

# **SIMULATION IN ACTION AT EUROSTAR: THE OPERATIONAL AND STRATEGIC BENEFITS FROM MODELLING PASSENGER FLOWS AND TRAIN OPERATIONS**

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Over the last 25 years, Eurostar has led the way in cross Channel travel. Eurostar is the only high-speed railway company operating international train services between London and continental Europe via the Channel Tunnel. One of its main appeals is that passengers can board trains in central London's St Pancras International (SPI) station and reach either Paris Gare du Nord (GdN) or Brussels Midi, in the heart of the French and Belgium capitals, respectively, in just over two hours. The popularity of the most recently launched service between London and Amsterdam shows the growing appetite among customers for international high-speed rail travel as a sustainable alternative to air travel. In addition to Paris, Brussels, and Amsterdam, Eurostar further runs services to Lille, Disneyland Paris and seasonally to the south of France and French Alps.

The popularity of Eurostar's services is, of course, an enormous boon to the company. However, this success has brought its own set of challenges. As an international service, passengers are required to pass through security screening and border controls (similar to airports) before boarding trains. Due to the growth in demand since services began in 1994, the throughput of passengers at these checks became, at times, a bottleneck, occasionally resulting in queues. Terminal throughput, in turn, has constrained the number of services that can be operated and the number of tickets that can be sold. What is more, scheduling of rolling stock to carry upwards of 11 million passengers per year is no easy task. Travelling at 300km per hour back and forth to Europe each day invariably causes wear and tear on trains, which necessitates that they undergo regular maintenance. Operating across several countries and sharing infrastructure with multiple other operators while managing planned and unforeseen maintenance and coping with daily events that cause disruption to the schedule, Eurostar faces the highly complex challenge of ensuring trains are in the stations and ready to depart on time. Needless to say, this requires extensive and holistic forward planning on Eurostar's part and the design of flexible operating procedures that are able to adapt to ever-changing conditions.

## **DEVELOPMENT OF STATION AND FLEET-LEVEL DIGITAL TWINS**

Starting in 2018, Eurostar and University of Kent Business School began a 2-year Knowledge Transfer Partnership (KTP) funded by Innovate UK. The aim of the KTP was to add new simulation and

analytical capabilities to Eurostar's planning framework and use them to help tackle key strategic and operational business challenges.

Eurostar can best be thought of as a complex system of systems. The cumulative efforts of several systems operating seemingly autonomously, including each station across Europe and the UK, individual trains, maintenance depots, and the control room, must interact together seamlessly in order for the service to run smoothly. Inefficiency or disruption within any one entity has ripple effects throughout the wider system.

Initial modelling efforts focused on the London and Paris terminals, where passenger throughput is highest and improving customer experience is a top priority. Each terminal is a very complex system in its own right and understanding the causes of queues is not immediately obvious. Speak to any customer service team member who welcomes passengers as they arrive and he/she will tell you it is not just the number of travellers but the profile of a traveller that causes throughput to slow. The team in London will point to the increased time required to process a family group going on a skiing holiday compared to that of an individual business traveller off to a morning meeting in Brussels as evidence.

Working closely with frontline staff and terminal managers, detailed simulation models of SPI and GdN were developed using AnyLogic. The simulation models combined both a discrete event type framework to represent the processing of passengers through a series of checkpoints as well as agent-based features to describe passenger profiles, their movements around the terminal, and interactions with each other. Ahead of any day, Eurostar can use the simulation, driven by data from their passenger bookings, to anticipate where and when bottlenecks are likely to occur in a station. That information can, in turn, be used to plan the availability and positioning of staff in the station and further adjust tensorator queue positions to ensure the processing of travellers can keep up with the speed of arrival. It can also be used to plan how to manage passengers in the event of foreseen or unforeseen disruption and to inform passengers how much time in advance of their service departure they need to arrive in order to check-in, clear screening and border control, and board their train. The use of simulation has been particularly useful to Eurostar by giving station staff a much better understanding of the key triggers that create queues and, in turn, adopt a much more proactive and less reactive approach to manage queues in response to varying arrival and passenger profile patterns. Besides day-to-day management, one of the more important benefits of the station simulation models has been to inform strategic level planning for addressing Eurostar's longer-term growth objectives. A case in point was the in-depth testing of a range of proposed changes to the border control layout at GdN. Simulation helped to identify how best to position new border control

stations and reorganise queue lanes in order to increase processing rates and smooth passenger flows through the station. The design ultimately adopted in May 2019 through iterative use of simulation and consultation with various companies, governments, and third-party stakeholders resulted in significantly improved throughput (c. 20%) and customer satisfaction throughout the summer peak period compared to the previous year.

