MI-LINK

Experiences of the Safety Operator Role in the MultiCAV Project

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Overview and Summary of Findings

The MultiCAV research and development project, co-funded by Innovate UK and the Centre for Connected and Autonomous Vehicles (CCAV), was established to deliver sustainable transport services in a 'Mobility as a Service' environment. The centrepiece of the project was a series of three phases of electric autonomous bus service trials, first operating on public roads within Milton Park Technology and Science Park, Didcot (Oxfordshire) and later linking to Didcot Parkway railway station. The demonstration services took place in 2023 and were branded to the public as part of the Mi-Link[1] suite of transport services. The project was conducted by a consortium which brought together First Bus as lead, Milton Park, Oxfordshire County Council, Nova Modus, Fusion Processing[2], Zipabout, and the University of the West of England (UWE Bristol).

The Potential for Bus Automation

Whilst promising many benefits, the widespread use of autonomous vehicles as private cars holds the potential to increase traffic flows, worsen congestion, worsen public health, and reduce public transport use (Ainsalu et al., 2018). At the same time, there is potential for public transport, its users and providers to benefit from autonomous driving systems. These benefits may include enhanced safety or an enhanced bus network; either more services for a given level of operating cost, or reduced user costs for a given network. However, whilst in the long run services in some Operational Design Domains may be unstaffed, for the immediate future safety operators will be essential. Hence, recruiting, training, qualifying, monitoring and retaining safety operators who can supervise, (and drive, if necessary) autonomous buses will be a vital component in making such operations viable. In addition, the acceptance of autonomous systems by drivers will be important to implementation, with a possibility that such systems may "challenge the traditional role of professional drivers as vehicle operators" (Johansson et al. 2022, p.624).

About the Report

The report examines the experiences of the safety operators involved in crewing the MultiCAV Project's Mi-Link demonstration Services 001 and 002. It considers the selection, specialist training and on-road operation of an automated electric minibus, a type-approved Public Service Vehicle. These were first-of-a-kind activities in the UK.

In this report we refer to the on-board personnel as 'safety operator' to emphasise the hybrid nature of the role. The safety operator was responsible for all the normal duties of a bus driver in the UK, including driving the vehicle when not in autonomous mode, and also for overseeing the safe and punctual operation of the service when in autonomous mode, including providing assistance to passengers with additional accessibility needs. Against those criteria, the operator took responsibility for determining when the vehicle should operate using automated or human driving, taking control or handing back accordingly.

Services operated

Service 001 required the vehicle to travel on a circuit within the Milton Park Science and Technology Business Park. Service 002 required the vehicle to use the public road network between Milton Park and Didcot Parkway railway station completing a 10km round-trip route including one section on which the bus was programmed to reach speeds of up to the legal limit of 40 mph (65km/h)

[1] See https://www.mi-link.uk/ for the public-facing website

[2] Initially a subcontractor to the project appointed through a procurement exercise, later a full project partner.

depending on conditions. The route also had instances of challenging junctions, encountered variously in heavy or lighter but fast-moving traffic conditions. For the most part the minibus operated with two members of staff on board: one in the driving position as safety operator and the other providing assistance to the colleague and offering information to passengers.

Summary of earlier evidence review

Prior to undertaking the empirical research with safety operators, an evidence review had the conducted (Calvert, Parkin, Parkhurst, & Bartle, 2020). The review examined earlier research on relevant attitudinal and behavioural characteristics when selecting and training safety operators of autonomous buses. It supported the framing of the methodology for the research reported here, and is drawn upon in the discussion.

The next three paragraphs provide a brief summary of the scope and key findings of relevance from the earlier review.

The review included the procedures followed by bus and train companies in recruiting and training drivers. Codes of operating practice for autonomous vehicles were also considered, noting that these emphasised guidance for trial situations rather than operating commercial services. Previous evidence gathered from simulations was also covered.

Considering the overall aptitudes for being the safety operator of an autonomous bus, some were common to traditional bus driving (spatial and situational awareness; ability to drive smoothly; ability to drive safely; friendly customer service; maintenance of concentration; ability to handle conflicting demands amidst distraction; low level of the personality trait *neuroticism*; reliable attendance for shifts; high level of conscientiousness; no excessive 'sensation seeking', another personality trait; and robustness against fatigue). Other necessary aptitudes though do not have precedents in human driving (ability to rapidly resume control; maintenance of driving skills if little used; confidence in switching between automated and manual modes; appropriate level of understanding of, and trust in, autonomous systems).

Amongst the attributes necessary for being an effective safety operator, evidence suggested that maintaining attention would be the primary challenge for safety. 'Resilience of character' also emerged as important, with fatigue a specific challenge.

Data collection method and study limitations

One-to-one semi-structured interviews were carried out with all six of the safety operators involved in delivering the two services and the trainer. The drivers were selected by the bus company partner and the trainer was provided by the developer of the automated driving system. To this end, the driver interviews were undertaken twice, towards the end of each of the operating periods of Service 001 and Service 002. Recordings of these interviews were then analysed, using the original interview guides as a structure.

Limitations include a lack of triangulation of different research techniques (compared, for example, with Johansson et al., 2022). Specifically, the subjective self-report in the interviews was not compared with objective measures of take-over time and other quantifiable metrics of driver performance. In the context of the on-road trial services in MultiCAV there were limited opportunities for experimental conditions to be achieved.

Findings from the Analysis of Interviews

Training for Service 001 involved a classroom session, initial familiarisation in an off-road context, and then on-road practice. According to both trainer and safety operators, the training was successful, with none of the drivers recommending any changes when asked, and the trainer expressing satisfaction.

Comparison of the initial review of previous literature and the data from Service 001 suggests that the selection and training of the safety operators was simpler in practice than hypothesised based on the literature review. The MultiCAV trainer affirmed an interviewer's reflection to this effect. This finding is likely influenced by the selection of the safety operators from a pool of already qualified and experienced drivers of full-size conventional buses. As the safety operator pool was the same, Service 001 provided a further training opportunity for Service 002, albeit with a two-month gap in between. Service 002 training simply required an introduction and familiarisation of the extended route and what operators could expect along it. The vehicle used was unchanged, although it had also been involved in 'orientation' to the new route by the autonomous driving system.

The safety operators' experience of supervising the vehicle during the trial was reported as being largely very positive and enjoyable, with enthusiasm universally expressed for taking part. All those involved in Service 001 agreed to staff Service 002. The drivers' confidence during Service 002 was even higher, after many weeks of experience supervising the bus, and a general feeling that the technology had improved, which increased their level of trust.

The most significant challenge during Service 001 in terms of driver experience was, for some, a level of fear on first operating the vehicle on real roads, although this seems to have abated quickly in all cases. During Service 001 the autonomous systems had some technical challenges to overcome at various points that the safety operators had to negotiate (e.g., such as alignment of the bus within the carriageway).

By the time of Service 002, all six drivers were much more confident with the environment and the technology, which they felt had been improved partly in response to issues that they had highlighted. This increased trust resulted in reduced intervention on safety grounds. However, the safety operators indicated that they were able to predict the behaviour of the autonomous bus in certain locations and scenarios and especially in heavy traffic or when there were passengers on board they sometimes pre-empted heavy braking or a swerve and retook control for a period, but this was more for reasons of comfort and maintaining progress against the timetable.

Most but not all of the interviewees by this point felt confident enough to not need a colleague onboard but felt that frequent crew changes and rest periods were required. Following feedback to the bus operator it was agreed that the safety operatives would be given the option as to whether they supervised the vehicle alone or in pairs.

Lessons learned for training and operation

- The use of experienced bus drivers as safety operators enables a fast but safe transition between roles. Where safety operators do not have that experience then the use of more rigorous selection procedures and additional training might be necessary.
- As alignment of the autonomous vehicle within the carriageway was a concern that emerged for the safety operators at the start of Service 001, it is a topic that should be included in future induction training.

- Mixed opinions and understandings amongst the safety operators about the level of capability of the autonomous system indicated that this matter could be clarified further during induction training.
- The presence of automation experts on the bus for a period after formal training was complete might have benefits for the accuracy of the mental model the safety operators develop of the autonomous system (with attendant performance benefits). If this proves unrealistic in terms of resource, there could be an ongoing 'question and answer' dialogue between driver and automation experts via email, messaging or voice calls.
- In practice there was a lot of monitoring of the technology from the automation experts and so they were frequently on the bus in Service 001 and the early part of Service 002. This allowed for a lot of interaction between the drivers and the technical experts.
- Most safety operators during Service 001 felt the two-hour shift could be increased in length, because they are used to longer driving shifts. None of the drivers reported difficulty with concentrating whilst operating the vehicle.

