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Optimising ambulance conveyance rates and staff costs by adjusting proportions of rapid response vehicles and dual-crewed ambulances: an economic decision analytic modelling study

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ABSTRACT

Aim: To model optimum proportions of dual-crewed ambulances (DCAs) and rapid-response vehicles (RRVs) in Ambulance Trusts with a view to generating a policy brief on the strategic procurement and allocation of emergency vehicle (EV) resources.

Methods: Historical EV assignments for 12-months of emergency calls were provided by an Ambulance Trust and analysed for back-up, see and treat, and patient to hospital conveyance. Unit costs were derived for paramedics and technicians using Agenda for Change pay rates. Time cycles were assigned for RRV and DCA attendances and unit costs assigned to these. Information was put into a decision analytic model to estimate the costs and numbers of vehicles attending incidents based on relative proportions of available RRVs and DCAs.

Results: Of 711,992 calls attended by 837,107 EVs, 514,766 (72.3%) required at least one emergency department conveyance. The rate was significantly lower with RRVs first on the scene. 27,883 out of 529,693 (5.2%) DCAs first arriving at an incident required some back-up; and this, too, was factored into the model. Modelling demonstrated high conveyance rates were counterproductive when increasing the relative proportions of RRVs to DCAs. For example, with conveyance rates of 65%, increasing the RRVs increased the cost and numbers of vehicles attending per incident. At lower conveyance rates, however, there was a levelling around 30% where it could become cost-effective to increase the relative proportions of RRVs to DCAs

Conclusion: At current overall conveyance rates there is no benefit in increasing the relative proportions of RRVs to DCAs unless additional benefits can be realised that bring the conveyance rates down.

INTRODUCTION

There is little published or grey literature on the optimum configuration of different types of resource, for example single-crew rapid response vehicles (RRVs), dual-crew ambulances (DCAs) or other emergency vehicles (EVs) in NHS Ambulance Trusts. The increasing year-on-year demand for ambulance services[1,2] and the need to safely treat people closer to home has led to ambulance services varying staff skill mix and resources to enable this. An estimate of optimum configuration will allow ambulance services to strategically reconfigure their proportions of single to double crewed vehicles to ensure that ambulance response times are improved while improving efficiency and maintaining high quality care. A key opportunity identified in the Carter Report[1] on Ambulance Trusts. was an overarching need to improve fleet management, arguing a common specification and procurement strategy would help to maximise EV availability to those in need. The aim of this study was to explore with modelling the question: 'In relation to economics, what is the most cost-effective configuration of RRVs and DCAs in an Ambulance Trust?'

METHODS

We used the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) methodology[3] in the economic decision analytical model design. The study population modelled calls involving additional RRVs as the intervention and DCAs as the comparator. The perspective was that of the NHS Ambulance Service. A 12-month timeframe was adopted and data on all EV arrivals and assignments for emergency calls for the period 1st January 2019 to 31st December 2019 were provided by East Midlands Ambulance Service NHS Trust (EMAS). Mean likelihood of conveyance, mean likelihood of there being a paramedic in the crew and mean likelihood of need for a backup were determined from this information with 95% Confidence Intervals. Conveyance rates for RRVs and DCAs were combined using Pearson's chi-square. As the period did not exceed 12 months, no discount rate was applied to the model. Following deduplication and removal of non-attendances, each attended incident was split into one that required either a see and treat (S&T) or a see, treat and convey (STC) of at least one patient to an emergency department. Unit costs for the model were generated by examining Agenda for Change (A4C) pay rates for 2019-20 and setting them at Median Band 6 for paramedics and top of Band 4 for Emergency Medical Technicians (EMTs). The annual salary was inflated by 25% to allow shift premiums and converted to a per minute unit cost using a 37.5-hour, 52-week denominator. This gave, for example, a cost of £0.35min^{-1} for a paramedic and £0.25min^{-1} for a technician. Outcomes were reported as cost per attendance and numbers of vehicles attending per 100 calls.

