance of ports.

B. Research on railway operations

Funded by DfT, the Rail Safety and Standards Board (RSSB), and Innovate UK, we worked with the rail industry to improve: (a) passenger experience [RP 8]; (b) train operations *e.g.*, more accurate delay prediction and estimation of 'slippery rail' [RPs 4, 7]; and (c) staff and infrastructure management/communication [RPs 4, 10]. For example, RO 6 proposed a novel algorithm that allocates passenger seats in real-time to increase seats utilisation and reduce congestion, taking into account arrival time, journey leg and length, passenger preferences, luggage and passenger groups.

C. Research on active travel, especially cycling and walking

Funded by the EU, the DfT, and additional support from industry such as [RP 6], we worked with local authorities, cyclists and walkers, police forces, delivery companies, and regional cycling and walking commissioners to develop new algorithms and models to tackle problems never previously addressed. This included the development of: (a) the first risk predictors associated with cycling for the LCR; (b) the first system that combines deep learning computer vision and IoT to monitor cycling/walking activities, and novel machine learning techniques to detect potholes by learning from cyclist behaviour. For example, RO 2 proposed a novel algorithm to address vehicle routing issues.

D. Research on strategic decision-making in the maritime industry

Funded by the EU and ERC, we worked with policymakers and port authorities to develop analysis models involving transport safety, logistics security, and supply chain adaptation to climate change [RPs 2, 5, 9]. For example, a new shipping resilience risk concept to reduce incident-related logistics costs has been developed [RO 3]. Port adaptation measures to climate change have been produced for port terminals that operate under uncertainties [ROs 4, 5].

3. References to the research

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

RO 1 - Kavakeb S., Nguyen T.T., McGinley K., Yang Z., Jenkinson I., Murray R. (2015). Green vehicle technology to enhance the performance of a European port: a simulation model with a cost-benefit approach. *Transportation Research, Part C*, 60: 169-188 (https://doi.org/10.1016/j.trc.2015.08.012).
RO 2 - Zhang D., Cai S., Ye F., Si Y-W., Nguyen T.T. (2017). A hybrid algorithm for a vehicle routing problem with realistic constraints. *Information Sciences*, 394-395: 167-182 (https://doi.org/10.1016/j.ins.2017.02.028).
RO 3 - Wan C., Yang Z., Yan X.P., Zhang D. (2017). Resilience in transportation systems: A systematic review and future directions. *Transport Reviews*, 38: 479-498 (https://doi.org/10.1080/01441647.2017.1383532).
RO 4 - Yang Z., Ng A., Lee P.T.W., Wang T., Qu Z., Rodrigues V.S., Pettit S., Harris I., Zhang D., Lau Y.T. (2018). Risk and cost evaluation of port adaptation measures to climate change impacts. *Transportation Research Part D*, 61: 444-458 (https://doi.org/10.1016/j.trd.2017.03.004).
RO 5 - Al-Yami H., Yang Z., Ramin R., Bonsall S., Wang J. 2019. Advanced uncertainty modelling for container port risk analysis. *Accident Analysis and Prevention*, 123: 411-421 (https://doi.org/10.1016/j.aap.2016.08.007).
RO 6 - Yazdani D., Omidvar M.N., Deplano I., Lersteau C., Makki A., Wang J., Nguyen T.T. (2019). Real-time seat allocation for minimizing boarding/alighting time and improving quality of service and safety for passengers. *Transportation Research Part C: Emerging Technologies*, 103: 158-173 (https://doi.org/10.1016/j.trc.2019.03.014).

Cited research projects

RP 1 - "InTraDE – Intelligent Transport for Dynamic Environment", €516k to the Unit (out of €3.5m), 2009-14, EU Interreg, PI: Yang Z.
RP 2 - "ENRICH – EU China Research Network on Integrated Supply Chains", €592k, EU FP7, 2013-17, PI: Yang Z.
RP 3 - "Sustainable maritime logistics research UK-Vietnam", £300k, UK Department for Business, Energy & Industrial Strategy, 2015-17, PI: Nguyen T.T.
RP 4 - "Data Sandbox - Anticipating and mitigating reactionary delays in railway networks", £108k, Rail Safety & Standards Board, 2018-19, PI: Nguyen T.T.
RP 5 - "GOLF - EC-Asia research network on integration of global and local agri-food supply chains towards sustainable food security", €189k (out of €1m), EU RISE, 2018-22, PI: Yang Z.
RP 6 - "Liverpool City Region green sustainable travel corridors", EU ERDF, £678k (of £8.5m), 2018-21, PI: Nguyen T.T.
RP 7 – "ANTI-SLIP: Anticipate and mitigate the impact of slippery rail", £123k, Rail Safety & Standards Board, 2019-20, PI: Nguyen T.T.
RP 8 - "COINS: Customer-Operational Information System for Stations", £265k, DfT (via Innovate UK), 2019-20, PI: Nguyen T.T.
RP 9 - "TRUST - Towards Resilient and Sustainable Container Transport", €1.99m, 2020-25, EU ERC (Consolidator Grant), PI: Yang Z.
RP 10 - "IRIS: Information System for Railway Station Staff", £330k, DfT (via Innovate UK), 2020-21, PI: Nguyen T.T.