Overview of Main Report

Section 1 describes the two services operated. Section 2 presents the methodology. Sections 3 and 4 present the findings from the trainer interview and the driver interviews respectively. Section 5 synthesises the findings in a discussion and compares them to the previous evidence. Section 6 presents conclusions and recommendations for future training programmes and management of safety operators.

1. MultiCAV Mi-Link Services 001 and 002

The MultiCAV research and development project, co-funded by Innovate UK and the Centre for Connected and Autonomous Vehicles (CCAV), was established to deliver sustainable transport services in a 'Mobility as a Service' environment. The centrepiece of the project was a series of three phases of electric autonomous bus service trials, first operating on public roads within Milton Park Technology and Science Park, Didcot (Oxfordshire) and later linking to Didcot Parkway railway station. The demonstration services took place in 2023 and were branded to the public as part of the Mi-Link[3] suite of transport services. The project was conducted by a consortium which brought together First Bus as lead, Milton Park, Oxfordshire County Council, Nova Modus, Fusion Processing[4], Zipabout, and the University of the West of England (UWE Bristol).

The present report details the experiences of the drivers chosen for the MultiCAV Mi-Link Services 001 and 002 operated by First Bus using an autonomous electric Mellor Orion minibus (Figure 11) fitted with Fusion Processing's CAVstar® Automated Driving System[5]. Six experienced bus drivers from the First Bus Slough Depot were selected to be the safety operators for both services.

Figure 1: Electric, autonomous minibus used on Services 001 and 002

[3] Mi-Link was the public branding used for the autonomous service and some associated sustainable mobility services. https://www.mi-link.uk/

[4] Initially a subcontractor to the project appointed through a procurement exercise, later a full project partner.

[5] Autonomous vehicles are often described in terms of levels of automation. The MultiCAV Minibus can be considered a prototype L4 vehicle because it is designed/intended to operate fully autonomously on routes (or within the design domain) that it has been developed for, but not the whole universe of roads. Whilst it was not intended to drive itself in and out of the forecourt hosting the terminus stop on Service 001 (although it did achieve this later in the project), it was intended to cope with nearly everything on the rest of the circuit. Description of automation through levels however can be cumbersome due to complications such as understanding what is in or out of a design domain. For example, the minibus was impeded in automated mode due to sensing vegetation impinging on the carriageway, until this was cut back. Drivers of traditional buses tend to brush through them, judging the risk according to the extent and solidity of the vegetation. This raised the question as to whether the 'design domain' assumes a certain standard of highway and roadside maintenance, or is able to cope with 'deficiencies' as human drivers do.

Service 001

The first demonstration service required the vehicle to travel on a circuit within Milton Park Science and Technology Business Park (Figure 12**Error! Reference source not found.**). Although the business park road network is privately owned, it is not a protected space in the sense that roads are not clearly distinguishable from the neighbouring public road network adopted by the local highway authority.

The roads on Milton Park are typical of those of business parks in the UK; two-lane single carriageways with kerb-separated pavements. The roads feature kerbside bus stops and are subject to a speed limit of 20mph (32km/h). The Milton Park road network presents a mixed-traffic environment, with typical traffic volumes of 14,000 vehicles per day (1,400 vehicles per hour in one direction in the peak period) on the main business park distributor road (Park Drive). Heavy Goods Vehicles are a feature of the traffic mix. To give a sense of the complexity of the mixed-traffic environment to be negotiated by the autonomous vehicles (in for example 'gap acceptance' manoeuvres), this is equivalent to about one vehicle passing a point every 2.5 seconds.

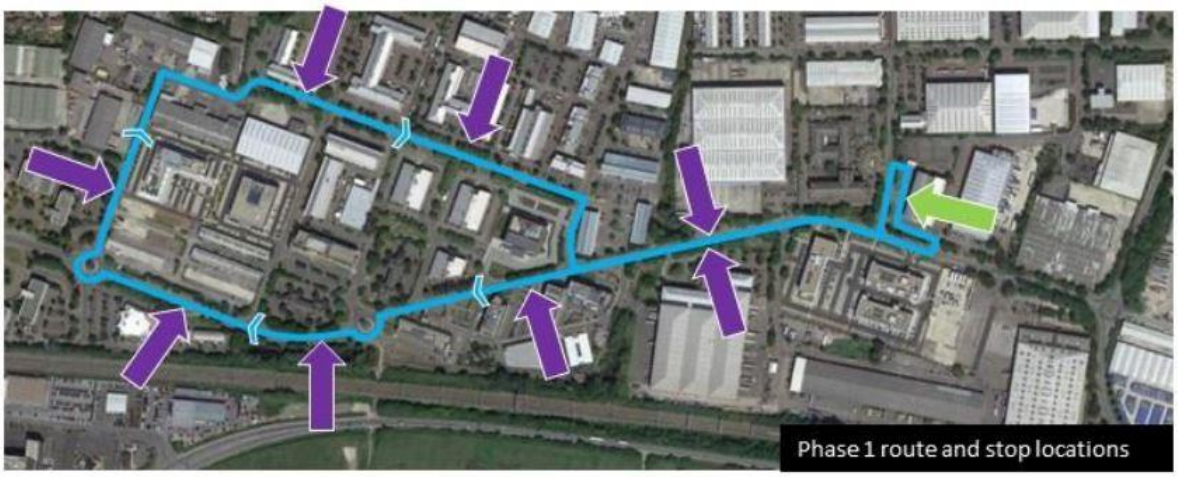

Figure 2: Service 001 route – business park circuit

Service 001 was operated for a five-week period during February and March 2023. The circuit took roughly 12 minutes to operate, with the timetable scheduling departures on the quarter hour between 07.00 and 18.30. There were two breaks in the timetable for topping-up the battery of the electric bus.

Two drivers were on board for each shift, and took turns every hour or two hours, to be the safety operator.

Service 002

The route connected the public road network between Milton Park and Didcot Parkway railway station (Figure 33), crossing the A4130 at a roundabout, and encountering busy traffic along the route at peak times. The route included a section to be operated at 65km/h, busier traffic conditions and more complex manoeuvres such as signalised junctions, large roundabouts and entering and leaving the station forecourt.

Figure 3: Service 002 - route from business park to railway station

Service 002 was operated for seven weeks in June and July 2023. The round trip took around 40 minutes to operate and the operating day was similar to Service 001. Again, two charging breaks for the electric bus were included in the timetable and the services were mostly crewed in pairs.

Patronage was much higher than in Service 001 due to the service connecting two important traffic generators. Other bus services were running similar routes so Mi-Link 002 attracted a share of the flow.

Both routes were operated without any without any safety incidents or near misses.

2. Interview and analysis methodology

Qualitative semi-structured interviews were employed to gain data from both the safety operators and the person who trained them. This approach enabled in-depth exploration of relevant topics. It provided a framework of topics that would be useful to explore, but also allowed unexpected details to emerge. Individual interviews enabled the safety operators to be frank about their experiences, without consideration of what their peers might think. Qualitative self-report did facilitate understanding of their experience of being a safety operator. It could not however, explore objective metrics of driving performance, such as take-over time or eye-tracking, for example.

The trainer interview guide can be found in Appendix 1. It was iteratively developed with input from CTS members and project partners more widely.

The safety operator interview guides can be found in Appendix 2 (for Service 001) and Appendix 3 (for Service 002). The Schedule was initially developed with reference to previous studies. These informed, for instance, questions on tiredness or stress resulting from monitoring autonomous systems (Molly and Parasuraman, 1996, and Hancock and Parasuraman, 1992, both cited by Waard et al., 2010, SAE mobilus, 2019), questions on levels of trust in the autonomous system (Waard et al., 2010, Ebnali et al., 2019, Saffarian et al., 2012), perceptions of risk (Saffarian et al. 2012), taking back manual control (Kaber & Endsley, 2004, p.114) and perceived understanding of the autonomous system (Saffarian et al., 2012, DfT, 2019). The safety operator guide was then iteratively developed with input from CTS team members and also project partners more widely. The Service 002 questions were adapted from the questions asked in Service 001, seeking input from the safety operators as to how their experiences of the autonomous bus had changed over time and with the introduction of a longer and more complex route to Didcot Parkway railway station.

The trainer interview and five of the safety operator interviews in Service 001 were conducted face to face, the sixth driver was not available face to face and his interview was conducted via a telephone call. All interviews were recorded by Dictaphone. Recordings were analysed for answers to the questions. In the case of the drivers, answers to each interview question, from all drivers, were brought together and then analysed collectively. A similar methodology was used for the Service 002 driver interviews, except all of the interviews were conducted face to face.