Cycle times were unavailable from the data so different job cycle times were considered for the model base case. Based on the Carter report[1], a mean cycle time of 29 minutes was considered for S&T for both a lone paramedic in a RRV and two staff in a DCA, giving attendance costs of £10.08 and £18.28 respectively. For STC episodes, mean cycle times of 64 minutes and 74 minutes were adopted for RRVs and DCAs respectively, giving STC costs of £22.24 and £46.65. The longer RRV times for STC reflected the time at the scene of the incident waiting for a DCA. Uncertainty was modelled using +/-25 & 50% for cycle times; +/-25 & 50% for proportion of paramedics, and conveyance probabilities of 0.30, 0.45, 0.60 and 0.85 in addition to the base case conveyance rate.

MODEL STRUCTURE

The model structure adopted is outlined in Figure 1 below. Value x represents the theoretical proportion of RRVs relative to DCAs, so if there are 2 RRVs to every 3 DCAs, x would be 0.40. Value y is based on likelihood of conveyance and based on rates during 2019 was set at 0.723, although as for x, this could be set at any value between 0 and 1. Value z is based on the likelihood of a DCA needing backup and derived from the EMAS dataset at 0.053. For RRVs, it was assumed that if conveyance was required then a DCA would also have to attend as RRVs rarely convey, so it would require two vehicles to cover the incident. Conversely if there was no conveyance only the RRV, if this attended first, would be required. For DCA-attended incidents there was also a (lower) likelihood that backup would be needed so if backup was required, two vehicles were costed.

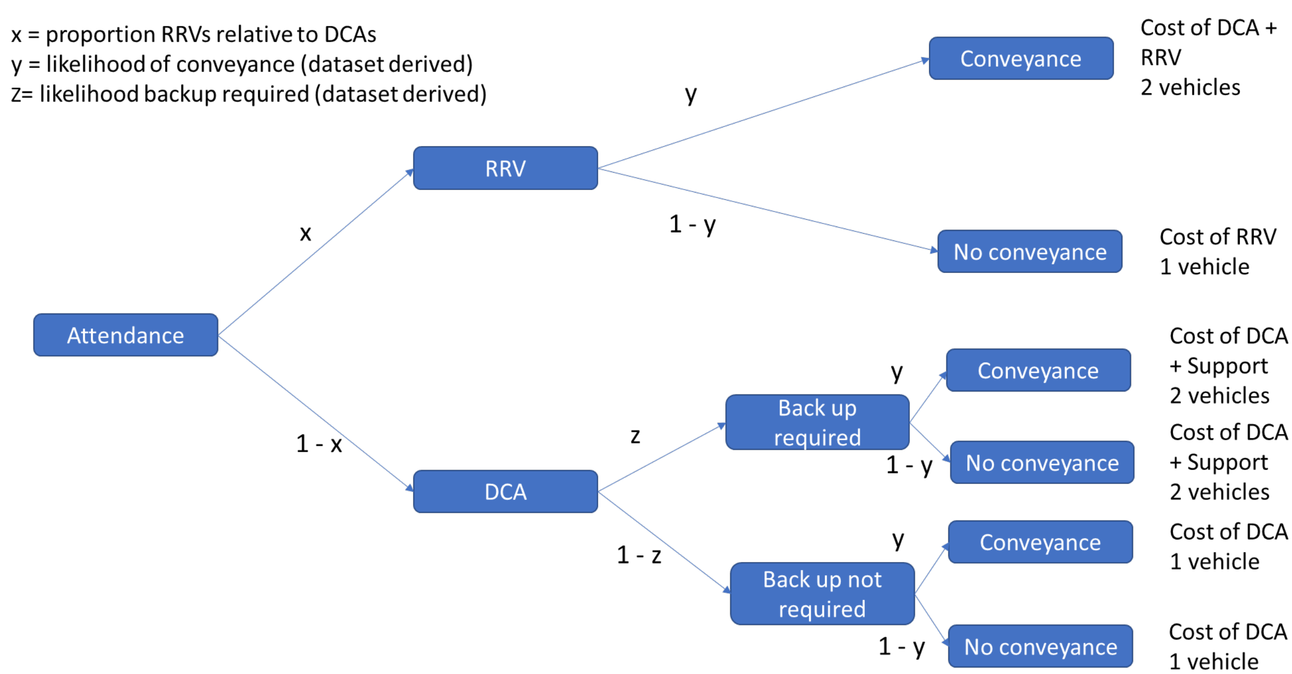

Figure 1: Structure of model

Analysis of raw data was done using Stata V. 16.1; the model was built in Excel 365.

