A System with AR integration for Vehicle Maintenance

Description

The objective of this project is to take advantage of emerging and existing augmented reality technologies to develop a system that is targeted towards technicians and vehicle users.

To achieve these aims, this project will be implemented on or with Google’s Android operating system for use on the many Android devices currently available.

The system will provide vehicle’s repair and maintenance assistance, as well as providing interactivity and social aspects to enhance their experience.

The project will choose an appropriate architecture which will be a client-server one. The client being the mobile or smart glasses devices and the server will handle all the data processing.

Requirements Engineering

Feasibility Study

1. Are there similar systems to this in the marketplace (in Desk top, Cloud, Android, iOS, Windows …)?

   Identify at least 4 examples of Similar Systems.

   Describe each of them, by gathering information from their websites, "*put directly copied material in quotes and italics*". The more information gathered here will reduce the time required to go back to the websites. Reference the URL for each.

ARTech (Peterbilt): point an iPad at the vehicle and it generates technical information and wiring in a 3D model on screen. "*The software tool re-conceptualizes 2D technical information (wiring diagrams) as full-scale 3D objects created from CAD models. Technicians can point their iPad's camera at a Model 579, for example, and ARTech populates the screen with dozens of colorful lines weaving around the image representing the flow of wiring.*"
https://www.fleetmaintenance.com/equipment/safety-and-technology/article/53057849/augmented-reality-in-vehicle-maintenance

Volvo: "*Using a Vuforia augmented reality experience, operators can quickly recall the most up-to-date configurations in 3D to ease the burden of sorting through stacks of paper, creating gains in productivity, quality control, and overall process efficiency. The AR solution is delivered using mixed reality, which overlaying 3D data and QA details directly on to the physical engines and utilizes computer vision to track and anchor the content.*"
https://www.ptc.com/en/case-studies/volvo-group-digital-thread

Porsche: The Atheer platform allows technicians at dealerships to connect to the Porsche technical support team based in other country. With the help of smart glasses the support team can see what the technician is seeing and project instructions and schemas.
"*Using smart glasses equipped with the Atheer AR platform allows technicians to access digital overlays and step-by-step instructions, enabling them to diagnose and fix issues more efficiently.*"
"*For example, a service technician at a dealership in Los Angeles connects via Atheer to the support agent wearing smart glasses. Now the Atlanta-based Porsche technical support team can provide assistance and resolve the issue some 2,200 miles away. The support team can see what the technician sees via high-definition*

live video from the smart glasses. The support agent, in turn, can project step-by-step instructions and distribute technical bulletins and schematic drawings onto the display inside the technician's glasses. A hands-free, interactive experience allowing the support agent or the technician to take screenshots, video, or annotate images for better visibility. The session is captured for data analysis, creating opportunities and insights that may benefit product improvements, warranty claims or updating the technician training and skills development programs."
*https://www.praxworxs.com/insights/atheer-i*mproves-porsche-dealership-service-support-with-ar

Hyundai: Using the phone camera, the app recognizes car parts and displays its information on the screen. This app is targeted to car owners, not technicians. *"The Hyundai Virtual Guide app allows Hyundai drivers to use their phones or tablets (Android or iOS) to get to know their cars and learn how to perform basic maintenance, without needing to consult a multi-hundred page paper owner's manual."*
"Then, point your smartphone at that area of the car. The Hyundai Virtual Guide app uses the phone's built-in camera to recognise the different components in the car, whether they are under the hood, in the trunk or within the interior.
As if by magic, informative labels describing what you're looking at pop up on the screen.
If you need to know more about a particular feature or part, simply tap on the labelled image and either a how-to video or a description will appear. These will consist of an AR overlay or regular 2-D graphics. Some of the app tutorials available include checking the oil, changing the air filter, pairing with Bluetooth and using cruise control."
https://www.hyundai.news/eu/articles/stories/how-augmented-reality-silently-revolutionises-your-driving-experience.html

BMW: *"BMW announced this week its technicians in North America will begin using smart glasses with augmented reality capabilities to help troubleshoot repairs, and even communicate in real time with engineers in Germany."*
"With the glasses on, technicians can summon and view vehicle data like technical bulletins and schematic drawings on the small screen while they work, or open or send documents, simply by using voice commands."
https://driving.ca/auto-news/news/bmw-technicians-to-use-augmented-reality-glasses-for-repairs

2. Identify the main system features and services provided in the reviewed systems, above. Consider the existing systems and the services they provide.
   [Reference and copy the URLs]

ARTech (Peterbilt): allow technicians to use an iPad to generate 3D models with information on the vehicle.

- Features: generate 3D models of wiring diagrams and other data on the vehicle on a full-scale representation.

- Services: provide diagnostics and real-time technical data through visual 3D models improving accuracy and reducing repair time.

Volvo: AR system that overlays 3D data and quality guarantee details.