3. Findings from the interview with the trainer

Background to the training

The safety operator candidates were chosen from amongst First Bus' experienced bus drivers based at a depot to the west of London. The opportunity to apply for the role was advertised on a noticeboard in the depot and applications were scrutinised against criteria including driving experience, number of collisions in the last five years, and number of public complaints. The bus operator regarding the drivers having a positive attitude orientation towards the trial was a key attribute.

The selected drivers were given additional training for the safety operator role within the project by Fusion Processing personnel. The trainer interviewed had given most of the MultiCAV training, although some colleagues had had some involvement also and some safety personnel from First Bus were at some of the sessions. The interviewee's experience was in the development and operation of automated driving systems rather than in driver training. However, he had experience of informally helping drivers familiarise themselves with automated systems as and when such drivers were needed for track testing in the past. The trainer also had "inside-out" technical knowledge of the autonomous systems. He considered this was useful, but probably not necessary to provide the training effectively. Rather, only a basic knowledge of the technology was needed, including:

> "…an appreciation of what's going on and what the different bits of the system are. And then mostly, it is just experience of using the system, I think is the most important thing."

He indicated it was more important for a trainer to understand the human-machine interface (HMI) aspect of the technology rather than the systems behind it. At the scale of commercial application most trainers would not have the background to be able to master the technologies forming the autonomous systems in any case. However, "a basic appreciation would be enough".

The MultiCAV training drew upon a package of material about training drivers taken from previous autonomous projects, including CAVForth[6]. The material included an internal guide document for how to do the training, and a PowerPoint presentation. The material covered what had and had not worked in previous training programmes, although broadly speaking previous training had worked very well. The overall structure of the training employed was broadly similar for MultiCAV.

There was no formal testing of the MultiCAV training process before it was implemented. Learning about how to conduct the training as it happened was considered part of the desired outcomes from the project. This would then inform finalised training programmes for commercial autonomous vehicles. The trainer considered that the MultiCAV training had provided good insight in driver training in this respect. In summary, he thought that the training had "worked quite well."

Training structure and content

The training was provided in three sessions. The first session of training was in the vehicle on an off-road track. This lasted two or three hours across the six drivers and enabled first experiences with the vehicle to be away from an actual road.

[6] https://www.cavforth.com/

The second session was a classroom-based session, which lasted a whole morning. Conducting the classroom session first, prior to the off-road track, was considered, but the trainers concluded:

> "The amount you need to know just to get on and have a go is so little, that actually we felt there would be more benefit in (the drivers) having experienced it and then going into the classroom because what they learn in the classroom reinforces what they've kind of already learnt…and it will mean more to them, because they've seen it and experienced it."

The trainer considered this strategy had worked and would likely be replicated in future. It meant that drivers were motivated and engaged on entering the classroom session.

The classroom training explained:

- The different elements of the system, including a high-level overview of what the system is doing.
- The sensors, their location and how they worked.
- Pre-operational checks (at the start of the shift).
- Operation of the vehicle, including how to enter and exit autonomous mode.
- Responses to hazards.
- The different screens on the HMI (some of these were not available in the off-road track session.)

There was little dialogue on "why autonomous vehicles." Drivers were taught about what to expect in different scenarios of different types of pedestrian crossing and junctions. They were also taught about which driving tasks the autonomous system could undertake and what it would not undertake.

The third training session was road-based training, which followed the route that would be used for the trial at Milton Park. This lasted four hours across the six safety operators.

> "Not a massive amount of time… On the other hand, it's quite a small route. Ultimately, operating the system isn't that difficult…It's quite straight forward…The HMI is designed to be quite self-explanatory."

There was no formal testing of the drivers in any of the sessions. However, in the third session a minimum of two loops of the route in the driving seat constituted proof that they had understood everything they needed to about the bus. If a safety operator had given cause for concern, they would not have been allowed to continue.

Safety operator tasks and performance

Taking charge of the autonomous vehicle differed from driving a conventional bus in that the safety operator had to be able to maintain concentration when not driving. It is a risk that drivers lose concentration even when driving a traditional vehicle; the hypothesis was that this might be more likely when the person is not experiencing the stimuli of being engaged with manual driving. The interviewee implied that in the case of the autonomous vehicle there were two potential layers of safety in this respect, suggesting that if the safety operator did fail to concentrate the autonomous vehicle *should* be safe:

> "In the event of an issue the vehicle should do the right thing in any case; but it's a trial."

As the safety operator is free to regain control as often as desired, the issue of how much they trust the autonomous system is important. The safety operators were instructed to take back manual control any time when they did not feel confident in what the vehicle was doing or if they perceived a potential safety issue arising (for instance, if the safety operator could see an uncontrolled dog). They were instructed 'if in doubt, take back control':

> "If they don't feel it's safe for whatever reason, don't [hesitate]…obviously we like it to be in autonomous as much as possible, but safety comes first."

Another way of operationalising the policy was the advice that the safety operators should be thinking that if the bus was doing something different to what they would do, and which was also dangerous, then they should re-take control. However, driving styles are different, and the autonomous system had its own driving style, which became familiar after a few loops of the route. The trainer considered that the MultiCAV safety operators had a suitable level of trust; not too much or little. He did not observe a tendency to take over unnecessarily. However, and in slight contrast to this, he also commented that the first few loops were "a little bit tense" for the safety operators and that he encouraged them to relax a little bit in some respects, including less frequent use of manual overrides.

During Service 001 some roadworks initiated unexpectedly on the route during the trial, and these required manual navigation.

In Service 002 there was a traffic signal-controlled bridge on the approach to Didcot where the safety operators were instructed to use manual override. Apart from that the safety operators in Service 002 reported that they were pre-empting parts of the route where the autonomous bus had a tendency to behave in a way that they felt would make passengers feel uncomfortable or that would be considered a nuisance or even dangerous (such as sharp braking) for other road users. So, when there were passengers on board and at peak traffic times, the safety operators tended to use manual override more frequently.

The safety operators had no technical issues with regaining manual control, which was achieved through throttle, steering or (most commonly) brake controls. The trainer commented that they quickly became comfortable with it and that, from his experience:

> "learning how to take control back…most people's natural reaction is the correct one."

The trainer considered the safety operators had similar responsibilities on the MultiCAV vehicles as driving a conventional bus:

> "Generally speaking, it's not that different to what they are responsible for when driving a normal vehicle."

They were still responsible for people in the vehicle, outside the vehicle, and also the vehicle itself:

> "So right now, it doesn't really change much. Legally they are responsible."

There were some unexpected mechanical issues experienced in the actual trial, but the trainer was not aware of anything that had occurred which indicated something new should be added to the training.

Summary

Overall, the trainer portrayed the safety operator training as being a smooth and successful process. He did not think any of the safety operators struggled with the training. There was no evidence that

they had not understood what was required, and they seemed very enthusiastic. Although the total time taken for the training was less than two full days, the trainer thought the training was sufficient and considered the safety operators felt the same. The trainer agreed with the interviewer's reflection that operating the bus required less training than might be intuitively expected and that it "shouldn't" be too difficult to learn as the system is meant to be doing the driving. The main challenge for safety operators to overcome was that it is "a bit of a weird experience when you first experience it". This slight tenseness on the part of safety operators and a resulting tendency to take back manual control more than necessary seemed to be the only issue requiring management that the training process encountered, from the trainer's perspective.

4. Findings from the interviews with safety operators

Safety operator experience and shifts

The safety operators had 16, 15, 13, 12, 6 and 4 years of experience of driving buses, so all had a good level of experience, and most had considerable experience. Their experience was mainly in urban areas, primarily London and Slough. Some had driven a variety of buses including coaches, double-deckers, and single-deckers. Some of the safety operators were aware, based on comments made, that they had been selected with reference to their accident, customer complaint and other performance records. They generally expressed feeling happy and lucky to take part.

The initial interviews came towards the end of the five-week operating period for Service 001. The safety operators usually completed two day-long shifts on the MultiCAV vehicles per week (in exceptional instances three). The shifts lasted from 07:00 to 18:30 with two half-hour breaks. However, there were always two safety operators on the vehicle, meaning they took it in turns to assume the safety operator role.

By the time of the second stage interviews in the last week of June and the first week of July 2023, the six safety operators had about four weeks of experience on the longer Service 002 route to Didcot Parkway railway station and again were typically doing two day-long shifts a week, working in pairs.

Training sessions, and understanding the autonomous systems

All the safety operators were very positive and enthusiastic about the training for Service 001.