4. Details of the impact

The system developed at LJMU has influenced industrial practice and benefited both industry and transport users. Evidence of impact is demonstrated below:

1. Adoption by the port industry to improve port operations (*e.g.* [RPs 1, 3]). For example:

   a. Vietnam's leading logistics corporation VICONSHIP reported that the system is capable of eliminating container re-handles, which are the number of times containers have to be reshuffled unnecessarily in the yard (55% of all containers in the 600,000 TEUs/year case-study port). This is equivalent to a 23% reduction in the total cost of cargo handling and a 19% decrease in emissions from container handling vehicles [**Source 1**]. In addition to cost saving, the reduction in emissions saves lives and improve quality of life. It is estimated that emissions from shipping alone cause 600 premature deaths annually in Vietnam, according to research from Nature Climate Change. [dates of impact: 2017]

   b. The system reduced ship imbalance from 230 tonnes to 4.8 tonnes [**Source 1**]. This work was conducted jointly with Vietnam National University Hanoi – LJMU contributed 50%. [dates of impact: 2017]

   c. The system [RO 1] has helped the Port of Liverpool (Peel Ports) to better evaluate the performance of its lock system. The lock is the main entrance to the port's second largest terminal, so understanding its performance is essential for maintaining a large throughput of 1.5m TEUs going through the lock [**Source 2**]. [dates of impact: 2016]

2. Adoption by the port industry for port safety (*e.g.* [RPs 2, 5]). For example, the system has provided safety self-assessment methods [RO 5], as well as a new risk analysis and alert software package. These have been incorporated into health and safety policy of several world-leading container ports such as the Port of Dalian, P. R. China. As a result, incidents occurring in the Port of Dalian (Dalian Container Terminal) in 2018- 2019 were reduced by approx. 8% (compared to the average over the past 5 years), while the annual safety cost saving has been estimated at £250k [**Source 3**]. [dates of impact: 2018-19]

3. Usage by the shipping industry to improve transport resilience (*e.g.* [RPs 2, 9]). For example, in 2018/19, by incorporating a new shipping resilience risk concept [RO 3] into COSCO's global shipping network configuration, the system has reduced its incident-related logistics costs by an estimated 10% [**Source 4**]. The new 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]

4. Usage by the UK rail industry to improve its performance and passenger experience (*e.g.* RPs 4, 7, 8, 10).

   a. The system, which is powered by algorithms from publications such as [RO 6], has enabled the Merseyrail franchise to monitor real-time train journeys in four of their busiest stations (~24 million annual rail passenger usage). The system, currently installed in Liverpool South Parkway station, a major regional multimodal transport hub, is also providing passengers with rapid and detailed real-time information in response to network disruption. It served about 200,000 passengers within the first two months of operation, receiving a score of 10/10 from staff who used it and 8/10 from passengers [**Source 5**]. [dates of impact: 2019-20]

   b. The system was tested by Merseyrail to anticipate and mitigate reactionary delays, which is the major source of train delays in the UK. Experiments on ~500 real train journeys showed that the system improved delay prediction accuracy in all instances [**Source 6**]. [dates of impact: 2018-19]

   c. The system has given Merseyrail insights into reasons and possible mitigations of slippery rail'/low railhead adhesion that has an impact on the entire Merseyrail and wider industry network. This benefits the entire Merseyrail network [**Source 6**]. [dates of impact: 2019-20]

5. The provision of cost-effective measures for road, rail and ports [RO 4] and recommendations for international bodies (*e.g.*, the UN) in global climate policymaking [RPs 1, 2, 9]. The identification of climate threat by major transport infrastructure via large international (30 countries) and UK national surveys [**Source 7**] has helped transport stakeholders (*e.g.*, operators and authorities) to improve service climate resilience. It has directly shaped UN policy 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 assisted UN policymakers to develop guidelines and approaches in climate adaptation planning in ports and transportation infrastructures by providing methods on how climate risks should be identified and how adaptation measures can be evaluated [**Source 7**]. [Impact period: 2014]

