A Human Factors Approach to Defining Requirements for Low-speed Autonomous Vehicles to Enable Intelligent Platooning

Roger Woodman, Ke Lu, Matthew D. Higgins, Simon Brewerton, Paul Jennings, and Stewart Birrell

Abstract—**This paper presents results from a series of focus groups, aimed at enhancing technical engineering system requirements, for a public transport system, encompassing a fleet of platooning low-speed autonomous vehicles (LSAV; aka pods) in urban areas. A critical review of the pods was conducted, as part of a series of technical workshops, to examine the key areas of the system that could affect users and other stakeholders, such as businesses and the public. These initial findings were used to inform a series of focus groups, aimed at identifying the public's views of multiple autonomous vehicles being deployed in a pedestrianised area that can join and form platoons. Analysis of findings from the focus groups suggests that while people view platooning public transport vehicles favourably as a passenger, they have some concerns from a pedestrian perspective. Thematic analysis was applied to these findings and a systematic approach was used to identify where subjective outputs could be formalised to inform requirements. Finally, a step-by-step requirements elicitation process is presented that illustrates the method used to convert qualitative user data to objective engineering requirements.**

I. INTRODUCTION

The capabilities of autonomous vehicles (AVs) are rapidly reaching the stage where they can be deployed as a public transport solution [1]. When compared to traditional public transport, AVs have the potential to provide improvements in safety, energy efficiency, traffic flows and passenger comfort [2, 3]. AVs also present new and enhanced opportunities for people with mobility issues, such as the disabled or elderly, and open up transport to new groups of people such as those not old enough to drive [4]. In the context of this paper, AVs are considered to be fully self-driving vehicles, with no driver controls (e.g. steering wheel, brake / accelerator pedals). A recent study by Clayton et al., surveyed 730 travellers to understand the public's willingness-to-pay (WTP) and willingness-to-share AVs [5]. Their results showed that, although there is uncertainty about AVs, people are prepared to pay a premium for privacy, with the highest WTP reported for single occupancy AV taxis.

In the field of AV public transport, one area, which has received little attention, is AVs for use in exclusively

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pedestrian areas. This type of transport solution would come under the term "last-mile", which denotes short inner-city type journeys [6]. By only considering pedestrian area usage, it is possible to ignore issues associated with road travelling, and interaction with incumbent vehicles. However, in such environments there will be considerably more close contact situations with humans. Additionally, vehicle routes are generally regulated, and people are accustomed to crossing at designated points [7]. These risks can be mitigated to some extent, as these AVs – often referred to as low-speed autonomous transport systems (L-SATS) or colloquially as "pods" in the literature – will be restricted to lower speeds, and external interfaces can communicate with pedestrians [8].

In recent years, cities in the UK, and across the world, have started to redesign shared public spaces. The trend has been to remove vehicle barriers and ground markings, which has the effect of making drivers pay more attention. This is attributed to not having a defined route to follow, which is visible to pedestrians [9]. This has shown to make drivers more cautious, and pedestrians more comfortable [10]. However, there is no evidence this relationship between pedestrian and driver would be the same for AVs.

For AVs to operate in the UK, as well as other countries, such as Australia, China, Japan and the US, a human operator is required to provide constant supervision, either in the vehicle or remotely [11, 12]. Economically, requiring a human for each AV makes little sense, as it would be less expensive to employee drivers in regular cheaper manually driven vehicles. A solution to this problem would be to minimise human supervision, as adopted within this research project, and enable the human to supervise more than one AV simultaneously. To achieve this, the project proposes using platooning, often referred to as a "road train", as this enables the lead pod to be supervised by a human, with other pods in the platoon to follow its path. This process of platooning is a well-established strategy in intelligent transport systems (ITS), but has mainly been used for fuel efficiency, and not to minimise supervision. This defining novelty was proposed to the UK funding body Innovate UK that led to the successful award of SWARM, which aims to address the UK's first cooperatively controlled autonomous public transport system.

As the pods described in this paper will be using shared public spaces, their trust and acceptance by pedestrians is essential. Therefore, the aim of this paper is to understand what users and the wider public would want from a platooning autonomous transport service. The study will focus on a pod service currently under development by RDM Ltd. in Coventry, UK. To the best of the authors' knowledge, this is the first public opinion survey looking specifically at platooning of passenger transport vehicles. The scope of the focus groups was limited to the platooning aspect of the

service and does not cover perceptions or misconceptions of autonomous transport or AVs in general. However, where it helps aid discussion and explain platooning functions, these topics are considered. Finally, an approach to incorporate human factors into requirements gathering is presented, in the form of a novel process for converting qualitative focus group data to system requirements.