> "I was interested to see how it was going to feel when I sat on the driver's seat."

One safety operator commented that all three sessions were very useful, another considered that the "driving side" had been the most important. Starting on an off-road (ex-airfield runway) environment had been useful in reducing the pressure experienced. The qualities of the trainer were also appreciated.

One safety operator also confirmed the trainer's thought that having the off-road session before the classroom session was effective, as it meant the classroom content was "running over that (learning) again, which was helpful." Others agreed that the classroom session was useful, (for example enabling understanding the problems that appeared on the dashboard,) and appropriate:

> "The training in the class was fantastic…we knew how everything worked, the cameras and all of that."

The safety operators acknowledged that they did not understand the in-depth technology behind the system. However, most of the safety operators commented that their training provided sufficient understanding of how the autonomous bus worked and behaved. There was general enthusiasm around the vehicle's capabilities. One safety operator thought that what the bus was doing was becoming more comprehensive as time went on. Several remarked that chatting with Fusion Processing[7] personnel was very helpful in them understanding the bus. This was not only during training, but also during the trial period itself, during which the Fusion staff were often on the bus:

[7] The MultiCAV partner company which created and installed the CAVstar® automated driving system.

> "The guys from Fusion were with us most days, so we were chatting with them about what it could do and what it couldn't do, it's limitations…so it was quite enjoyable".
>
> "It was a massive help".

Similar to the trainer, the only slight issue reported relating to the training experience was one of nerves or stress:

> "We did half a day before it went live, driving around and that was quite good, again when you are on the roads with more traffic it was quite stressful, to start with, because you're concentrating: 'What's it going to do?' [and] touching icons and stuff, but no, it was very good".

In Service 002 the training took the form of a route familiarisation with a member of the Fusion team. They were instructed where and in what circumstances they should take manual control.

> "We received route level training, but nothing more. The training is OK, nothing more needed."
>
> "A day with [Trainer] from Fusion. We went round with him and then we drove the route ourselves."

For both stages, which used the same vehicle, the safety operators did not think anything should be different in future training and felt it equipped them well. In Service 001 a couple of safety operators considered the more they supervised the vehicle the more effective they became and so considered they just needed more driving time to build up confidence. This collective building of confidence continued into Service 002:

> "It helps that we are the same six drivers, and we know the bus and the route well. For a new route or vehicle, we would require additional training, but the training has been fine."
>
> (Safety operator quote following the Service 002 training)

Level of safety operator trust in the autonomous system

An appropriate level of trust in the autonomous vehicle was important, for safety primarily, but also project learning. The safety operators were unanimous in trusting the vehicle least when starting the Service 001 trial and more by the end. They described their initial attitudes towards the bus as "[not] 100 percent confident", "careful", "nervous", "very alert", and "confused." Some felt stronger apprehension, with one particularly worried by the fast acceleration to 20 mph on entering autonomous mode, reporting: "It was a bit scary". Another safety operator also admitted feeling initial fear but reported this abating by his second run operating the vehicle. One source of concern was the other traffic on the route. In this respect the initial training session in an off-road space had been particularly helpful. Confidence across all six safety operators had grown significantly by Service 002. As one safety operator put it:

> "before we used to take over many times, but now [during Service 002] it's not all the time, maybe once or twice [in a circuit] the bus can't cope itself and we have to take control."

A result of initial wariness towards the autonomous system's driving was that the safety operators took frequent control "for every small reason." However, all safety operators had greater trust in the autonomous system by the end of the Service 001 trial period. One commented that it took time to understand the behaviour of *any* new vehicle. After two or three weeks (four to six working days) he was more comfortable with it:

> "From the beginning it was a little bit confusing, but [due to] training we are getting more experience. And in the last week [of the trial] the bus was responding very, very, good, so we were happy."

As well as becoming more familiar with the vehicle, comments indicated that the vehicle itself was functioning better by the end of the Service 001 trial, which may have further increased feelings of trust. By the end of the trial, some safety operators reported increased relaxation whilst others a retained cautiousness in some areas.

By Service 002 new levels of trust and confidence was emerging across the safety operators in the vehicle's autonomous driving abilities. One safety operator reported that "everything's improved, even following traffic and at the pedestrian crossing as well", while another said that, since transferring to the extended route to Didcot:

> "the technology is fantastic. Like now it copes well along the 40 miles per hour road section."

Safety operators remarked in both stages of the trial that they had to learn the driving style of the autonomous system:

> "The bus was reading our mind, so we have to read his mind."

By the second stage safety operators were pre-empting what the vehicle would do at certain times and take manual control in advance: "there is a point by the old power station entrance where it brakes, well, I feel quite harshly, so I often take manual control there to stop it happening."

One of the main initial causes of concern, and limits on trust, in this driving style was road placement, which caused some nervousness:

> "Pretty nervous...because it was programmed to drive a set route, it would take different lines [to those] I would take as a professional driver, if I was driving manually."

Specifically, some were concerned about how close to the kerb the vehicle sometimes came. One was concerned the vehicle would be scratched by the kerb. Conversely some were also worried about the vehicle going "too wide" and far from the kerb for some left turns, which concerned them in relation to oncoming vehicles. These road placements led them to initially take control frequently. They came to learn however that the autonomous system would leave some space and became used to the various road placements. One safety operator reported that by the end of the trial if the autonomous system started veering the vehicle off course, he would give it the benefit of the doubt, until it started crossing the white line, in which case he would take control. If the bus was on the wrong side of the road coming out of a junction, he would let it "settle itself" if there was no other traffic, but if traffic was present however he would take control. Another commented that the best thing to do was not to take control too soon but to observe in the mirror how close to the kerb the bus was going to go. It seems that the safety operators' understanding of the autonomous system's driving style matured throughout the trial period and was understandably not complete by the end of the training period.

The road placement issue seemed to be reduced by Service 002, but some safety operators still expressed nervousness when passing large vehicles such as HGVs and buses on the40mph (65 km/h) stretch of road as they felt the autonomous bus left a narrower gap than they would when driving manually. Occasionally the autonomous bus would do something unexpected:

> "sometimes the bus will drive itself perfectly, but earlier today on the second trip we were coming along Park Drive by Innovation House. It's going round the roundabout and then it's gone up on the kerb and I think 'it shouldn't be doing that'. That time I didn't take control immediately as it can go quite close to the kerb, but it usually corrects itself."

Other sources of initial nervousness were around whether the bus would stop in time in traffic and also, for one safety operator, an incident, on the first day, at a T-junction when the bus started "creeping forward" leading him to take control. This safety operator remained cautious at that junction from then onwards and recounted the incident again in the Service 002 interview:

> "So, I'm always nervous about the junction there."

One safety operator hinted that his initial lack of trust during Service 001 had limited the full potential of the autonomous system:

> "Actually, when I was driving this bus it never hit the kerb, in autonomous mode, maybe we didn't give it the chance, because we always feel, as a driver, if it's going to hit the kerb…we always take control…but (in the) last week I didn't take control, it didn't touch the kerb".

By Service 002 the safety operators were prepared to let the bus run almost the whole route autonomously when they did not have passengers, or the traffic was light. However, they were concerned about passenger comfort:

> "I don't want to make them uncomfortable. Yeah, because sometimes when the bus will do hash braking, maybe they'll think, like, what is this? So, I'll take over."

Similarly, at busy times they were concerned about slowing down other vehicles:

> "It may be slow, and slow down the other vehicles. So, we take the control manually to not make any problems."

Another safety operator hinted that he was aware about the benefits of maximising autonomous running for maximising the data produced.

One safety operator considered the autonomous system had had few faults, suggesting it was:

> "Very, very smooth….and there was no issue".

Other aspects of operating/driving the MultiCAV bus

As well as being autonomous, the MultiCAV vehicle was electric. The safety operators generally thought the vehicle was as they would expect an electric bus to be, although they did not have experience of driving such vehicles previously. Some did remark that it was much quieter than a diesel vehicle, and was easier than a normal bus, due to its smaller size. (The implication being that larger buses require more attention to drive and can be heavier to steer and operate.) One safety operator considered that, when in manual mode, the MultiCAV vehicle drove like a normal bus.

The safety operators were asked if they ever found driving the autonomous vehicle boring when in autonomous mode. They unanimously said 'no'. Rather they reported enjoyment and interest. One commented it was more enjoyable than a normal bus and considered it part of a brighter future. Another considered it less stressful than a traditional bus. Interest for the safety operators was further heightened in Service 002 by going beyond the bounds of the business park to Didcot Parkway railway station. The safety operators found the next stage of the trial, with a longer route

and more passengers even more interesting. They were particularly impressed about the bus' performance on the 65 km/h stretch.

