Institution: Heriot-Watt University

Unit of Assessment: UoA 11 Computer Science

Title of case study: Environmental, Economic and Policy Impact in Road Freight Transport

Period when the underpinning research was undertaken: 2007 – 2019

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:
David Corne	Professor	Oct 2006 – present

Period when the claimed impact occurred: 2017 – 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

An award-winning fleet planning company began exploiting Heriot-Watt University optimization research in 2014, leading to the following impacts:

(1) Economic: GBP11,650,000 investment and B2B income, plus GBP9,600,000 estimated gains for end-users, four jobs created (15 person-years in the period).
(2) Environmental: the associated cloud service was launched August 2018 and by end 2020 had reduced CO2 emissions by approx. 3,000 tonnes and started recruiting nationwide home delivery fleets.
(3) Policy: founded on results of an associated project, the World Business Council for Sustainable Development now recommend asset-sharing platforms in their guidelines for freight procurement.

2. Underpinning research

Commercial users of optimisation almost invariably use standard single-objective tools, which treat optimisation as the requirement to minimise a single objective, such as 'cost'. However, this is increasingly regarded as suboptimal, since the 'single objective' formalisation distorts the underlying problem, and the optimizer will often miss solutions that would have been preferable. Rather than a cost-minimizing solution, for example, a vehicle fleet manager may prefer a plan using fewer vehicles, or providing a fairer balance between drivers' working hours, better utilization of electric vehicles, and so forth.
Much of our research has been on algorithms for multi-objective optimization, which avoid distorting the underlying task, and deliver solutions that straddle the inherent trade-offs, providing more value and insight to the decision-maker. Early algorithms in this area were slower than their single-objective counterparts, however we are responsible for some of the more widely cited, faster and effective algorithms. In particular, they explore theoretical issues and algorithm design in the context of *many-objective* optimization [3.1,3.2]. While research in this area tends to focus on problems with typically 2 or 3 'headline' objectives (e.g. cost and risk), the Many-Objective Optimization (MOO) area recognizes that (arguably) most optimization tasks involve 4-10, or even more, conflicting objectives.

Our MOO research has included theoretical work, to build an understanding of the consequent algorithm design challenges [3.1], and algorithm design work, in particular reference [3.2], which presents an effective algorithm for problems with 5-20 objectives. The technical challenge in many-objective optimization relates largely to the difficulty in assigning relative quality among groups of candidate solutions, since they will often be 'mutually non-dominated'. The work in [3.2] published in 2007 at the primary conference in evolutionary computation, GECCO found an approach to assigning quality in such circumstances that was relatively efficient and outperformed rival methods. The paper was awarded the "2017 ACM SIGEVO Impact award"; which recognises "…papers published in the GECCO conference 10 years earlier, which are both highly cited and deemed to be seminal" (https://tinyurl.com/ds4xnvp4).
During our collaboration with Route Monkey Ltd (RML) [3.3], we developed further refinements of [3.2] for real-world vehicle fleet planning tasks (broadly known as Vehicle Routing Problems (VRPs). Real-world VRPs are inherently many-objective, (e.g. cost, mileage, emissions, time, CO2, resources-used, etc.), and we found that our approach reliably outperformed leading commercial software, even in terms of the standard single-objective targets of mileage or cost. Finally, from late 2015, we worked with the World Business Council for Sustainable Development (WBCSD) on horizontal collaboration between freight operators. Such collaboration has the potential for substantial savings in CO2 emissions, however is hard to achieve in a business context. With WBCSD, we exploited the aforementioned research, with adaptations for business collaboration models. The findings [5.1] were the basis of an innovate UK project [3.4] which went on to co-develop algorithms for multi-fleet asset sharing and an associated business model which could cope effectively with the often disproportionate utilisation of assets that arises in optimised multi-fleet solutions [3.5].

3. References to the research

The CS/logistics impact case study is underpinned by three research publications. [3.1] and [3.2] respectively underpin the theoretical and practical aspects of the research that led to all of the environmental and economic impacts. [3.1] is published in the primary international medium for its specialized research area; [3.2] is published in what is regarded the top conference in the wider research area and is regarded as seminal (and explicitly indicated as such by an award). The study also has policy impact that arises from the same overall body of work, and is best represented (in terms of underpinning) by the research published in [3.5] (co-authored by a team from the 'Connected Places Catapult', and in an open-access international journal).

