Traffic Modelling at the Port of Dover

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THE PORT OF DOVER has undergone many reincarnations over the centuries: from a fortified port complete with lighthouse in the 1st century AD, to a military Cinque Port in the middle ages, to the ferry and hovercraft terminal of the late 20th century. Dover's principal role now is as a Roll-on, Roll-off (Ro-Ro) Ferry Terminal, in which 2 ferry companies (P&O and DFDS) between them make up to 60 round trips a day to the French Ports of Calais and Dunkerque. They carry over 2.6 million lorries, 2 million cars, and 12 million people a year. The economic value in goods handled through the Port is up to 17% of the UK's overall trade in goods. Based on 2016 projections, freight traffic is expected to increase by up to 40% in the next 30 years. However, the Dover Eastern Docks Ferry Terminal is small, around half a square kilometre, and expansion is challenging since it is hemmed in by the sea, the White Cliffs of Dover, and Dover town.

Modelling traffic flows

In 2015, the Port and University of Kent Business School began a 2-year Knowledge Transfer Partnership (KTP) funded by Innovate UK. One objective of the KTP was to determine how the Port could best handle future volumes of traffic based on modelling current and future traffic flows. The aim of modelling was to identify potential bottlenecks in the system and evaluate a range of options and investments for the future.

> *"The Knowledge Transfer Partnership between the University of Kent and Port of Dover has given us a better understanding of the dynamics of traffic flow and how to handle these flows more effectively. Fluidity of movement and utilising the space we have as efficiently as possible is a fundamental aspect of master planning that benefits both our customers and the community. Handling 17 per cent of the UK's total trade in goods, this work has helped us keep Dover, Kent, and Britain moving for both businesses and consumers, as well as plan for the future."* – Rikard Bergstrom, General Manager of Engineering, Port of Dover.

Early in the KTP, a decision was made to use discrete-event simulation to model road traffic flows at the Port. The discrete-event approach was preferable to agent-based modelling, since the Port consists of a series of process steps, each preceded by orderly queues rather than a melee of interacting vehicles. The layout and processes of the Port are shown in Figure 1. Traffic heading for the continent approaches the Eastern Docks from the M20/A20 and M2/A2 roads. On entering the Port, the first checkpoint is the French border control (Police aux Frontières, or PAF), followed immediately by Kent Police. Next, there is ferry operator Check-In, after which vehicles are marshalled in an Assembly Area prior to embarkation onto ferries. The unusual arrangement, in which French immigration entry checks into the Schengen Area are performed in the UK, has been in place since the Le Touquet Treaty of 2003. As can be seen in Figure 1, there are 3 areas in the Port where traffic queues are formed: the marshalling/assembly area next to the ferry berths, a small plaza in front of the check-in booths, and a large “Buffer Zone” – lanes at the entrance to the Port capable of holding 4km of traffic that was created in 2016 as part of an £85m project co-funded by the European Union.

From an applied research perspective, the Port has interesting dynamics, consisting of a series of processes and associated queues in series. The arrival rate of vehicles at the Port is periodic, rather than constant, and processing rates are fairly efficiently matched with average arrivals such that queues frequently ebb and flow as the arrival rate exceeds then falls back below processing rates.

There are two further queue management systems that the Port can make use of. The first is called the Dover Traffic Access Protocol (TAP), in which freight vehicles (and only freight) can be held on the A20 approach via traffic lights. Dover TAP ensures the free-flow of tourist and local traffic along the A20 and through the town by controlling freight when demand is at its highest. TAP has been in place since 2015, first as an experiment, but following its initial success is now a permanent option operated by the Port with the consent of Highways England. The final queue management control is the well-known “Operation Stack”, an option of last resort in which the M20 motorway is used as a lorry queueing area. Operation Stack is only triggered in exceptional circumstances – not at all during 2016/17 and last used in 2015 due to unprecedented events, including the Port of Calais blockade and closure and migrant disruption of the Eurotunnel train line. Operation Stack is estimated to cost the UK up to £2m per day in direct costs and lost productivity.