The main reason that the safety operators thought they did not get bored was the need to monitor the situation outside of the bus. This might include scenarios such as oncoming big trucks needing extra space for example, or people stepping out into the road. The range and frequency of these scenarios increased in Service 002.

> "…so, you wouldn't really switch off, you're still focused. You're a lot more relaxed than you would normally be, because it's driving it for you, but you are still looking ahead, making sure everything's correct, you can always take control of it."

Only one of the safety operators thought that more concentration was required in Service 002 on the longer route:

> "Actually, you're always concentrating, especially on that bit of the route that is outside the Park. This is because it's more speed and more pressure coming on you."

There was also the need to check the autonomous system for errors.

One safety operator remarked during Service 001 that the icon system (relating to upcoming crossings and junctions) was a bit slow to start with, which the safety operators fed back about, but this was later improved. Another suggested that the iPad which facilitated the HMI could be temperamental when low on battery power.

The safety operators reported no problems with maintaining concentration. It was akin to normal driving in requiring full concentration. It was important to have full concentration because if the autonomous system did something wrong then perhaps drivers of other vehicles would not respond well because it was a new situation. "We are all starting from zero." Again, the two main centres for concentration were what was occurring outside the bus, and the autonomous system working correctly. Monitoring the autonomous system included using the HMI icons correctly. The short stints made concentration particularly easy, and safety operators didn't report needing techniques to maintain concentration. One safety operator commented that observing his colleague was useful, when he was on the bus but not in the driving seat, as too was observing the vehicle's behaviour when acting as the second crew member.

The pairs of safety operators who shared the driving each day were initially intended to do two-hour stints before swapping. As they found operating the bus quite intensive at the start of the trial this was changed to swapping every hour, but within the first four days they decided to return to two-hour stints. One commented that a one-hour stint was too short, because in normal shift work he would drive for four hours at a time. Others thought one hour was "ok" but, likewise, most pointed to their four-hour shifts on normal buses, and indicated they would not mind doing two or three-hour stints.

The safety operators reported being less tired than after a usual bus shift. This was attributed variously to the shorter shifts, not having to use the right leg or operate the steering, fewer passengers, not handling cash, passengers knowing where they were going, and, on Service 001, the 20mph speed limit. Clearly, some of these factors relate to autonomous technology, whilst others do not. Overall, the safety operator experience seemed to be satisfying. One interviewee remarked that, in any case, the task wasn't aimed at enjoyment, it was a professional situation where he was serving the passengers.

The number of passengers was significantly higher for Service 002 compared with Service 001, especially at peak morning arrival and evening departure times. The safety operators reported liking this, both due to the extra interaction and because they were performing a service.

Responsibility and risk

The safety operators were asked how far they felt responsibility for the vehicle when in autonomous mode. There were a range of views on this. All felt that the safety operator had responsibility, this was often linked to a concern that the system might malfunction:

> "...Because the machinery, if there is any error or anything, it will make a disaster."

This led one participant to conclude he felt "exactly the same" level of responsibility as on a normal bus. Likewise, some others felt the safety operator had one hundred percent of the responsibility:

> "There is no responsibility for the machine…[Laughs]…The driver is the responsible person."

In some contrast, one safety operator considered the system had some responsibility as well as the safety operator, because "it was driving itself" and was able to be "in control" of itself. But "if it was doing something silly, you'd take control of it." This echoed the trainer's suggestion that the safety operator and the autonomous system effectively formed two layers of protection against danger. Another safety operator answered with a different perspective, suggesting that, out of ten, his own impact on the driving was two, whilst the autonomous system's contribution was eight, due to the amount of time spent in manual or autonomous mode.

Battling the machine to assume responsibility was not an issue: One interviewee joked that, before the trial, he thought if something went wrong in the autonomous system it might go crazy, as in a film, and he might not be able to regain control, but in fact if something went wrong it would just shut down altogether.

The majority of safety operators felt that in autonomous mode, the bus was as safe or safer than a normal bus, again because of the human as a 'back-up.' The autonomous system was considered safer in some specific respects. One safety operator considered the high placement of the vehicle's camera meant that it could be able to assess approaching vehicles at a T-junction more comprehensively than a human driver. The autonomous system was also considered to react instantly, rather than after a delayed reaction as can be the case with a human driver. Another commented:

> "…A man can do an error on a red light…Sometimes we will make mistakes, the machine will not".

Feelings of low levels of risk were also related to the Milton Park road conditions in Service 001. They were considered gentle conditions in which to drive, with little poor driving by other people, few other vehicles and a 20mph (32 km/h) speed limit. Other vehicle drivers tended to know it was an autonomous bus, so they kept distance. Drivers of other vehicles at Milton Park tended to be "nice people" and obeyed the rules of the road.

Generally, the safety operators did not feel that the environment was less safe on the longer route to Didcot Parkway in Service 002. However, at times they felt that the autonomous bus was over cautious and slow in some situations and in heavy traffic they sometimes felt compelled to take manual control so as not to slow other drivers down. As the road user culture outside the park was different, and less benign, sometimes it was the behaviour of other drivers that made them feel unsafe:

> "There is an issue with people tailgating the bus when they feel it is going too slow. They don't realise that it is an autonomous bus and might brake unexpectedly. I want a sign on the back of the bus saying it is autonomous[8]. Keep back."

Whilst none of the safety operators felt the MultiCAV bus was riskier overall than a normal bus, one thought that it could feel risky:

> "You could say it was riskier because you didn't know what it was going to do… but you could say also that it was safer because it's pre-programmed to do set things, and it's going to stop automatically, whereas you might sometimes have a lapse of concentration".

The autonomous system's handling of specific manoeuvres.

The interviewees were asked about how well the autonomous systems handled certain types of manoeuvres. The safety operators considered the vehicle handled some manoeuvres very well:

- The safety operators were unanimous in thinking that the bus handled passing vehicles coming the other way well, although one noted there were some initial problems at the start of the trial and another that the vehicle might slow down or stop if there was a large lorry coming the other way. By Service 002 some were more concerned about the gap left between the bus and on-coming large vehicles, particularly when the combined closing speed could exceed 130km/h[9] on the 65km/h section.
- The autonomous systems negotiated roundabouts well. It was commented that if anything got close to the bus on a roundabout it would slow down.
- The 'rainbow crossing'[10] confused the vehicle at first, but this was overcome by the end of Service 001.
- Four safety operators considered the vehicle handled turning right at junctions well in Service 001. One reported it sometimes completed this perfectly but at other times encroached beyond the centreline of the road.
- The safety operators thought the vehicle did very well at traffic lights. The only comment was that, in the future, it might be able to differentiate between green and red lights (meaning the safety operators would no longer need to manually override the vehicle stopping if the lights were green). Automated response to traffic light controls was a project objective, and by Service 002 the autonomous bus could handle this situation at the lights on the 65 km/h section.
- The autonomous system did reasonably well with pedestrian crossings. Some safety operators reported the bus suddenly stopping if there was a large vehicle coming the other way or someone was near the crossing. One safety operator thought it was better that the system tended to be over-cautious, rather than insufficiently cautious. The safety operators reported that they were happy with the performance at the crossings in Service 002.

[8] The vehicle livery did in fact include the words 'Autonomous Vehicle' in large lettering on the rear panel, but the interviewee perhaps wanted something even more obvious or directing about how other drivers should behave in the proximity of the vehicle.
[9] Given that although the autonomous bus could not exceed the speed limit, the oncoming vehicle might be.
[10] The crossing painted in rainbow or 'pride' colours does not comply with the UK Department for Transport's (2019) Traffic Signs Manual which only considers pedestrian crossings with alternative black and white stripes.

The autonomous system was found to have more difficulties with some other manoeuvres:

- Most, although not all, safety operators reported problems with the autonomous system's handling of left turns at junctions in Service 001. One considered it was still being 'worked on'. As mentioned above, there seemed to be variation between circuits with how much space to the kerb the bus left, with this sometimes being insufficient and sometimes excessive: "Every trip there was a difference". This issue was not mentioned in Service 002, so it is likely performance was enhanced by then.
- The vehicle handled stopping and starting at bus stops fairly well, but there were some issues in Service 001. Four safety operators mentioned the bus stopping too far from the kerb, although this was improved. There was also one comment that the bus sometimes ran too far past the bus stop before stopping and another that the bus sometimes wouldn't pull away from the stop. These situations had improved by Service 002. At one stop the vehicle responded to tree branches, when these were cut back the problem was removed.
- The autonomous system coped quite well with vehicles that were parked or stationary on the carriageway. Although the autonomous drive system has a facility to pass stationary vehicles, for the MultiCAV services this was not engaged, and so the system did not attempt to pass stationary vehicles in autonomous mode. Instead it halted. The safety operators reported that sometimes the autonomous system would bring the vehicle too close behind the stationary vehicle, so that full lock was necessary for the safety operator to then manoeuvre to pass the vehicle.
- In Service 002 problems with tree branches and bushes were reported by the safety operators. There were places on the 65 km/h section where the bus would seem to swerve unnecessarily away from branches or bushes to the side of the road. Again, these issues were addressed with additional vegetation cutbacks arranged by the local authority partner.