RESULTS

A total of 711,992 incident calls were attended by 837,107 vehicles giving a total of 118 vehicles attending per 100 incident calls. Of these incident calls, 514,766 resulted in at least one conveyance (probability of conveyance = 0.72299, 95%CI: 0.72195 to 0.72403). Category 2 calls were the most common (446,329, 62.7%) and had a high rate of conveyance (332,827, 74.6%) whereas Category 4 calls were less common (8,085, 1.1%) but had a low rate of conveyance (3,368, 41.7%). The likelihood of all DCAs needing back up was determined from the dataset as 0.05264 (95%CI: 0.05204 to 0.05324, n=529,693 observations) and the likelihood of the ambulance being crewed by a paramedic was 0.65520 (95%CI: 0.65392 to 0.65648, n=529,693 observations). Less than 10% of the incident calls had an RRV on the scene first; however, the probability of conveyance when an RRV was first on the scene was significantly lower than a DCA at 0.59377 (95%CI: 0.58994 to 0.59760, n=63,262, $p<0.001$).

Model inputs were set at the following values for the base case analysis:

1. x=variable running from 0.00 to 1.00 to reflect different RRV and DCA proportions
2. y=0.723 (based on EMAS data analysis)
3. z= 0.053 to represent the likelihood of back up DCA being required (based on EMAS data analysis)
4. Cost of RRV S&T = £10.08 (reflecting a single paramedic at mean cycle time 29 mins)
5. Cost of RRV STC = £22.24 (reflecting a single paramedic at mean cycle time 64 mins)
6. Cost of DCA S&T = £18.28 (reflecting a 0.655 likelihood of a paramedic assigned to DCAs at mean cycle time 29 mins)
7. Cost of DCA STC = £46.65 (reflecting a 0.655 likelihood of a paramedic assigned to DCAs at mean cycle time 74 mins)

Model outputs are illustrated in Figures 2, 3, 4 and 5.

