

# TfW: Preliminary results for the Class 150 design

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## Key points

- We have integrated the seat layout of both carriages of the Class 150 into our software from the designs provided.
- We achieved a maximum seat occupancy of 22.5%, whilst strictly adhering to a 2m social distancing measure.
- Preliminary stochastic simulations suggest our solutions are optimal.
- We have developed a web-based application for the Class 150 train seating that allows the user to specify the social distancing measure and return the maximal capacity. Available here: [https://lucyhenley.shinyapps.io/TFW\\_socialdistancing/](https://lucyhenley.shinyapps.io/TFW_socialdistancing/)
- We provide a user-friendly theoretical framework to produce optimal seating arrangements while adapting to dynamic social distancing measures.

## What we could do next

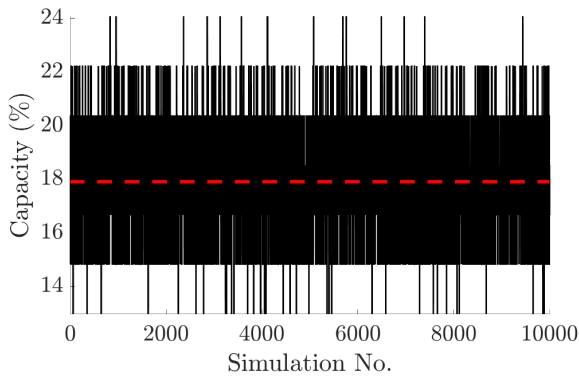
- Carry out the computations for all other train designs, and integrate these designs into the web-application for TfW use.
- Include passenger direction to the analysis; a 1m social distance may be sufficient for passengers facing away from each other.
- Include the use of plastic shields for each carriage type in computation, allowing for possible cost-benefit analysis.
- Develop computational techniques to seek more optimal seating arrangements.

## Methods and results

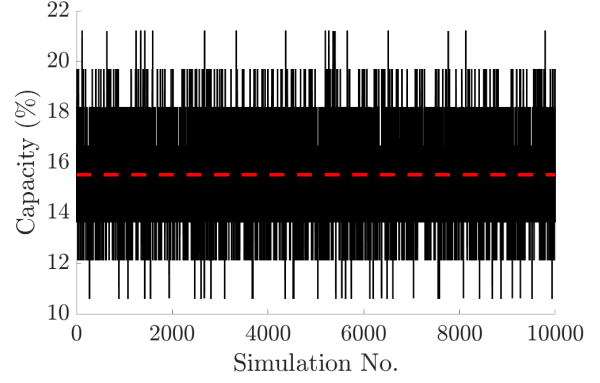
Following our discussions, we added the seating arrangements for the Class 150 train layout to our software. Distance calculations are taken from the centre point of each seat, upon selecting a fixed seat, the algorithm sweeps through all other seats and removes any seat that is within the social distance measure provided, repeating this process until all available seats have been checked. In order to find an optimal solution, we simulated the seat selection randomly 10,000 times for each carriage (see Figure 1), selecting the order of fixed seats that yielded the greatest capacity. The results of the optimal seat selection algorithm are displayed in Figure 2 and in Table 1.

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(a) Stochastic seat selection results for carriage 1.



(b) Stochastic seat selection results for carriage 2.

Figure 1: Results from stochastic seat selections. The fixed seats were selected at random, the algorithm then swept through all seats and removed seats that were too close. The black line represents the resulting capacity from each simulation, while the dashed red line corresponds to the mean of all simulations.

	Maximum capacity at 2m social distancing
Benchmark	28 (23.3%) <sup>1</sup>
Cardiff App	27 (22.5%)

Table 1: Comparison of the performance of the Cardiff seat finding app against the benchmark provided in the supplied report.