The paper contributes to the literature by presenting user findings from an autonomous platooning public transport system, for use in urban areas, and presents a novel method to capture system requirements. The findings from this paper, and further planned studies, will be used to influence the design decisions of the RDM pod system (and other transport systems). It is argued that involving users at an early design stage will result in a system that can deliver a useful service with greater user acceptability.

II. METHODOLOGY

A. Focus Groups

To capture user requirements for an autonomous platooning transport system, interviews, observations and surveys were conducted with six focus groups. The focus group method was chosen, as it is a fast, effective way of obtaining a large data set of people's attitudes, feelings, and beliefs about a given subject [13]. As this was an exploratory study, we asked two open-ended questions. These were "As someone who is sharing the same area (e.g. driver, pedestrian, cyclists), how do you feel about public transport vehicles that platoon?" and "As a passenger, how do you feel about public transport vehicles that platoon?". Throughout the session, short use case scenarios were presented, to stimulate debate. These user stories followed the pattern "As a <role> I want to <action> so that <result>", which is a syntactical convention often used in software development [14, 15].

The focus groups ran for 90 minutes, with a 30 minute explanation of the pod service, including time for participants to experience a pod. This was particularly important, as many participants have not seen, or been in a pod previously, and this experience would help ground future discussions. The pod demonstration took place in WMG's 3xD Simulator for Intelligent Vehicles at the University of Warwick. A presentation of the service was given, using concept videos of the proposed service, and animations to illustrate the three main components of platooning (joining, splitting, and travelling together). The remainder of the session involved a discussion of the two open-ended questions. A facilitator was used to help encourage participation and to steer the discussion when required, without stifling responses.

Participants were recruited from the University of Warwick, Coventry University, and Jaguar Land Rover. To comply with ethical clearance (granted via BSREC) participants had to be over 18 years of age. In total, 30 people participated in the focus groups, of which 14 were males and 16 females. The participants consisted of a mixed age, $M = 31.41$, $SD = 10.12$. The occupation breakdown was 42.9% Student, 39.3% Professional, and 17.9% Clerical. There was no requirement for the participants to have knowledge of AVs. Details of participants was captured using a questionnaire, which included demographic

Figure 1. Autonomous pod developed by RDM Ltd.

information and transportation preferences and usage. To analyse focus group data, we used the "key concepts" analytical framework [16]. The aim is to discover core ideas, by understanding how participants view a topic. The process involves identifying a limited number of important ideas, experiences, or preferences that illuminate a study.

During the focus groups, extensive notes were taken, as well as details of how people responded to specific topics. Notes were entered in a spreadsheet, where data could be cleaned and analysed. This process involved refining responses into short sentences, without removing any meaning. To derive our findings, we used thematic analysis, which is a process to identify patterns within the responses. This iterative process starts with understanding the data, before codes and sub-codes can be generated. This coding process assigns one or two words to the response, which identify its core meaning. These codes are then grouped into categories, which can be analysed to identify the main themes and concepts [17].

B. Pod Specification Summary

The pod service proposed by RDM Ltd., will be made up of a fleet of electric autonomous pods (Fig. 1) and demonstrated in Milton Keynes, UK. In the context of the SWARM project, the pods will be operated exclusively in pedestrianised areas and will not be allowed to travel on public roads. Each pod can seat 4 people, travel at a maximum of 24 km/h. The pod service is classed as a last mile transport solution, although initially, journey distances will be between 0.1 km and 2.5 km. Pod users will be able to request a pod using a mobile phone application.