- Features: 3D visualizations of advanced structures. Provide quality assurance and real-time data to improve manufacturing processes.

- Services: increase productivity, reduce human errors and increase quality control in the assembly process.

Porsche: technicians use smart glasses to connect with remote technical support, access instructions and perform diagnosis.

- Features: live video streaming from smart glasses. Step-by-step instructions and data projection on the glasses. Hands-free interaction with the system (record, take screenshots, take notes).

- Services: real-time remote troubleshooting and diagnosis support. Reduce repair time and improve technician training.

Hyundai: app target to car owners, using their phone camera to display information on the vehicle’s parts.

- Features: recognize vehicle’s parts via camera and provide information on the phone’s screen. Provide videos and tutorials for basic mainenance tasks (check oil levels, change air filter, ...).

- Services: help customers doing basic maintenance tasks improving user experience.

BMW: use smart glasses to assist technicians with repairs and diagnostics.

- Features: view technical data and schematics using the glasses. Real-time communication with engineers for remote support. Hands-free operation using voice commands.

- Services: improve technician efficiency providing real-time access to data and remote support.

3. In what ways would users have accomplished the activity (get/use information), when not using a system, an app or online services?

Users would have to read vehicle manufacturers manuals and mechanic manuals, or if they don’t have enough knowledge or capabilities, they would have to ask for technical support via phone call, email or going to a repair shop.

4. Describe a new type of system, The proposed system
   Explain in detail how it might operate for different end users.
   Consider the existing systems that provide similar services to different end users and system adminstrators.
   Take inspiration from the systems identified in section 1 and key features identified in section 2.

The desired AR app system for car repair and maintenance must provide easy to follow step-by-step visual instructions along with 3D models and animations to guide users through the complex repair processes of their vehicle. Each step would also need to include tool recommendations, to ensure that the user selects the best suited tool for each step, facilitating the repair process. To improve usability and make it more comfortable towards the clients, the system would be able to support hands-free operations making use of smart glasses, similar to the systems used by Porsche and BMW.

In addition, the system would provide real-time diagnostics, showing sensor data and errors over the affected component. Based on this diagnosis, the system would offer guided troubleshooting steps to help the users identify and fix the issues. With the use of image recognition technologies, the system must be able to identify the different vehicle parts and components.

Another feature that the system may include is remote assistance, allowing technicians and users to collaborate with experts who can provide feedback and guidance along the process. The system could also include training simulations or rehearsal features in order to offer technicians a way to practice and improve their skills in a virtual environment.

Additional features could be safety warnings to alert users of potential risks and quality control assistance to ensure the repair meet the manufacturer's standards.

If we were to consider non-functional requirements, the system would need to deliver the visual instructions in real-time, minimizing the repair time. It should support multiple users and devices simultaneously and it should be intuitive and easy to use. The system must also be compatible with different devices and offer help a wide range of vehicles.

5. Who are the stakeholders? How would this new system affect them positively or negatively?

The stakeholders would be car enthusiasts, training mechanics, former mechanics and vehicle manufacturing companies.
It would affect them positively as it would make things easier to them, as information would be more accesible, fast to get and easier to understand. However, at the beginning they would have to adapt to the system, which may take some effort and time.

6. What other research would be necessary to ascertain feasibility, Market Research information for marktet size e.g., ownership of smartphones …? (Gartner Research etc.)

- Age group: +18 (legal age to drive)

- Users: vehicle owners, technicians, manufacturers, car enthusiasts, training mechanic personnel

- Technology requirement: smartphones or tablets with camera and AR capability, smart glasses, access to the Internet (live support).

- Stakeholders: technicians, manufacturers, service centers, customers.

7. Make an initial list of **functional** and **non-functional** requirements.

Functional requirements:
- Recognize what is being shown via camera or smart glasses
- Make a diagnosis of the issues
- Provide step-by-step visual instructions, 3D models and animations
- Access the database to get all the information regarding a vehicles
- Remote assistance (connect end users to manufacturers)

Non-functional requirements:
- Fast processing and data retrieving
- Support multiple users and devices simultaneously
- Intuitive and easy to use
- Compatible with different devices
- Information on a wide range of vehicles

Requirements Elicitation

8. Could observation of exisitng processes or behaviours (Ethnography) be used in this case study? If so, in what way?

Yes, ethnographic methods could be used by watching how technicians works and what tasks are harder for them to perform. This can help us understand in what tasks AR technology could make their work easier.

9. Identify one or two significant stakeholder(s), which will be **interview**ed to get more information on the intended product.
   Justify your choice of stakeholder(s).
   Do up an interview plan.
   Prepare approximately 10 questions if interviewing 1 stakeholder or 6 to 8 questions if interviewing 2 stakeholders.

Significant stakeholders are technicians because they are the primary end-users of the system. Their feedback can help improve the product and they can provide very useful information towards the features the system should include.