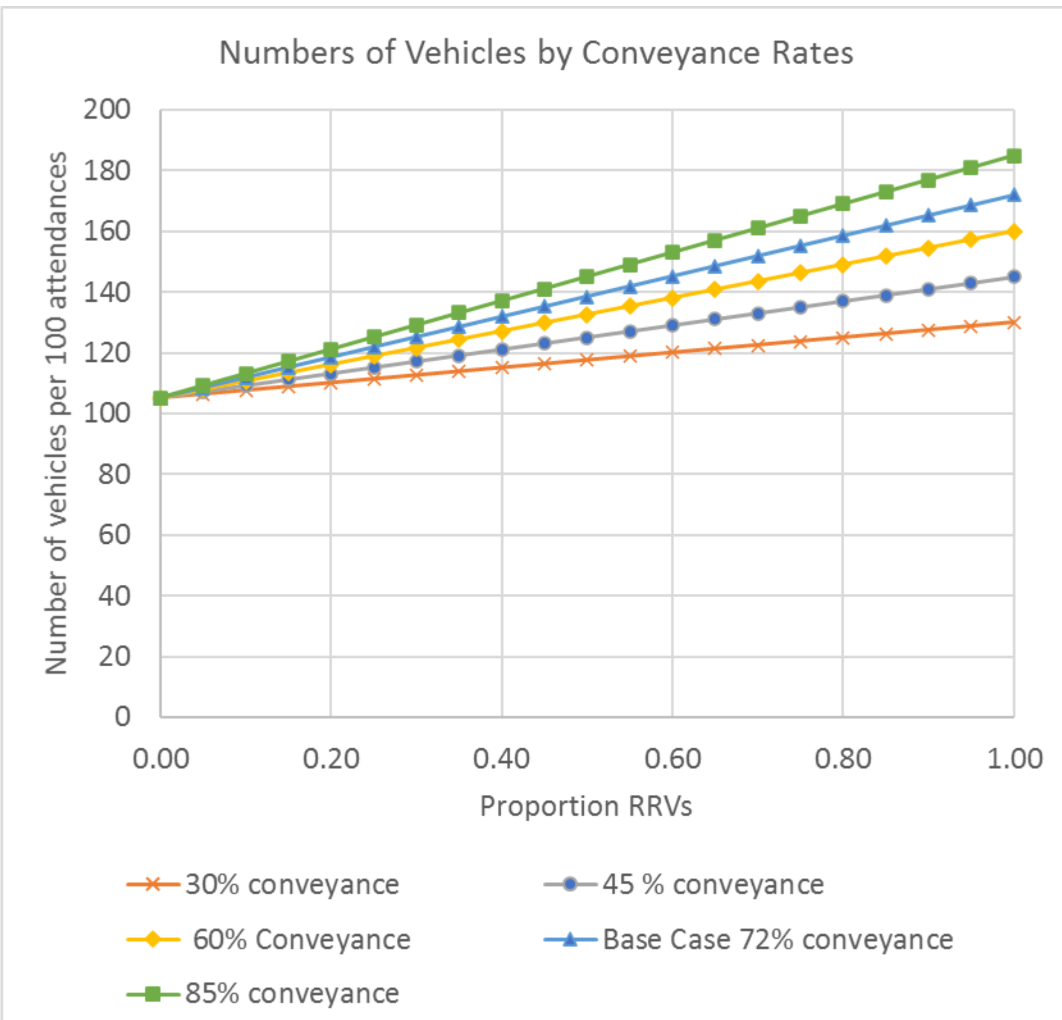

Figure 2: Number of vehicles attending a call by proportion of RRVs in fleet by conveyance rate