III. RESULTS AND DISCUSSION

Gathering user data for the proposed autonomous transport service posed several challenges. Firstly, as this is a public transport solution, it is important to involve the public as early as possible. However, although the AV concept is straightforward to explain, its travel limitations are difficult to convey. With AVs it is possible to make comparisons with taxis, buses and trams. However, with platooning, it is a significantly greater challenge to get people to a level of understanding at which they can start identifying potential issues. When participants were asked about their existing knowledge of AVs, 60% reported little

TABLE I.   SAMPLE RESPONSES FROM PARTCIPANTS

Participant Response
If platoon looks like it's stopped, people will try and walk between them
Wouldn't like empty pods going past me in a platoon, if I'm waiting for a pod, should have a sign to say why I can't use it
I like the idea of a platoon of vehicles at night, if I was travelling alone. Although, could be scary if the people in other vehicles were anti-social
Frustrated if people getting in the pod behind slowed my journey
A platoon of pods should be able to cross a zebra crossing (or similar crossing point in at least 15 seconds
Pods should travel a bit faster than walking pace when following people and when alongside people, the pod should speed up to jogging pace
It will be awkward being sat in a pod in a pedestrian area, especially if the pod is getting in people's way and making them annoyed

TABLE II.   SAMPLE USER STORIES

User Story
As a passenger I can request the pod to stop at any time, so I can complete my journey on foot
As a user I can pay a premium ticket price, so that I can be in a pod that doesn't platoon
As a pedestrian I can see the route of the pods on the ground, so that I know where they are going
As a user I can choose which position in the platoon my pod is, so I can be more comfortable
As a passenger, I want to be notified if my arrival time will be longer than that stated when I booked
As a passenger, if the pod stops for more than 30 seconds before reaching the destination, I want to be notified with the reason why

to no knowledge, 30% moderate knowledge, and 10% high knowledge. For platooning, some participants knew of fuel saving strategies for trucks. However, none had knowledge of the reasons for platooning proposed by this project.

The output from the focus groups was captured as 562 separate and individually identifiable rows in a spreadsheet; a sample of which are provided in TABLE I. Thematic analysis was applied to identify themes in the data. The first stage of this process involved assigning each row one or more descriptive codes, which explained the core meaning of the response. For the first coding cycle, these codes were analysed and grouped in to five categories: comfort; cost; safety; security; time. From these categories, several themes were identified. A second coding cycle was later conducted, which looked in more detail at the perspective participants were making their response from. From these two main categories emerged, which was responses from (1) a passenger perspective and (2) issues external to the pod.

In addition to discussions about the proposed transport service, participants were prompted to express their thoughts in terms of a user story. The prompts were made when there were natural breaks in the conversation, with the aim to minimise any disruption or leading of the participants. The participants were not required to give user stories in any format, with most participants preferring to give examples of a scenario they experienced in the past, and how it would be applicable to the pod service. For our analysis we followed a strict format (as discussed in the methodology) to record user stories, a sample of which are provided in TABLE II.

A. Passenger Perspective

The themes identified from the perspective of the passenger, which includes requesting; accessing; and travelling in a pod, have been collated and presented as a chart (Fig. 2). This chart shows the total number of responses for each theme combined from all focus groups. The results reveal a number of interesting things; firstly, as a passenger, people mostly raised issues relating to the journey time. Typical reasons for this was that participants felt pods travelling as a platoon could impact the journey time, mainly due to the time it takes for people to enter and exit other pods. This was consistent with similar studies looking at public transport, which have found journey time as a key consideration for people's transport choices [18, 19]. Additionally, participants reported issues with the platooning process, feeling that joining and splitting from a platoon, as

well as travelling as a long group of pods, would have a large impact on journey time. A surprising finding the analysis revealed, is that participants had very few safety concerns from the perspective of a passenger. This may have been due to experiencing a pod first-hand and knowing it was restricted to 24 km/h. Of the few safety issues reported, participants were worried that the pods travelling in a platoon may run in to each other if they had to brake suddenly.

Several participants reported that they preferred the term "supervisor" over the term "operator" (which is used in the literature), when talking about the person responsible for the safety of the pod remotely. The term operator made people think of someone who was in control of the pod movements, like a driver, whereas the term supervisor made it clearer that the persons' role was to simply supervise the pod and react when it did something unsafe.

B. External Perspective

The themes identified from an external perspective, which includes issues involving pedestrians; cyclists; infrastructure; and the environment in general, have been collated and presented in Fig. 3. This chart shows the number of responses categorised as safety, by the author, rose drastically to be the main talking point, when participants were asked to think about being external to the pod. It is worth noting that participants did acknowledge that there was a difference between being in physical danger and being unsure, or unfamiliar with the actions of this new transport system.