Modelling the present day

The first step in the KTP was to develop a Simul8© model (Figure 2) of present-day operations at the Port for validation. The Port is data-rich, with excellent historical data on ferry schedules, vehicle/passenger carryings, and arrival rates for different traffic types. This was supplemented by direct timings of processes where needed. The Port has also invested in Blip Systems’ Blip-Track® system, which anonymously senses mobile phone and satellite navigation signals that can be used to monitor transit and dwell times of traffic on the approach to and through the Port. The accuracy of the baseline model was checked under normal conditions as well as under a variety of extremes (check-in IT failure, ferry re-fit schedule causing low daily capacity on routes, and heightened security procedures). The model was considered adequate for its intended use.

Modelling the Port's present-day operations provided a number of useful insights, some of which were not immediately obvious. The first was that the physical infrastructure of the Port system and controls could handle present-day traffic volumes quite well, so that when, for example, check-in processes caused excess queues, it was generally due to technical issues rather than physical capacity limits (e.g. IT problems requiring slow manual check-in processing or staff shortages due to illness). Second, the modelling showed how incredibly useful the Buffer Zone is, since it can provide a selective buffer for different traffic types and ferry operators, as seen in Figure 2, where freight and tourist traffic for each ferry operator are handled separately. Additionally, being at the entrance to the Port, the Buffer Zone provides resilience against problems at any point in the system, in contrast to say the Assembly Area, which fails to mitigate against problems at border controls or check-ins.

Modelling future growth

The next step in the modelling study was to consider future traffic volumes. Three forecasts: expected, optimistic, and pessimistic were constructed to bracket possible future growth, based on varying assumptions and the use of sensitivity analysis to pinpoint future pinch-points. Part of the work also considered how best to use two parcels of land which could be converted (at a cost) from other purposes to operational space. A key performance measure to assess different options was "TAPs per year" – the number of times the capacity of the Port itself is exceeded, resulting in the need to trigger Dover TAP. This is not primarily a financial metric, but rather the degree of inconvenience to the Port, its customers, and the local community.

Modelling showed a mixture of obvious results and some surprises. In the former category was the observation about the importance of daily uplift – the total amount of vehicles ferries can carry per day. This must ultimately match or exceed daily traffic arrivals to avoid queues, although, as mentioned previously, it is quite feasible for arrivals to exceed uplift transiently within a day, causing occasional traffic queues. This is unsurprising since the ferries provide the only "sink" which removes outbound traffic from the system.

More surprising was that even allowing for considerable increases in traffic volumes, the physical infrastructure of the Port could suitably cope with future demand, with the proviso that staffing would need to increase proportionally to handle increases in traffic. However, as volumes increase, resilience falls. For example, an interruption to check-in would cause queues to form much more rapidly under future traffic volumes than in the present day. Essentially, any dynamic process would be sped-up.

For the land which could be converted, the best possible use would be flexible space, ideally with the same characteristics of the Buffer Zone. Modelling identified a costed, sequenced set of investments that optimally addressed traffic growth, together with critical traffic volume thresholds that should trigger investments in the future.

The overview being given may make it sound as if the KTP was a routine exercise in simulation modelling. This, however, would very much underplay the how work had to quickly adapt to real-world events as and when they occurred. The first such instance was in November 2015, one week into the KTP project. On the night of the 13th, terrorists attacked numerous targets across Paris, including the Bataclan Theatre and Stade de France Stadium. The resulting change in security procedures had a major knock-on effect on the Port, resulting in PAF processing becoming a key limiter of vehicle throughput. Over time, the Port has adapted to this change and continues to use modelling to investigate adjustments to security levels on traffic flows.