Taking back manual control of the vehicle

The safety operators were asked about their experiences of taking back manual control for the first time in Service 001. None of them had any complaint about the technical process by which they regained control. Some had been comfortable with it and didn't experience nervousness. One participant had found it a slightly difficult experience, which had resulted in some fear at the same junction on the next run, but added:

> "It's all about experience."

Fear also initially caused some of the safety operators to take control more frequently than they did by the end of the trial:

> "I was scared, [laughs] it picked up speed very quickly, I was scared… So everywhere, on the T-junction, roundabout, everywhere I was taking control manually".

Another safety operator first took control when there was a lorry approaching on the opposite side of the road. He was worried the bus would go too far to the right. He was confused because he didn't know what the autonomous system would do. He thought that if the bus had done the same thing in the third or fourth week, he would have trusted it. More widely, none of the safety operators reported concerns with taking control by the end of the trial. Neither did any of the safety operators recall instances of regaining control going badly.

Generally, by Service 002, most of the safety operators were trusting the autonomous driving of the vehicle in situations where they had previously felt nervous.

Apart from places on the route when manual was always necessary, three safety operators reported needing to regain manual control in Service 001 between two and four times a run. This excluded temporary roadworks, which always required manual navigation. Another reported usually only taking over control for the roadworks or if the bus was unnecessarily slowing down in reaction to an oncoming, passing vehicle. So there seems to have been some variation between safety operators in the frequency they took control, according to their reports. Some commented that the autonomous system "improved a lot" during the trial, requiring less manual take-over by the end. Others commented that there was a lot of variation in the need for take-over from run to run, sometimes the autonomous system performed a perfect run; other times it required frequent correction.

In Service 002 the traffic conditions and the number of passengers seemed to have the biggest bearing on how many times the safety operators took manual control. Another change in Service 002 was the introduction of an electronic sign in the bus which informed passengers when the bus was driving autonomously. This addition was well received by the safety operators who spoke positively about it.

Other aspects of providing the bus service

Safety operators were asked in Service 001 about aspects of being a safety operator beyond supervising the driving by the vehicle. The interviewees reported that passengers had been positive, peaceful, enthusiastic or curious about the bus. One commented he didn't get any negative feedback from anybody. Some passengers commented that they hadn't been aware it was in autonomous mode. For some the seatbelts had restricted their ability to see the cab. Some passengers came with their small children:

> "That's their future…That's for them. I am telling every child, that is for you" [laughs]

Some safety operators considered the passengers were easier to deal with than on the buses they drove in their normal roles, particularly in London where fights sometimes broke out between passengers. Others found dealing with the passengers the same as on the buses they normally drove. Having a colleague on board, who could chat with passengers, was a benefit. Embarking and disembarking was easy because of the absence of cash: the safety operator just had to open the door. One safety operator said he always enjoyed interacting with passengers. As a bus driver it was important to communicate well with passengers and colleagues. He felt he may have given the passengers a little bit of extra attention for the autonomous bus:

> "We always give a hundred percent, but maybe we just went a little bit over [that]"

The safety operators were asked if they had to do anything before or after a shift that was different to a normal bus. One mentioned needing to focus the mind for the day ahead. Some mentioned needing to clean and charge the bus, which would normally be done by others at the end of a shift. One safety operator explained the duty to clean the bus's sensors and cameras at the end of a shift. Another mentioned there was no cash tray or ticket machine to take care of. Others felt there was no substantial difference to a normal bus.

Key aspects of the MultiCAV safety operator role

The safety operators felt the most important aspects of their role on the bus were safety and concentration. Some considered safety paramount:

> "Safety. As long as they are safe, that's the only concern."

Continuous concentration was also important:

> "Every single second… We have to read his mind [talking of the bus]. For instance, the autonomous system sometimes did hard braking for a pedestrian crossing."

> "The driver needs to be 100% concentrated and needs to be a calm person…It's not like a toy for funny driving, so you need to be calm."

Others also mentioned passenger comfort in relation to sudden braking: harsh braking in autonomous mode would prevent passenger comfort. For this reason, if the autonomous system would brake harshly it was better to take manual control. Passengers wouldn't expect it. Good customer service was also mentioned, as was protecting the vehicle from knocks, given the vulnerability of the technical equipment. This aspect came through strongly again in Service 002 when they had more passengers.

The safety operators were also conscious of other drivers on the roads especially at peak times and did not want the bus to unnecessarily hold up other traffic.

Concluding comments from safety operators

In concluding comments, the safety operators expressed pride and enjoyment at having been involved in the trial:

> "It is excellent…I am proud I am one of the first six drivers to be driving that bus. And our bus depot got it."

> "The autonomous bus is such a brilliant thing. Once you know what the autonomous system will do then it's very relaxed…It will see everything before you see, especially on the T-junction".

> "I was interested in driving it over and over".

But Milton Park wasn't a typical situation, compared to going out on other roads and the safety operators expressed enthusiasm at taking part in the next stage of the trials.

> "When you are out of Milton Park, then you are going to face the reality."

The novelty of the experience was remarked upon, as was the substantial difference arising from not having to do anything manually.

One interviewee highlighted the value of the safety operators having had a feedback form to complete for Fusion Processing, especially as the safety operators had more experience of driving buses than Fusion employees. Another interviewee explained that the safety operators had to override various icons in different on-road scenarios. If they did this in the wrong order (i.e., not a particular one first) this could lead to harsh braking. This didn't give much reaction time for the safety operators. He explained this and Fusion corrected it.

In Service 001 the safety operators had the novelty of the new technology, but they were only going round a small loop of Milton Park, “it was fine, but quite short.” They appreciated the longer, more involved route in Service 002:

> “Yeah, we’re getting a better experience of the bus. It’s driving itself with the longer route to Didcot Parkway, and round into the station, which is quite nice, actually.”

5. Discussion

It is important to note that the interviewer during Service 001 detected a strong motivation amongst the safety operators to take part in the further MultiCAV services. It may well be that in some respects the MultiCAV shifts were an enjoyable change from more regular duties and that this created a positive aura around the safety operator experience. All six safety operators did continue into Service 002. As mentioned, they expressed pride at being involved, and identified elements that made the MultiCAV experience easier than their normal shifts, such as operating within less stressful traffic contexts and not having to handle ticketing transactions.

A more complex route was introduced in Service 002 with speed limits up to 40 mph, but by this stage the safety operators reported that the longer route and mix of road conditions made it more interesting. Again, this motivation may have encouraged the safety operator interviewees in giving a positive portrayal of the trials, with few significant problems.

Nonetheless, this positive disposition is in itself a notable finding. That the safety operators were keen to take part further suggests an enjoyable experience. Further, the positive framing of their experiences did not prevent the safety operators from mentioning some of the drawbacks with the vehicle's performance or some of their apprehension on first driving it. So, while there may be some narrative tendency towards positivity in their self-reports, negatives and challenges were reported as well.

Safety operator selection and training.

A literature review (Calvert et al., 2000) had informed the research team's conception of what would be necessary to research in respect of safety operator selection and training. The trainer interview indicated that in practice, it might not be as complex as hypothesised, with the trainer suggesting there were many similarities with driving a traditional bus and that the training need not be as detailed as might be imagined, taking less than two full days, and not requiring the use of a vehicle simulator. The safety operators' satisfaction with the training, and the fact they would not suggest any changes, supports this view, although objective metrics of their performance were not taken.

The experience of the Milton Park and Didcot Parkway trials would indicate that the Automated Vehicle Safety Consortium best practice document (SAE Mobilus, 2019) on selection and training of test safety operators is reasonable. A small number of safety operators were needed, for a limited amount of time, for Service 001 in Milton Park and for Service 002 with the extension to Didcot Parkway railway station, but within these significant limits, the safety operators' selection, based on accident records, experience in driving traditional buses, customer service record, and managers' knowledge of them, seems to have been successful. None reported struggling with the role. The trainer did not detect any serious problems or issues with the safety operators in their training, and neither, presumably did the Fusion staff during the services. They seem to have exhibited the necessary attributes for a safety operator (see Calvert et al., 2020, particularly Table 3).