The concept of platooning raised several questions, as participants didn't understand how they should behave around a platoon of pods, when it splits and joins. Suggestions were made that there should be markings on the ground or defined paths for pods to follow. A related issue was raised about the distance between pods travelling as a platoon. Participants felt people or cyclists would either intentionally pass between, if the following distance was too great, or animals and young children would unknowingly walk in the path of the pods. A similar issue identified in previous studies, has shown there is a risk people will have more confidence with AVSs in their stopping abilities, compared to traditional vehicles. As a result, less time is required before crossing, which would potentially force AVs to stop [20]. A solution to this issue could be to have pods travelling close together, to dissuade people and animals from walking between. However, this would conflict with

views expressed from the perspective of passengers, where the fear was pods travelling closely may be more likely to collide. Therefore, further research is required to determine acceptable travelling distance between pods.

Participants were asked about the environmental impact of the pod service. Each of the focus groups followed the same route when discussing this topic, which was to first praise the all-electric transport system, as a much cleaner alternative to current fossil fuels. They thought this would help lower air pollution in the area the pods operate, with some participants highlighting the issue of charging batteries, which could likely increase pollution in other areas of the country. Finally, it was agreed among participants that the convenience of an autonomous last-mile service, would likely increase journeys taken in vehicles, and may result in less people, walking and cycling. Participants worried that this would have a detrimental impact on the environment, as it would mean more vehicles being made, and would also have an impact on people's health. This view is supported by previous studies, which found that AVs could encourage people to travel more regularly and use vehicles for journeys they would have previously done on foot [4].

C. General Discussion

Participants were asked if they were in favour of the proposed autonomous public transport service and reasons why they would or would not use it. The fact the service was autonomous was shown to be more of a positive for most participants, with people reporting they liked the idea of not having a driver in the vehicle. A reason several participants gave for this, was they were uncomfortable with their children riding in a traditional taxi. However, they would likely allow it, if there was no driver. For the participants that said they wouldn't use the service, the reason was typically due to not wanting to use a service of this type and not due to the service being autonomous. Finally, many participants said they liked the idea of autonomous public transport more than owning an AV, as they felt that in a vehicle they owned or had any kind of responsibility for, they would be liable if there was an accident. Additionally, a few participants highlighted potential issues with the cost of maintaining an AV and thought that it would require a higher skill level to fix any faults compared to regular manually driven vehicles. As a result, they thought it would be likely that small issues would render an AV immobile more often than a traditional car. Therefore, there was strong support for using an AV, but not for owning one.
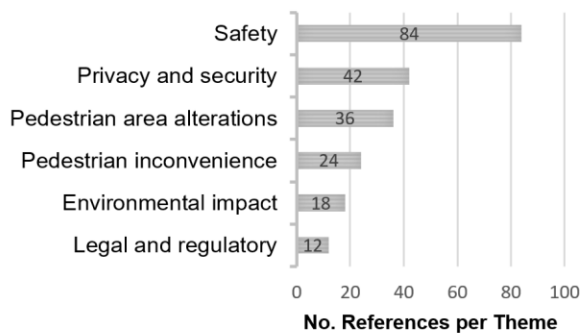

Figure 3. Frequency of topic – Issues external to the pod (e.g. pedestrians, cyclists, infrastructure, environmental)
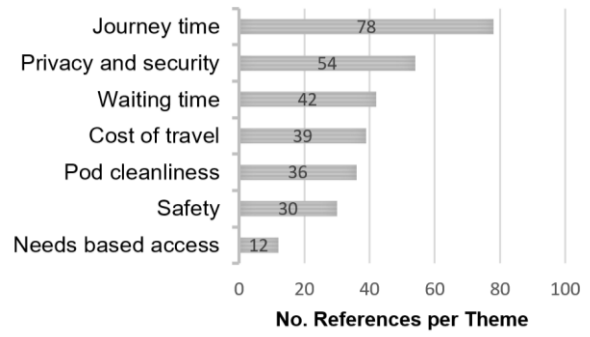

Figure 2. Frequency of topic – From the perspective of someone accessing/travelling in a pod

Several participants suggested the pod service should prioritise to support mobility for those who find it difficult to travel, either due to disability or travel restrictions. Therefore, the service should prioritise these people, and only if there was extra capacity, should other people be allowed to use it. It was thought that if this did not happen, then some people in the pods could be stigmatised if their journey was preventing other people who were not able to travel without the service.