The second key event to influence the modelling study has yet to play out fully. Early in the KTP, an influence diagram was built representing both permanent and transient factors affecting traffic flows. One factor, considered unlikely, was “that Britain should vote to leave the EU”. As we now know, on 23 June 2016 that risk crystallized. As of early 2018, what ports and airports need to do to fulfill new requirements imposed by Brexit are still unknown. However, the Port has used modelling to try to understand possible impacts of increased processing times on Port performance, both inbound and outbound. This has shown, for example, that as little as 2 minutes per freight vehicle added on to check-in times would result in massive queues and, since the Port has extremely limited space available, queues would be external to the Port, thus necessitating increased use of TAP or, worse yet, Operation Stack.

Impacts of the work

Overall, the KTP project has had several positive impacts for the Port, both tangible such as saving money and resources, and intangible such as facilitating dialogue with government agencies. But arguably the most lasting of benefits is the development of a few simple principles that apply under virtually any future circumstances, as detailed below.

- **The value of flexibility**. Given the intrinsic variability in traffic flows (transient over a day, week, or season) no one fixed configuration of the Port’s hard infrastructure could possibly be optimal all the time. Any investments which increase flexibility, such as using temporary or relocatable structures, are to be welcome. Conversely, investments which reduce flexibility run the risk of being regrettable at some point in the future.

- **Ask key questions when evaluating any future plans.** Does it increase capacity? Does it improve fluidity? Does it enhance flexibility? Does it increase resilience?
- **Recognising the difference between the "anatomy" of the Port (i.e. physical infrastructure) and its "physiology" (i.e. how it works)**. More specifically, it is preferable, where feasible, to adapt performance by changing behaviours through incentives, nudges, and other means, rather than resorting to changes in physical infrastructure.
- **Understanding the importance of modelling to support planning**. The Port is a dynamic system influenced by many external factors (e.g. road conditions, weather, economics, and socio-political events) and relies on highly-skilled and experienced staff to manage the system. Forecasting and analytics serves an important role in supporting real-time, evidence-based decision making of Port staff.

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Figure 1. Port of Dover Eastern Docks ferry terminal.