At St Pancras International, simulation has helped Eurostar to evaluate the merits of proposed plans to repurpose a portion of space used for arrivals into a new departure area. Simulation experiments provided a firm evidence base that this proposal could indeed increase departure throughput at peak times over the week and the year, without adversely affecting arrivals. Eurostar has since gone ahead with implementing the new departure area and, as a result, seen the highest ever throughput and customer satisfaction scores over the peak summer travel period.

Despite the improvements, sporadic disruption on the rail network always risks spoiling the station teams' best efforts. In an effort to mitigate against this, a second phase of the KTP project explored how simulation might be used to improve the robustness of timetables by modelling the movement and control of trains. Given the distributed nature of Eurostar's operation, an agent-based modelling perspective was deemed the most suitable way to represent the different interacting components of the business involved with trains movement/control, including individual stations, maintenance depots, main control room, and the trains themselves. Here, an agent-based architecture was implemented with individual agents defined for each sub-system being modelled (i.e., station, depot, control room, train). The interactions of the different agents, in turn, produce emergent behaviours that effectively mimic how the overall system behaves in practice. As with the station-level simulation, the fleet-level simulation model adopts hybrid features in which discrete-event process models, contained within each agent, are used to capture the individual actions and processes of that agent.

The fleet-level model allows Eurostar to simulate a whole day's schedule based on the set of trains available. Simulation runs can indicate which trains are most at risk of delay and identify the source of those delays, which subsequently allows managers to propose preventative actions. This may be as simple as notifying a particular station that they are likely to be stretched during a certain period with several fast 'turn arounds' required to get incoming trains heading out again on time. In a more extreme case, such as when bad weather has led to significant unforeseen maintenance, resulting in a shortage of trains, preventive action involves notifying passengers that their train has been cancelled and re-allocating them to other services. Although very much a last resort, this is much better done a day in advance, rather than after passengers have arrived and are waiting in the

station. For more long-term planning, the model can even be used to compare and rank proposed timetables

#### EVIDENCE-BASED DECISION MAKING

As well as a model to run and test out different scenarios, undertaking a simulation study provides several other ancillary benefits. Working with key stakeholders to develop a model requires the group to agree and articulate their understanding of the impact of certain actions on the system. This logic can then be tested in the simulation and perceived wisdom challenged, perhaps leading to revised understanding. Further, the process requires a thorough exploration of available data. This can highlight gaps that need to be redressed by new data collection programmes and form the basis for improved monitoring of an organisation's performance. Above all, for Eurostar, the simulation study has provided a sound and objective evidence base for decision making in situations where the best choice is not obvious. As the organisation continues to grow, simulation and other analytic techniques will play a key role in ensuring decisions are based on the best available information. This will help ensure the smooth flow of passengers through stations, confidence that they will cross the channel as scheduled, and ensuring the Eurostar brand remains strong and the enthusiasm for fast, efficient, low carbon travel continues.

*Add short bios*

Figure captions:

Fig 1: 3D visualisation in AnyLogic of St Pancras International Departure area. Passengers proceed to the 1<sup>st</sup> floor via the escalators when their train is ready to board.

Fig 2: A highly simplified illustration of the developed fleet-level simulation model structure. An agent-based architecture was implemented with individual agents defined for each sub-system being modelled (i.e., station, depot, control room, train). The interactions of the different agents produce emergent behaviours that effectively mimic how the overall system behaves in practice. Discrete-event process models, contained within several agents, are used to capture the individual actions and processes of that agent. Other agents simply record data.

Fig 3: 3D visualisation in AnyLogic of Paris Gare du Nord. Here Eurostar's border controls are on a raised mezzanine layer. Passengers proceed to the departure area and then return to the ground floor via escalators to board the trains.