IV. REQUIREMENTS ELICITATION PROCESS

As the transport service is still under development, and no real-world system exists, it was chosen as an ideal candidate to test a novel requirements elicitation process being developed at the University of Warwick. This user-centred process, which is presented as a list of steps in TABLE III, involves testing use case scenarios with potential users as part of focus groups. A facilitator is used to separate the system engineers and other stakeholders from the user discussions, to allow users to evaluate use case scenarios and develop them in to user stories. Thematic analysis is applied to the feedback and combined with user stories to generate system requirements. This process enhances existing formal techniques, such as Joint application design (JAD) [21] and Joint Requirements Planning (JRP) [22], by incorporating focus groups and thematic analysis.

TABLE III. REQUIREMENTS ELICITATION PROCESS ACTIVITIES

Step	Activity
1	System experts and other relevant stakeholders assess the business requirements
2	Use cases are generated, which detail how different types of user interact with the system
3	Use case scenarios are formed from use cases and grouped by user role (e.g. passenger, administrator, maintenance engineer)
4	A series of focus groups are run for each role identified in the use cases (multiple focus groups for each role)
5	Participants evaluate use case scenarios and give feedback in the form of statements and user stories
6	Thematic analysis is applied to the participants feedback to identify themes with a high frequency of responses
7	The results from the thematic analysis is used to filter the user stories, to identify those that correspond with a significant issue expressed by the participants
8	The remaining user stories are categorised as either functional requirements, (what the system should do) or non-functional requirements (constraints and quality criteria)
9	A new iteration begins, first analysing identified requirements and using these to create and amend existing use cases

The purpose of the use case scenarios in our requirements elicitation process, was to guide the focus group participants and provide information about the capabilities of the system. It proved to be important for the focus group discussions that we did not constrain the debate too much by explaining limitations of the system, as often ideas raised by the participants, which at first were not possible, lead to further achievable suggestions. Feedback from participants, in the form of statements and user stories, were compared and combined to find levels of agreement. Often multiple user stories made the same point; therefore, it was important to carefully review what people said during the focus groups, in order to create the best representative user stories.

A diagram illustrating the requirements elicitation process is provided in Fig. 4. This process involves domain experts and other stakeholders, iteratively feeding results identified by the users, back in to user story creation, which can be tested with further focus groups. The requirements are either categorised as *functional*, which generally dictate what the system should do, or *non-functional* requirements, which are often in the form of system constraints and quality criteria [23]. Additionally, requirements that have an input/output or any type of interaction, would be classed as a functional requirement. When documenting requirements, it is important to make clear the purpose of the requirement and the necessary inputs/outputs. Additionally, it is usual to designate each requirement a priority and importance value. For our approach, a reference value could be taken from the focus groups data, with higher levels of support from participants, indicating higher priority levels.

The requirements elicitation process can be compared to Volere Requirements Process, developed by Robertson and Robertson [24]. However, in their process they suggest a wide variety of activities engineers could use to capture requirements. Whereas, our process limits the number of activities to only key decision-making parts, and puts the intended system user at the centre of the process. This process shares similarities with Alexander and Beus-Dukic [25] approach for discovering requirements. The benefit for requirements engineering, is each requirement can be traced to a business requirement, use case scenario and multi-modal feedback from users, which demonstrates support.

A. Defining Requirements Example

To illustrate how our user-centred requirements elicitation process can be used in practice, we will look at how one functional requirement was defined. A few examples of the requirements we identified are presented in TABLE IV. To encode the requirements, we used the "Easy Approach to Requirements Syntax (EARS)" as defined by Mavin et al. [26]. This discussion will focus on requirement 3.2, which is concerned with the time one pod is held in a platoon, while it is waiting for the loading/unloading of another pod.

The first step in the requirements elicitation process, is to create use cases for the system under examination, based on business and stake holder requirements. The use case, which informed requirement 3.2, is presented in Fig. 5. This use case illustrates interactions between customer and pod supervisor, from requesting a pod, to travelling from origin to destination. Additionally, the diagram shows how the supervisor will continually monitor the pod.
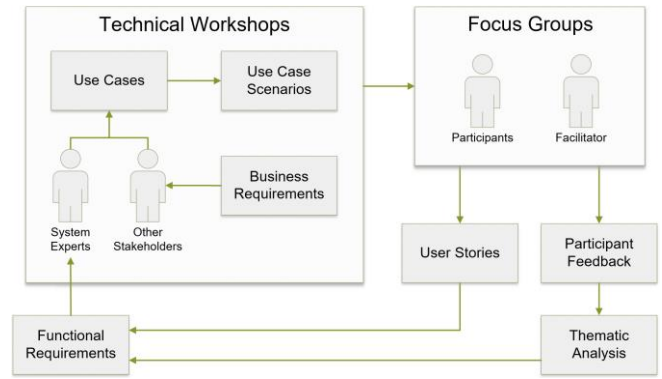