[3.1] Knowles JD, Corne DW 2007, Quantifying the Effects of Objective Space Dimension in Evolutionary Multiobjective Optimization. in Obayashi S, Deb K, Poloni C, Hiroyasu T, Murata T (eds) *Evolutionary Multi-Criterion Optimization*. EMO 2007. Lecture Notes in Computer Science, vol. 4403, Springer, Berlin, Heidelberg.
https://doi.org/10.1007/978-3-540-70928-2_57

[3.2] Corne, DW & Knowles, JD 2007, Techniques for highly multiobjective optimisation: Some nondominated points are better than others. in *Proceedings of GECCO 2007: Genetic and Evolutionary Computation Conference.* pp. 773-780, 9th Annual Genetic and Evolutionary Computation Conference, London, United Kingdom, 7/07/07.
https://doi.org/10.1145/1276958.1277115

[3.3] Innovate UK KTP partnership no. 9839 between Heriot-Watt University and Route Monkey Ltd, 10/2014 – 04/2018.

[3.4] FreightShare Lab (FSL), Innovate UK Project 103890,
https://gtr.ukri.org/projects?ref=103890

[3.5] Vargas, A, Fuster, C & Corne, D 2020, 'Towards Sustainable Collaborative Logistics Using Specialist Planning Algorithms and a Gain-Sharing Business Model: A UK Case Study', *Sustainability*, vol. 12, no. 16, 6627.
https://doi.org/10.3390/su12166627

4. Details of the impact

In 2014, Route Monkey Ltd (RML), was establishing a reputation for innovation in fleet software, developing business plans around the vision of a fast/flexible 'online scheduler', and radically simplifying fleets' access to optimisation capability. RML adopted Corne's research to help realise these plans, and a series of associated Innovate UK, EU and B2B projects began in October 2014 [3.5]. One project in this HWU/RML partnership explored multi-fleet collaboration, leading ultimately to policy impact; meanwhile, others transformed RML's technology portfolio, setting the stage for RML's acquisition in 2015/16 by Trakm8 PLC, who sustained the HWU partnership, and launched 'Vortex' (incorporating Corne's algorithms) in August 2018. Associated impacts are outlined below.

Environmental: Trakm8 released the 'Vortex' API in August 2018, incorporating the research and underpinning their optimization service (https://www.trakm8.com/optimisation). Vortex is used for new clients since August 2018, while gradually migrating pre-existing clients. Daily emissions savings accumulate, which can be estimated as follows: Before Vortex, we can estimate that fleets would have used, on average, 10% additional mileage. This is more conservative than the 12.5% estimated gains from top-tier optimization across diverse fleets [3.1], which takes into account that some may previously have used optimization services. This translates into reduced CO2 emissions, mitigating pollution and climate change, and contributing to the UK's CO2 targets. Meanwhile in 2017 RML commissioned an estimate revealing savings of c. 2,200 tonnes per month (from 3,240,000 miles saved per month) across its customer base (https://tinyurl.com/rmlest). Since August 2018, around 5% of pre-existing RML customers have migrated to Vortex, suggesting further reduced emissions of 110 tonnes per month, accumulating to c. 3,000 tonnes by end 2020. Meanwhile some very significant fleets will adopt vortex in 2021 on the basis of proven benefits beyond their current service [5.1]. These include two top-10 supermarkets accounting for over 90,000,000 home-delivery miles p.a. The latter projects and associated product confidence contribute to pre-2021 Trakm8-based economic impact, as presented below.

Economic Impacts

Route Monkey Ltd / The Algorithm People Ltd (TAP): In 2015, Trakm8 PLC acquired RML for GBP7,100,000 (for a consideration of up to GBP9,100,000); this investment was driven in large part by the distinctive and novel algorithm capabilities, and associated development roadmap, afforded by engagement with Corne's group, which also enabled RML to leverage further R&D and private funding summing to approx. GBP3,000,000, and enabling ~15 additional person years of employment in technical positions. RML's CEO went on to found TAP, which raised GBP1,300,000 to develop its novel pay-as-you-go online scheduling platform 'My Transport Planner', which makes use of vortex [5.2].