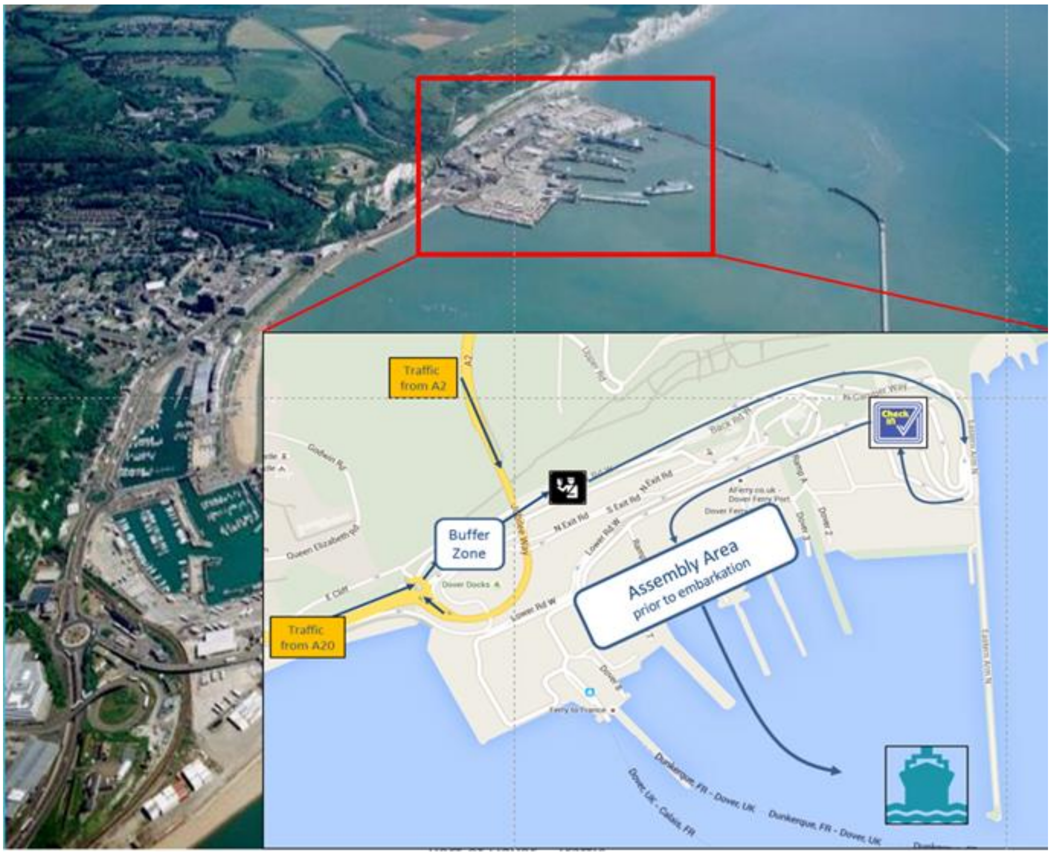

Figure 2. Baseline Simul8 model of the Port of Dover Eastern Docks.

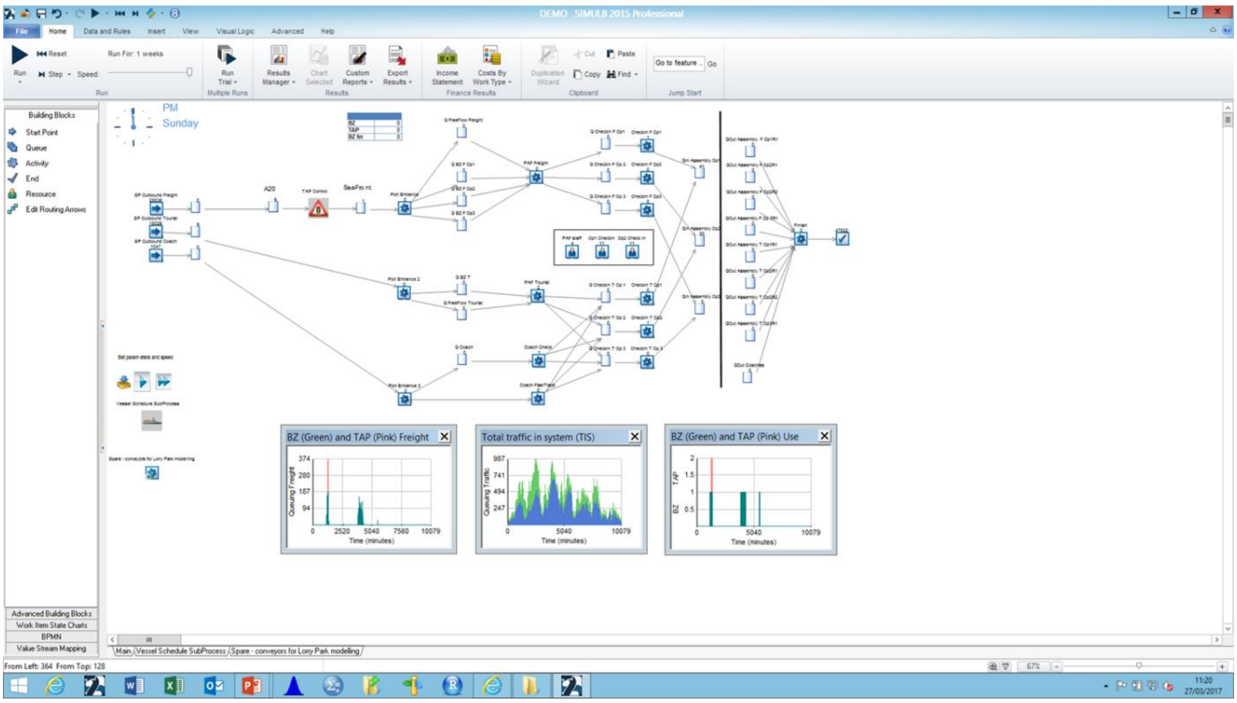

Figure 3. The Port of Dover Buffer Zone with a mix of traffic types.