6. Assisting active travel infrastructure development and promoting active travel (*e.g.* [RP 6]).

   a. Utilising novel sensors and artificial intelligence techniques across the six LCR local authorities, the system gathers and analyses real-time data to support decisions such as the prioritisation of cycling/walking infrastructure development (out of 31 strategic corridors). Using inputs from the system, 57.5km green cycle/walking routes are being developed/upgraded to reduce regional GHG emissions by an estimated 334 tonnes in the period 2019-21 [**Source 8**]. This saves lives and improves quality of life, since the research of the British Lung Foundation in 2020 found that 1,040 deaths per year in the LCR can be directly linked to exposure to air pollution. [Impact period: 2019-20]

   b. Supporting seven regional authorities to assess current levels of walking/cycling, the impact of pollution, traffic, and measures to improve active travel. For example, using sensors located in a busy area covering over 10 schools and education settings, plus a major hospital in Liverpool, the system has informed the authority the directions of vehicles, pedestrians, and cyclists at peak time. This finding has fed into the development of a segregated lane for pedestrian/cyclists and thus benefited over 14,000 people and vehicles per day [**Source 9**]. [Impact period: 2020]

7. Helping government, local authorities and transport operators to respond to COVID-19 [RP 6].

   a. Helping government and local authorities with monitoring traffic trends during lockdown. At the request of authorities, the system has been used to monitor traffic (cars, cyclists, pedestrians *etc.*) as well as air quality and weather across the LCR during lockdown. The data has been shared with the Department for Transport at their request, and has also been

shared with the six local authorities, the Combined Authority, and the cycling/walking commissioner [**Source 8**]. The data has informed the authorities of quantitative correlations between the significant increase in cycling and walking in every area of the LCR during lockdown and an improvement in air quality. It has also quantified how the public's travel behaviour changed over the lockdown period and the impact of weather on active travel. Importantly, the data from the system has provided evidence to support local authorities' plans for 11 emergency popup routes across the LCR, enabling people to travel safely with social distancing, and connecting them to key locations like hospitals, workplaces, and transport stations. Using algorithms from outputs such as [RO2], the system has also provided a journey planning app (available on Google and Apple app stores) that allows local authorities to input the emergency popup routes as soon as they are installed, and also monitor traffic on these routes in real-time. So far 23km of routes have been added to the journey planner. This is the first app that allows citizens to plan journeys on popup cycling/walking routes [**Source 9**]. [Impact period: 2020]

b. The system has been continuously providing rail passengers, especially key workers who had to travel to work during lockdown, with key real-time journey information using our intelligent information system at Liverpool South Parkway station. During the four months of lockdown, the system benefited over 56,000 passengers [**Source 6**]. [Impact period: 2020]

c. The data from the system has helped the DfT and its partners to analyse how the COVID-19 national lockdown impacted local road and cycling networks. Partly thanks to this contribution, the aforementioned work by DfT has been awarded 'Project of the Year 2020' at the ITS (UK) Awards, and also 'highly commended' for 'Outstanding Contribution to the COVID-19 Response' at the British Construction Industry Awards 2020. The project team at LJMU have been issued with a certificate for this contribution [**Source 10**]. [Impact period: 2020]

Some relevant events and public awards that have enhanced public awareness of the research:

- Newton Prize 2017 runner up and Highly Commended recognition (one of only 3 Highly Commended projects in 2017).
- Shortlisted for the Mersey Maritime innovation award 2018.
- Invited speech at the industry event "Data Sandbox: Improving Network Performance", organized by the RSSB, with more than 200 industry representatives, 2018.
- Included as an example of UK research on the theme "Sea and Trade routes" in the German Ministry of Education and Research's Science Year: 2016-2017.
- One of top 1% projects chosen by British Council to feature on their global website as Newton Fund success stories https://www.britishcouncil.org/education/science/newton/success-stories, https://www.britishcouncil.org/reducing-vietnams-port-emissions-using-new-technologies.
- Highlighted on the official social media site of the British Embassy in Vietnam as a successful example of collaboration between research organisations, government, NGOs and industries.
- Broadcast by Vietnam state television news (Haiphong TV) and recognised by regional newspapers.

5. Sources to corroborate the impact

Source 1 - IT Manager, VICONSHIP (Vietnam Container Shipping Corporation), Vietnam.
Source 2 - Deputy Chief Operating Officer, Peel Ports, UK.
Source 3 - Safety Manager, Dalian Container Terminal Co. Ltd., P. R. China.
Source 4 - Logistics Division Manager, COSCO Shipping Logistics, P. R. China.
Source 5 - Station Compliance Manager, Merseyrail, UK.
Source 6 - Performance Delivery Manager, Merseyrail, UK.
Source 7 - UN climate adaptation working group expert member, UN.
Source 8 - Manager, Liverpool City Region Combined Authority, UK.
Source 9 - Manager, Merseytravel, UK.
Source 10 - ITS Policy Lead, Department for Transport & the Transport Technology Forum, UK.