However, it should be remembered that the group had already gone through selection processes to drive traditional buses for First Bus and are subject to performance management in their normal roles. In effect, then, the safety operators' selection for MultiCAV was the second round of selection they underwent. Moreover, Service 001 provided a further in-role training opportunity as it had a lower level of complexity, partly due to lower speed, than Service 002. Hence, in this context these two rounds of selection have been sufficient and the employment of psychological tests and scales (See Calvert et al., 2000, Table 4) in this specific context was not necessary. This finding may not hold

in the case of recruitment to the safety operator role from amongst people without extensive experience as bus drivers, or if the role were to become more arduous, as might be the case of supervising long periods of fully autonomous running.

The MultiCAV safety operators' training seems to have been in accordance with the Automated Vehicle Safety Consortium's guidance, although ascertaining every detail of the MultiCAV training was beyond the scope of the interview with the trainer.

Both trainer and safety operators thought the training was successful, with the trainer indicating that training for previous projects had also been successful. Whilst the previous evidence gathered on simulation suggested it could have played a useful role in training potential safety operators, the MultiCAV approach of having an 'off-road' hands-on session with the vehicle, then classroom teaching, and then a real road session has proved effective, so negating the need for simulations for training in this case (although simulators would still play a role for research and testing practices such as inducing fatigue, Saxby et al., 2013, which cannot be safely carried out without using a simulator.) Safety operators and trainers agreed that having the off-road session before the classroom session was helpful. To some degree, the off-road session could be considered a replacement for simulation in allowing the trainee to practice operating the vehicle in an environment of minimal risk.

Different interviewees gave varying accounts of the bus and the safety operator experience. For this reason, training should take account of a range of 'affect', or emotional response, when operating an autonomous bus for the first time. Although trainer and safety operators considered the training sessions went very well and neither trainer nor safety operators mentioned capability difficulties in operating the bus, some reported feeling nervous or scared when first driving on the road. This isn't necessarily a bad thing: a degree of nervousness around this new, but responsible, role may have been appropriate. Maybe it could have been anticipated and discussed more in the classroom session. This nervousness had largely dissipated by the time Service 002 took place and the features of the more challenging extended route were more seen in terms of points of interest for the safety operators rather than in terms of anxiety.

Safety operator performance and experience

It is important to note that safety operator performance was not measured objectively. The research relies on self-reports by the safety operators and the trainer. It has been noted that subjective reports of performance do not always match objectively recorded performance (Nielsen et al., 1994, cited in Frison et al., 2020). For this reason, some of the challenges for safety operators reported in the literature are hard to comment on in relation to the MultiCAV trials. Specifically, the level of inattention, or being 'out of the loop' amongst the safety operators is hard to know (although they clearly understood the necessity of concentration and scanning their surroundings as with a normal bus.) The fact that safety operators usually had to regain control several times during the 12 minute route in Service 001, had a break for a few minutes after each run, regularly swapped driving shifts with their partner, were always accompanied by him and sometimes Fusion personnel, were engaging with passengers, and additionally had to press manual override icons at crossings, may have helped reduce the risk of inattention, compared to long shifts in a vehicle where the need to take control was very much a rarity, or the operation taking place in an environment with more limited stimuli. The durations of the experiences in the MultiCAV services are particularly relevant in the light of the drop-off in attention after fifteen minutes noted by Warm et al. (2008). The additional features, such as higher speeds, heavier traffic, a greater variety of manoeuvres and more passengers, may have further helped reduce the risk of inattention in Service 002.

The interviews were better able to uncover the levels of stress experienced. Stress did not appear to have caused any substantial problems, with the exception of apprehension on first driving on the roads. This seemed to vary amongst safety operators, ranging from being 'not 100% confident' to 'substantial fear'. This may indicate the relevance of different personality types and their attitudes to risk, as discussed from the literature, when selecting safety operators. However, all safety operators became happy with their role quickly after the trial started. Additionally, presumably stress is also experienced on first-time driving full-size manual buses without significant automation features in cities.

The interviews were also able to cover the issue of fatigue. Again, this does not seem to have been an issue. The safety operators did not experience any of the ill effects of a shift of supervising automated systems as described by Warm et al. (2008). None of the safety operators indicated that supervising the bus in autonomous mode was any more difficult or fatiguing than driving in manual mode. Neither did the risk of boredom raised as a possibility by Merriman et al. (2021) seem to have been substantially experienced. The level of automation is likely to have been a factor here: there were not sustained periods of passive attention required. Ironically some of the planned, and unplanned, limitations of the autonomous system in this trial may have enabled the safety operators to perform better than they might have with a perfect, fully autonomous vehicle.

The interviews asked about experiences of manual takeover, inspired by previous studies, but this seems to have been almost a 'non-issue' in both stages of the trials. The research team could not assess the important metric of take-over time. However, another element of safe and effective takeover, that of the takeover being controlled and ordered, was achieved, as reported by the safety operators, with some feedback given to further enhance ease of use of the interface. The low traffic density (Gold et al. 2018) and absence of substantial fatigue (Neubauer et al., 2014) may have aided development of the takeover technique in Service 001. The addition of more traffic in Service 002, especially at peak times, did not seem to make takeover any more difficult or stressful, but did cause some of the safety operators to take control more frequently in these conditions if they felt that the autonomous vehicle would be perceived by drivers of other vehicles as travelling too slowly. It also suggests the mechanics of regaining control in the vehicle were well designed.

Mental models, trust and responsibility

The training seems to have provided the safety operators with a mental modal that satisfied DfT's (2019) code of practice. Safety operators' comments suggest that they found the presence of having Fusion Processing staff on the bus informative and useful, and perhaps comforting. It may be that whilst, as the trainer indicated, only a limited understanding of the autonomous system, particularly focusing on the HMI, is necessary for effective safety driving, ongoing post-training dialogue with system experts about the way the system is functioning on the road can be both enjoyable and useful for the safety operator's mental model of the vehicle.

Previous evidence had suggested that appropriate levels of trust in the autonomous system are important for effective safety driving. The first stage trial suggested that safety operator trust in the autonomous system was less than warranted for the first few days, but quickly increased amongst all safety operators. This was partly due to becoming familiarised with the safety operator task and the 'driving style' of the autonomous system. It may also have been affected by the improved functioning of the vehicle towards the end of the trial. A high level of trust in the autonomous bus continued into the second stage. There were several comments indicating that the safety operators kept the autonomous system on a 'looser leash' towards the end of the trial. The same was true in the second stage, particularly during the quieter periods of the day when traffic was light and

passenger numbers were low. This has implications if safety operators were measured for desirable levels of trust in the vehicle. The same safety operator who has insufficient trust during selection, training and first days of operating, may have greater levels, even excessive, trust later on. The degree to which this increase of trust occurs may possibly vary between individuals.

Whilst understanding their responsibility is an important aspect of the safety operator's role (DfT, 2019) there was some variation in this amongst the safety operators interviewed. There were no instances reported of safety operators having to make moral judgements that could not be left to the autonomous system. All the safety operators accepted they had responsibilities, but some considered the autonomous system also had some responsibility, in addition to their own, whilst others did not. This could be further, or more emphatically, defined in future training. A difference in the second stage was that safety operators reported intentionally retaking control pre-emptively on occasions when they felt that passenger comfort might be compromised by the driving style of the autonomous mode or the traffic flow might be slowed.

6. Conclusion and recommendations

Whilst the autonomous system itself seemed to have some performance constraints during Service 001, performance of the safety operators was not implicated in those issues, and they were in any case largely resolved by Service 002.

The selection, training, management and performance of safety operators seems, from self-report, to have been very successful. Little discontent regarding these was expressed by either trainer or safety operators, and so there are relatively few recommendations arising for future autonomous vehicle operations.

A point to emphasise is that training safety operators who are already trained in human-driven vehicles and used to complex road environments may be simpler in practice than might be suggested than established conceptual models and experimental evidence.

Recommendations for further training programmes

Nonetheless, there were some points that might be considered for future training and trials:

- The issue of how the vehicle aligns itself within the carriageway might be discussed more in training, as this was a main cause of concern for the safety operators on encountering the vehicle in Service 001 and later, in Service 002, with the introduction of the 65 km/h limit section or route, with potential closing speeds with HGVs in excess of 130 km/h.
- The question of who, ultimately, has responsibility for the autonomous system when a safety operator is in the vehicle should be clarified further.

Recommendations for management of safety operators.