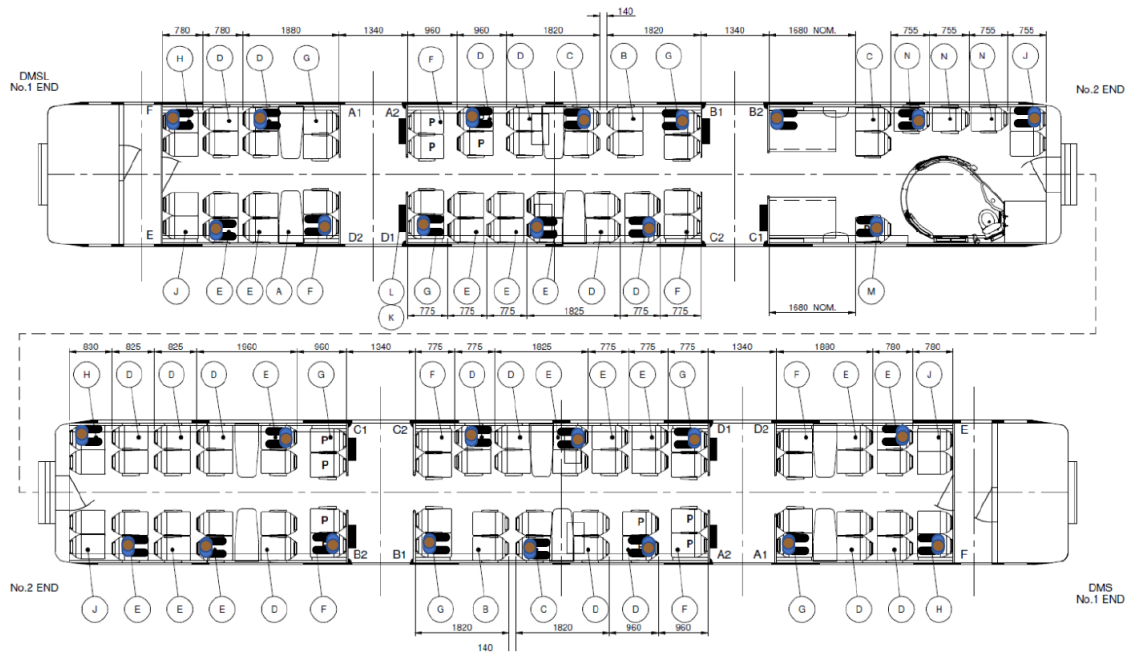
As demonstrated in Table 1, we can very quickly achieve similar occupancy rates in the train without violating social distancing measures. Given more time, we can develop methods for taking passenger direction into account, and geometrical constraints (walls/partitions in the carriages) allowing for higher occupancy rates.

## Prospective developments for improving optimality

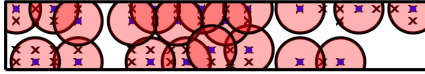
Our application always provides seating arrangements that obey social distancing measures, and provides locally optimal solutions which are similar to the given benchmarks. Returning the absolute optimum arrangement, however, is a lot more difficult because the problem is what is known as ‘NP-hard’. Simply put, the only way to guarantee you have the most possible seats used is to try every possible order of seat checking, and pick the one which has the most seats used. Actually trying out every seat ordering would take a very long time; there are more ways to order 120 seats than there are particles in the universe.

What we can do, though, is develop techniques to check our solutions and continuously improve upon them where possible. At a cost of additional time and computing power to implement, these methods would improve the likelihood we have found the best possible seating arrangement, allowing us to potentially further improve on our already powerful result. For example, we have provided preliminary calculations in Figure 1 to show that our current results are optimal up to 10,000 simulations, however, this can be extended with computational power and theoretical applications.

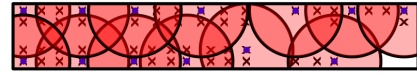
<sup>1</sup>We note that in the provided estimation of the Class 150 design, there exist ‘usable’ seats that are within 2 metres of each other.



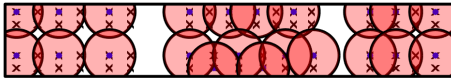
(a) The seating arrangement for the class 150 train.



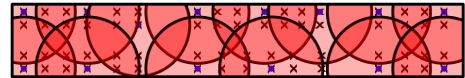
(b) A sample layout for carriage 1 with a social distancing measure of 1 metres. 20 seats are available.



(c) A sample layout for carriage 1 with a social distancing measure of 2 metres. 13 seats are available.



(d) A sample layout for carriage 2 with a social distancing measure of 1 metres. 22 seats are available.



(e) A sample layout for carriage 2 with a social distancing measure of 2 metres. 14 seats are available.

Figure 2: A proposed seating layout given by the app for 1 and 2 metre social distancing for both carriages of the class 150 train. Seat locations are marked with crosses, available seats are marked with dots and the 'region of safety' is denoted by a circle around the available seats. Overlapping circles imply that certain regions are exposed to contamination from multiple sources, but no available seats are located in these regions.