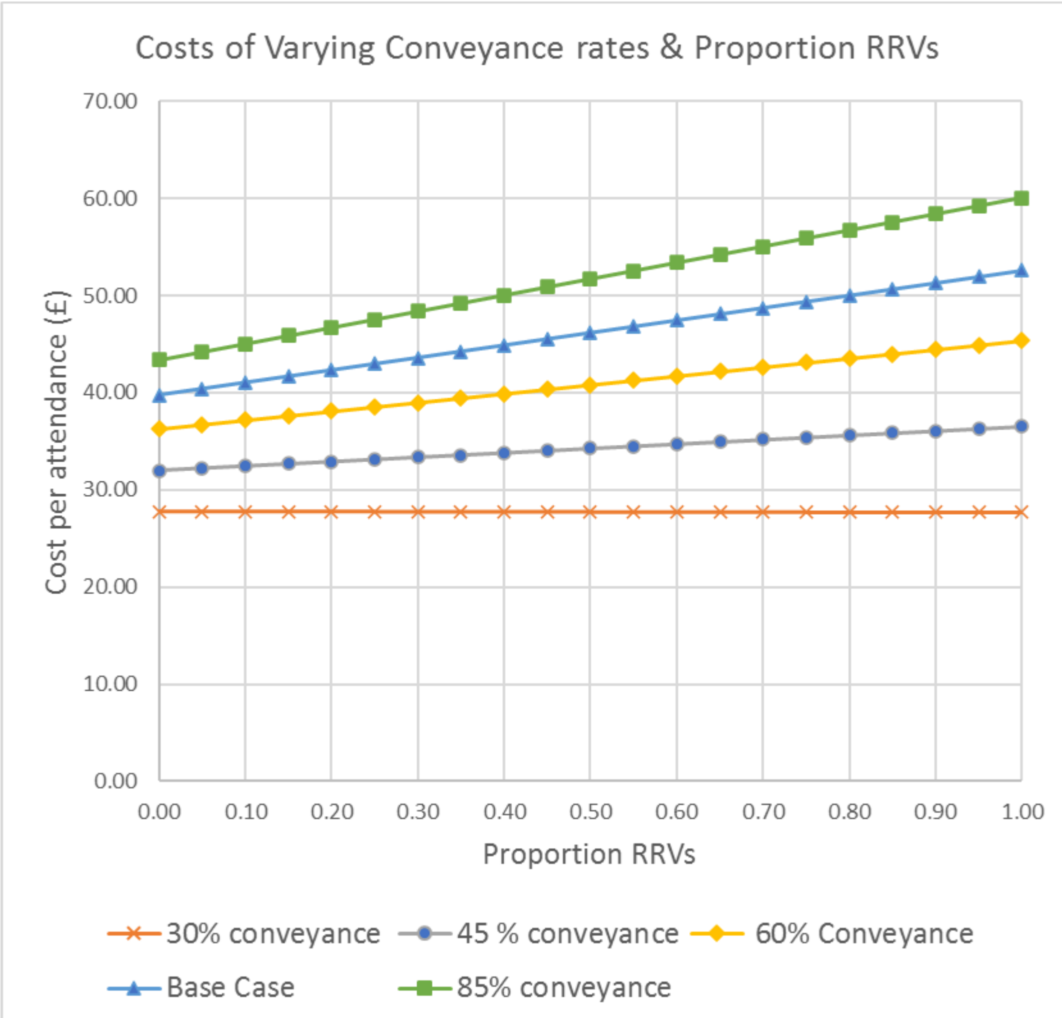

Figure 3: Cost of Vehicles attending a call by proportion of RRVs in fleet by conveyance rate

The number of vehicles needed in the base case ranged from 105 to 172 per 100 calls and increased with increased proportion of RRVs (Figure 2). This had a knock-on effect on the cost of each incident giving a range from £39.75 to £52.65 per attendance (Figure 3). Additional sensitivity analysis was explored using different conveyance rates, different cycle times and different crew mixes. Changing the conveyance rates had a large effect on the overall numbers of vehicles and costs involved (Figures 2 and 3). Cost change due to cycle time had, as expected, the most profound effect on cost per attendance (Figure 4). Changes in crew mix had less of an effect (Figure 5), for example in the base case, uplifting the probability of a paramedic being on the DCA from 0.655 to 0.98 increased the cost per attendance by between 6 and 10% on the proportion of RRVs. Decreasing the conveyance rates to 60% and 45% (Figure 3) showed a start in the costs levelling out across the proportion of RRVs and at lower rates (30%) showed cost savings could also be achieved (Figure 3).