- The presence of automation experts on the bus for a period after formal training is complete has benefits for developing the conceptual models that safety operators have of the autonomous system. If this were to be unrealistic in terms of resource then there could be an ongoing 'question and answer' dialogue between safety operators and automation experts, either face-to-face, or via synchronous or asynchronous digital communication (online drop-in sessions; feedback portal).
- Most safety operators felt the two-hour shift length could be increased, being used to longer shifts in their normal course of work. None of the safety operators reported difficulty with concentrating whilst operating the vehicle. Longer shifts may therefore be possible for autonomous vehicle applications with similar levels of stimulus in the operating environment.

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Appendix 1: Driver trainer interview questions

Interviewee background

1. I'd be grateful if you could start by giving a brief overview of your experience as a driver trainer…
2. Would you tell me what your responsibilities have been in relation to this autonomous bus project?

What happened in lead up to training period

3. What guidance or other sources were drawn upon to create the training?
4. What development or testing did the training program itself go through before the actual training began?
5. What experience did you gain of the autonomous bus prior to the training?
    a. Did you find this useful?
    b. Would you have preferred an alternative?

The training

6. How was delivery of the training organised?
    a. Different stages?
    b. total duration?
7. Could you summarise the content of the training?
8. What were drivers taught about how the autonomous technology systems actually work: what they are and are not capable of?
9. Did the drivers have to pass formal tests as part of the training?
10. How did training to drive the autonomous bus differ from training to drive a new type of conventional bus or taking a bus on a new route?
11. When they first drove the bus, to what degree did the drivers seem to trust the autonomous system?
    a. Too much, too little?
12. What were drivers taught about when and how to take back manual control?
    a. If they focus on "how", press for "when"
13. Did the drivers experience any problems establishing manual control during the training?
14. Did the drivers seem to find the training hard or easy to undertake and master?
    1. Did the drivers have any problems maintaining attention during training?
15. Were drivers taught anything different with regards to interacting with passengers, compared to on a traditional bus?

In-Service Driving

16. What are the drivers responsible for when operating the vehicles?
17. Are you aware of any issues that have arisen in the actual running of the vehicles, that were not prepared for in the training?

Close

18. Any last comments?

Appendix 2: Safety operator interview questions – Service 001

Introductory Questions

1. Would you briefly summarise your experience of driving public service vehicles?
2. How did you end up being part of the team selected to drive the automated bus?
3. How much operation of the autonomous vehicles have you completed?
    a. how many hours or days?

Training

1. How far do you think you have a good understanding of how the autonomous bus works?
    a. Are there particular things that you are aware it is capable of or not capable of?
2. Which parts of the training to drive the autonomous bus did you find most useful?
    a. Were there any parts that didn't seem necessary?
3. Is there anything you would recommend should change about the training in the future?

Operating the autonomous bus

1. How far did you trust the autonomous bus when you first drove it?
    a. Did your feelings of trust change along with having more experience of the bus?
    b. In what way?
2. When the bus is in autonomous mode do you ever feel that driving is boring?
    a. [If yes] Less interesting than driving a normal bus? In what ways?
    b. [if no] What keeps you interested?
    c. [all] Is there anything you would change about driving the autonomous bus to make the task more interesting or enjoyable?
3. When the bus is in human-driven mode, does it drive exactly like you would expect for an electrically powered bus?
   [NB unlikely respondents will have experience of electric buses so this will likely be a comparison with their expectations]
4. How have you found the task of keeping your concentration whilst supervising the bus when it is in autonomous mode?
    a. Difficult or straightforward?
    b. Do you use any techniques to help you maintain concentration?
5. How does driving the autonomous bus compare to any previous similar experiences you have had as a driver or more generally?
    a. For example, long-distance bus/coach driving on motorways?
    b. Monitoring machines in a factory environment?
6. The driving shift has been restricted to one hour for the autonomous buses. Do you think this is too long, too short, or about right?
    a. Why do you think that?
7. At the end of a shift working on the automated bus, do you feel more or less tired than when working on a normal bus, or about the same?
    a. [if different] Why do you think that is?
8. When the bus is in autonomous mode, how far do you feel responsibility for the vehicle?
    a. Is responsibility shared between you and the autonomous system?
    b. [If feel it is shared] How do you feel about the way the responsibility is shared?
9. When the bus is in autonomous mode, how would you describe the level of risk compared with driving a normal bus?
    a. Is the level of stress you experience the same or different to a normal bus?
    b. [If different] Why is that do you think?
10. Are there any specific manoeuvres that the bus needs to make in autonomous mode which you feel it handles particularly well? Or alternatively you think it needs improvement?

a. Passing vehicles coming the other way
b. Negotiating roundabouts
c. Turning left at junctions
d. Turning right at junctions
e. Stopping/starting at bus stops
f. Responding correctly to pedestrian crossings
g. Responding correctly to traffic lights
h. Dealing with vehicles that are parked or stationary on the carriageway.

Taking back manual control of the vehicle

11. Can you recall the first time you had to take back manual control of the autonomous bus, probably during training?
    a. Do you remember what you felt at the time?
12. How do you find that switch now you are more used to it?
    a. What has changed compared to the first time?
    b. Can you recall any specific instances of the handover going particularly well or badly? What do you remember?
13. How often do you find yourself overriding the autonomous system away from (emphasise) places where you have been instructed to take back control, such as turning into the Bee House forecourt?
    a. How many times a circuit?
    b. Are there any particular occasions you remember?

Other aspects of providing the bus service

14. How do you think passengers relate to the autonomous bus?
    a. Were there any differences?
15. How do you feel about your interaction with passengers boarding and alighting?
    a. Is this easier or harder than when driving an normal bus?
    b. Why? [expect answers based on no fares being charged – if that is the response, prompt for other issues]
16. What do you think are the key aspects of the role of being the member of staff on an autonomous bus?
17. Is there anything you have to do before or after a shift that relates to this being an autonomous bus which is unusual for you compared to a normal bus?
    a. How did you find this?

Final questions (if time)

18. How did you find the experience of operating the autonomous vehicles overall?
    a. And how does it compare with driving a normal bus?
    b. What would you see as the biggest difference?
19. Is there anything else you think we should know about your experience with the autonomous bus?

Appendix 3: Safety operator interview questions – Service 002

Introductory Questions

1. How many days have you operated the autonomous bus to/from Didcot Parkway?

Training

2. Has you understanding of how the autonomous bus works changed since the route has been extended to Dicot Parkway?
    a. If so, how?
    b. (Are there any new things that you are aware it is capable of or not capable of?)
4. Did you receive any additional training for the extended route?
5. Is there anything you would recommend should change for future training?

Operating the autonomous bus

6. Have your feelings of trust in the autonomous bus changed since you have been driving to Didcot Parkway?
    a. If so, in what way?
7. When is it necessary to take control and use human-driven mode?
    b. Certain parts of the routes?
    c. Certain situation/scenarios?
8. What makes you anxious when supervising the autonomous bus on the longer route?
9. When are you most at ease/relaxed when supervising the autonomous bus on the longer route?
10. Is it easier or harder to keep your concentration whilst supervising the bus in autonomous mode on the longer route?
    a. What (if anything has changed)?

11. When the bus is in autonomous mode on the longer route, how would you describe the level of risk compared with driving a normal bus?
    a. Is the level of stress you experience the same or different to a normal bus?
    b. [If different] Why?

12. Are there any specific manoeuvres that the bus needs to make in autonomous mode which you feel it handles particularly well? Or alternatively you think it needs improvement?
    a. Passing vehicles coming the other way
    b. Negotiating roundabouts
    c. Turning left at junctions
    d. Turning right at junctions
    e. Stopping/starting at bus stops
    f. Responding correctly to pedestrian crossings
    g. Responding correctly to traffic lights
    h. Dealing with vehicles that are parked or stationary on the carriageway
    i. Passing overgrown trees or bushes.

Taking back manual control of the vehicle

13. How often do you find yourself overriding the autonomous system?
    a. How many times a circuit?
    b. Has this changed on the longer route compared with the shorter route?
    c. Are there any particular occasions that you remember?

d. Can you recall any specific instances of the handover going particularly well or badly on the longer route? What do you remember?

Other aspects of providing the bus service

14. Has the way passengers relate to the autonomous bus changed on the longer route?
    a. If so, how?

15. Has your role as a member of staff on an autonomous bus changed on the longer route or since you have had more passengers boarding?
    a. If so, how?

Final questions (if time)

15. Has your overall experience of operating the autonomous bus changed since moving to the longer route?
    a. If so, what has been the biggest difference?

16. Is there anything else you think we should know about your experience with the autonomous bus on the longer route?