Figure 4. User-centred requirements elicitation process

In developing requirement 3.2, three components were combined. These were a user story, results from thematic analysis and an existing functional requirement. The results from the thematic analysis, identified journey time as the most important user issue. Therefore, it is reasonable to conclude that requirements in this area will have the largest impact on user's acceptability of the system. For requirement 3.2, the following user story formed the basis: "As a passenger in a platoon, I should only have to wait for a maximum of 2 minutes for other pods to load and unload passengers". In developing this user story in to a requirement, it is critical to check that it doesn't contradict any other requirements. To achieve this, we identified all other requirements that were concerned with journey time and splitting from a platoon. An existing requirement (2.6) was identified that stated, "The pod shall not platoon if it adversely affects a passenger's journey time". This requirement reinforced the new requirement and made it more straightforward to document as the existing requirement was tied to a business requirement.

The example requirement discussed in this section, was not considered prior to user testing. Although journey time was considered an important factor for users prior to the testing, the requirements elicitation process was able to verify this assumption, and importantly, add user derived objective inputs to the original requirements. Finally, it must be remembered that our requirements elicitation process should be run iteratively, as and when the system becomes available to more user testing. Ideally this would happen at the initial development phase (as with the example in this paper), and at different testing phases, (e.g. controlled testing and real-world testing). It is argued that by involving users early on, developers can design solutions incorporating user feedback, instead of adding functionality later, which would likely involve more substantial costlier work. The intention is that following a user-centred development process will result in a system with greater user acceptability

TABLE IV. EXAMPLE REQUIREMENTS

| Req. Id	Requirement
2.6	The pod shall not platoon if it adversely affects a passenger's journey time
3.2	If an occupied pod, which is part of a platoon, waits longer than 2 min for another pod in the platoon to move, then the pod shall split from the platoon and resume its journey
3.7	If occupied pod stops > 30 seconds, prior to reaching the destination, the passenger must be informed of the reason
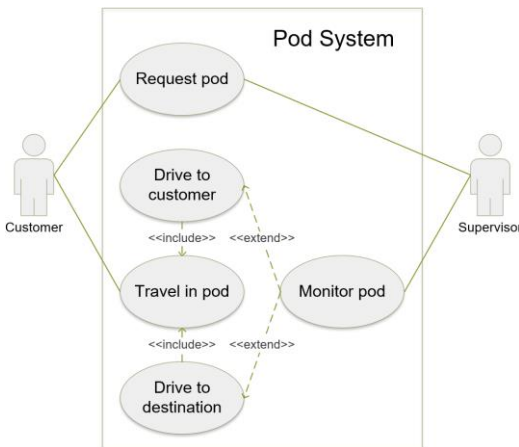
Figure 5. Customer pod request scenario – UML use case diagram

V. CONCLUSION

In this paper we present results from a series of technical workshops and focus groups, on the subject of a platooning autonomous urban transport system. The findings revealed people generally accepted the idea of platooning AVs as a transport solution. However, some questioned how it would impact journey times. Additionally, questions were raised on how pedestrians and pods would interact in shared spaces, particularly on the topic of crossing paths. Participants also raised future research questions, which focused on the distance between pods in a platoon and how people would be prevented from crossing between. An interesting finding was how different technical terminology was perceived, with the term "operator" perceived as a term for someone in control of the pod's movements. The term "supervisor" was found to reassure participants that pods were fully autonomous.

The study results were analysed using a requirement gathering process developed at the University of Warwick. This process involved selecting existing requirements and creating use cases, which could be discussed with focus groups, in order to garner feedback and user stories. It is argued that this approach gives greater transparency of the requirements engineering process, allowing each requirement to be traced to a business/system requirement, use case scenario and multi-modal user feedback.

Future work will incorporate real-world testing of the pod service and introduce additional questionnaires and structured interviews to capture user's experiences. Additionally, it is clear from the findings that the distance between pods in a platoon is an important issue. Therefore, further research will be conducted to determine the gap acceptability for the user. For the requirements process, further work is required to refine and validate the process. This will be achieved by trialling with different systems and comparing the effectiveness with other methods identified in the literature.

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