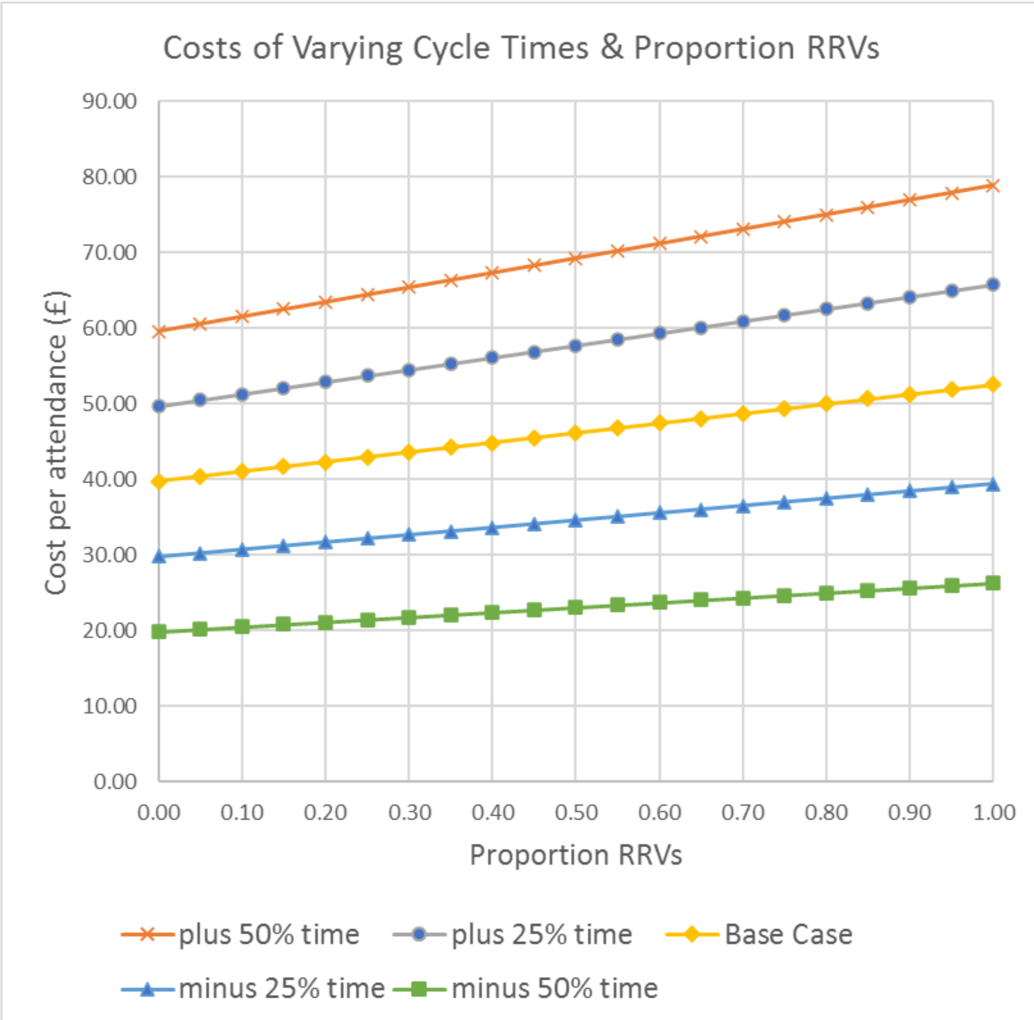

Figure 4: Cost of Vehicles attending a call by proportion of RRVs in fleet by overall cycle time

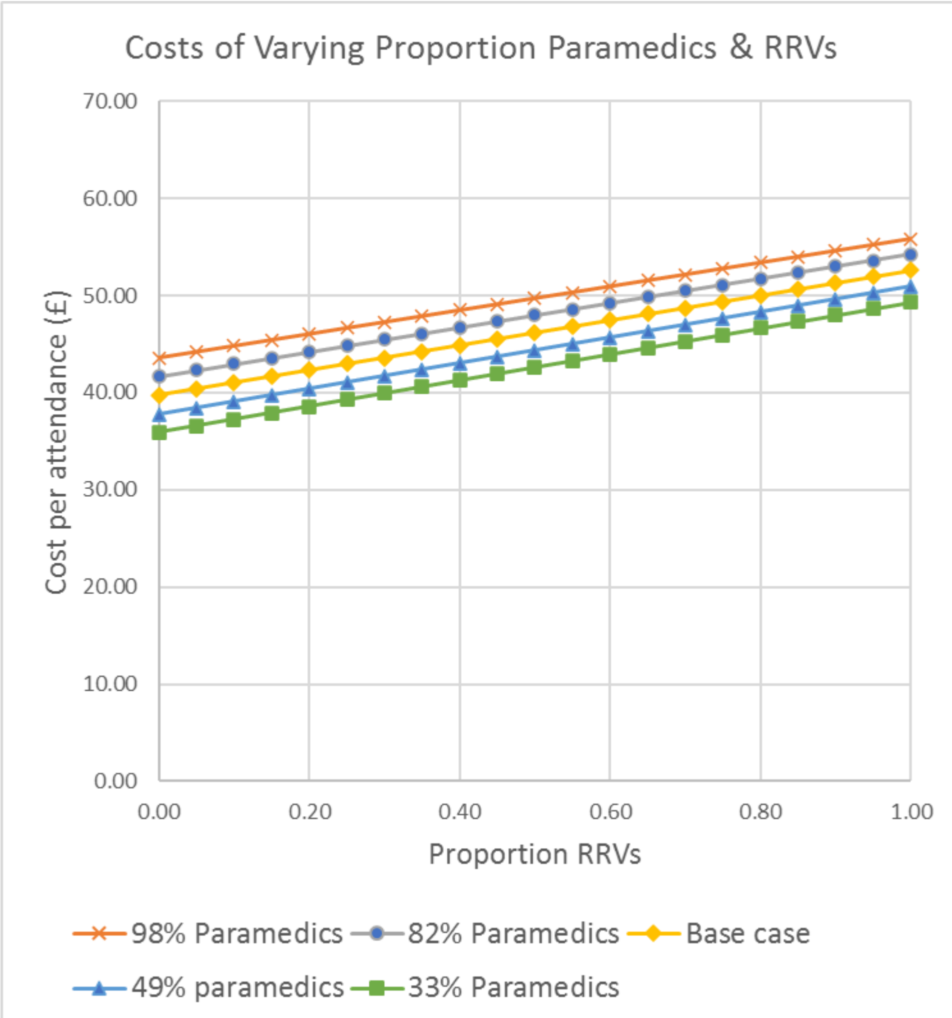

Figure 5: Cost of Vehicles attending a call by proportion of RRVs in fleet by percentage paramedics (crewmix)