Trakm8 PLC: associated economic impacts for Trakm8 can be quantified in terms of jobs created in connection with the Vortex API service, and associated project income from a number of IUK and B2B projects, on topics ranging from integration/deployment of Vortex through to specific consultancy tasks that exploit Vortex. Trakm8 estimate these impacts (until end 2020) as: project income: GBP250,000; creating 4 jobs [5.1].

End Users: where case studies have been done by Trakm8 PLC on the impact of Vortex on individual customers reports include, e.g., savings of GBP150,000 p.a. for a charity's transport costs [5.3], and 10% savings on fuel costs along with 30% improved driver productivity for Iceland Foods Ltd [5.4]. Estimating economic benefits across all end users is confounded by the variety of ways that end-users exploit increased plan efficiency; however a lower bound can be suggested, based on cost-per-mile of the most fuel-efficient diesel vans (11p - https://tinyurl.com/fuelppm). Assuming 3,240,000 vehicle miles per month saved to December 2020 (RML estimate noted above), the resulting figure is GBP9,600,000 [5.1].

Policy Impacts

The WBCSD is an organization in Geneva, funded by businesses globally and by the World Bank, advising businesses and influencing policy globally around sustainable practices. Corne's research on asset-sharing was central to two reports from the WBCSD's Low-Carbon Freight working group, and also underpins (via the FSL project), procurement guidelines for freight operators published by the WBCSD's 'Transforming Heavy Transport' project.

The first WBCSD report [5.5] was built around Corne's research as part of the Low Carbon Freight working group, and co-authored by the consortium, including Nestle, UPS, and Scania, promoting non-trivial horizontal asset sharing among fleets (i.e. beyond simply 'backhaul') as one of the more significant measures to be recommended for reducing emissions. Meanwhile, the freight procurement guidelines (WBCSD report 2) is a deliverable of the WBCSD's 'Transforming Heavy Transport' initiative, which brings together 20 global transport organizations to guide the sector towards zero emissions by 2050 [5.6].

Additionally the WBCSD report from the World Business Council's 'Transforming Heavy Transport' project, Sep 2019; "*provides professionals engaged in logistics procurement, supply chain and logistics management, and logistics emissions management with action-based guidance on how to reduce greenhouse gas (GHG) emissions and air pollutants from their freight transport and logistics procurement practices*"; the report describes the 'Freightshare Lab Asset sharing platform", an outcome of the Innovate UK project [3.4], as an exemplar and a signpost to best practice that is "*applicable to all companies*" [5.6].

5. Sources to corroborate the impact

[5.1] Group Director of Big Data, Trakm8 PLC will provide corroboration of economic impacts at Trakm8 PLC, and environmental impacts from the Vortex software.

[5.2] Chief Executive Officer, The Algorithm People Ltd (TAP), (formerly CEO of Route Monkey, 2014-18) will provide corroboration of economic impact regarding Route Monkey and TAP.

[5.3] The Challenge, Trakm8 customer case study https://www.trakm8.com/case-studies/the-challenge/

[5.4] Iceland Foods, Trakm8 customer case study
https://www.trakm8.com/case-studies/iceland-foods/

[5.5] *"Demonstrating the GHG reduction potential of asset sharing, asset optimization and other measures",* World Business Council for Sustainable Development, first report of the Low Carbon Freight Working Group, focusing on research outcomes, November 2016. Contains and summarises Corne's research on the benefits of asset sharing, https://tinyurl.com/wbcsdghg1

[5.6] *"Smart Freight Procurement Guidelines" (*Sep, 2019), by Smart Freight Centre (smartfreightcentre.org) and World Business Council for Sustainable Development (wbcsd.org), a publication from the World Business Council's 'Transforming Heavy Transport' project, September 2019, https://tinyurl.com/wbcsdfpg