DISCUSSION

The model provides a strategic tool to help ambulance trusts review their existing proportions of RRVs to DCAs and plan future requirements. In the first instance it was clear, at current conveyance rates of 72%, there is no benefit in increasing the relative proportions of RRVs without first finding a way of bringing down the conveyance rates. Some limitations do exist in this preliminary modelling study. For example, smaller staff groups (<2%) such as emergency care assistants and nurses were assigned as top of Band 4 in the costing and longer cycle times in Category 3 and 4 calls were replaced with a single shorter cycle time based on the Carter Report. In addition, equipment, vehicle and depreciation costs were not considered in the costing as insufficient data was available to factor this in. There was also insufficient granularity in the data to estimate the impact of more specialized Band 7 paramedics, the use of emergency care practitioners in RRVs or critical care teams.

Nevertheless, the model accounted for over 80% of the first arrivals data, the staff cost increases were consistent across all cycle times as shown in Figure 4 and staff mixes as shown in Figure 5. The staff mix in the base case reflected a 0.655 probability of a paramedic on the DCA which was also consistent with observed data. Using existing tools[4], more detailed costs can be assigned at an Ambulance Trust level and be further adjusted to reflect localised cycle times, staff mix and categories; however these do not take into account the vehicle mix like this reported model does. If these are known, proportions of RRVs to DCAs can be incrementally adjusted over a period of time to fine tune reductions in overall conveyance rates. This in turn can help free up more resources to help maximise emergency vehicle availability to those in need in line with the Carter Report recommendations.

Our preliminary analysis provides demonstrable evidence for ambulance service policy at both a regional and national level that decreasing conveyance rates can potentially have a marked effect on EV costs and pay for increased proportions of RRVs relative to DCAs in the EV fleet. Furthermore, we saw from the Trust data itself a significant decrease in the number of conveyances in the smaller proportion of calls first attended by a paramedic-crewed RRV (Conveyance rate going down from 0.72299 to 0.58994) although it is uncertain if this rate would be replicated if applied across all calls. The model clearly demonstrated further time-based cost savings can be achieved by reducing the cycle times spent on each call whereas increasing the likelihood of finding a technician on a DCA by for example upskilling technicians to paramedics would have a relatively minimal cost impact. This brings in a classical chicken versus egg dilemma and raises the question would increasing the proportion of paramedics in the crew mix potentially reduce conveyance rates and cycle times or would it be more pragmatic to find ways of reducing cycle times and conveyance rates first and then upskill the workforce?

CONCLUSION

At current overall conveyance rates of around 72% of calls attended there is no benefit in increasing the numbers of RRVs relative to DCAs. For cost benefits to be realised there need to be reductions in cycle times or conveyance rates. Upskilling more technicians to paramedics may go some way to help resolve this.

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What this paper adds box

Section1: What is already known on this subject

- The 2018 Carter review of 'Operational productivity and performance in English NHS Ambulance Trusts' identified specific areas for improvement for the ambulance service, including more effective management of the emergency vehicle fleet.
- There is very little research about what this might mean, leaving ambulance trusts unable to make decisions based on real data.

Section2: What this study adds

- The model shows increasing the proportion of rapid response vehicles (RRVs) to dual-crewed ambulances (DCAs) is counterproductive where high conveyance to hospital rates exists.
- Provides NHS Ambulance Trusts a way of reviewing existing proportions of RRVs and DCAs and a means of planning their replacements using actual Trust data to help maximise EV availability to those in need.

- Provides academic and NHS Ambulance Trust researchers a means of examining differences between Trusts in the numbers of EVs attending emergency calls
- A tool to aid strategic thinking by NHS Ambulance Trusts and academics on which emergency vehicles are assigned by category and how they are crewed
- A tool to aid NHS Ambulance Trust and academic investigative work on vehicle cycle times and unit costs of attendance and conveyance by category
- A tool to aid future NHS Ambulance Trust and academic research on ways of bringing conveyance to hospital rates down

LIST OF ABBREVIATIONS

RRV	Rapid Response Vehicle
DCA	Dual-Crewed Ambulance
NHS	National Health Service
EMAS	East Midlands Ambulance Service NHS Trust
EV	Emergency Vehicle
S&T	See and Treat
STC	See, Treat and Convey
A4C	Agenda for Change

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