Interview Plan: during the interview, my main goal would be to understand how AR could be integrated, getting to know all the challenges technicians face in maintenance processes. I would also want to learn about how their job could be made easier having into account user experience.

Interview Questions:

1.- What is the current process for diagnosis and complex vehicle repair?

2.- Do you currently use any type of technology to help you perform your job? If so, which one(s)?

3.- How do you think aumented reality (AR) could help you perform daily tasks in your job such as repairs, training or diagnosis?

4.- Do you expect any challenges to arise when using aumented reality (AR) for repairs? If so, which ones?

5.- With our app, real-time remote assistance could become easier. How do you think this would improve your job?

6.- Which device would you prefer to use with aumented reality (AR) (smart glasses, tablets, mobile phones or other devices)? Why?

7.- Which factors, regarding costs, would affect the decision to adopt aumented reality (AR) technologies?

8.- How do you see vehicle maintenance in the next 10 years?

9.- What role do you think aumented reality (AR) will play in the vehicle maintenance sector in the future?

10.- What kind of training would suit you best to feel comfortable with this technology?

10. Identify a significant group of stakeholders, which will receive **questionnaires**.
    Justify your choice of stakeholders.
    The questionnaire should have approximately 10 questions.

A significant group of stakeholders would be vehicle owners as they are crucial end-users of this system, and they are a large group of people from whom we can obtain important information.

Questionnaire questions:

1.- How comfortable are you using smartphone apps for tasks related to your vehicle?
[Very comfortable | A bit confortable | Not comfortable | I don't use any]

2.- Have you ever user aumented reality (AR) technology?
[Yes | No]

3.- Would you be interested in using an aumented reality (AR) app to assist you with vehicle maintenance?
[Yes | Maybe | No]

4.- Do you have a device (smartphone or tablet) with a camera that supports aumented reality (AR) features?
[Yes | No | I don't know]

5.- How confident are you in performing basic maintenance on your vehicle?
[Very confident | A bit confident | Not confident]

6.- What would it more likely for you to use an aumented reality maintenance app?
[Open question]

Another significant group would be technicians in service centers, as they may use it performing daily tasks at their job and for training, and they are also a big group from which we may obtain a lot of information.

Questionnaire questions:

1.- Do you currently use digital tools in the diagnosis and repair processes?
[Yes | No]

2.- How familiar are you with aumented reality technology?
[Very familiar | A bit familiar | Not familiar]

3.- Do you think AR tools which display diagrams or repair instructions would make your job easier or faster?
[Yes | No | I dont’ know]

4.- What challenges do you predict in adopting AR tools into the repair process?
[Lack of training | Time consuming | Difficult to use | Other (specify)]

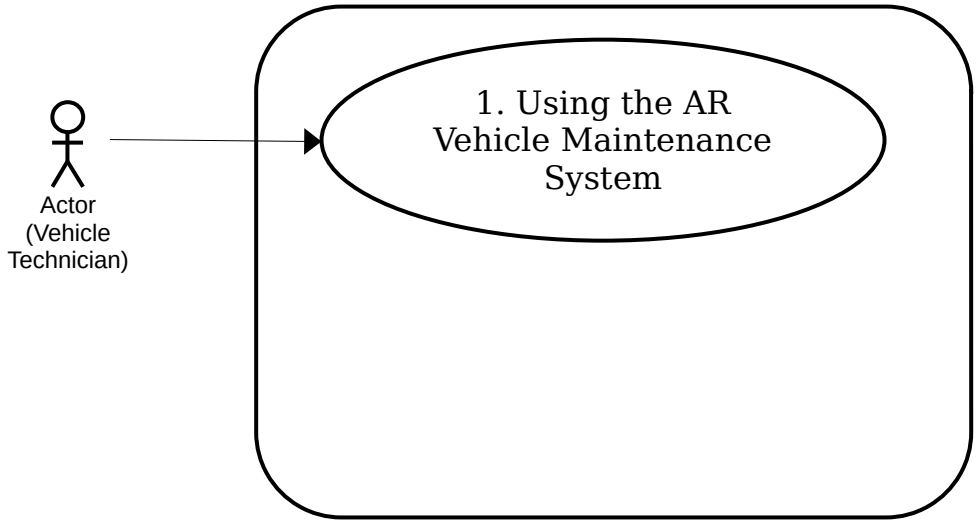
5.- How comfortable would you be using AR technology to guide you through complex repairs?
[Very comfortable | A bit comfortable | Not comfortable]

6.- What features would you like to see in our system to help you perform your job?
[Open question]

Requirements Analysis

11. Use the use case template to analyse the proposed system

Draw an initial *use-case diagram* with supporting scenario description for this app (possibly using *StarUML* for the diagram). The first iteration of the use-case diagram can consist of a single overall use case with supporting main flow and 2 or 3 alternative flows.



The use case description is developed from analysing the description of the use case. This is the long description of the use case, in the use case narrative.

For the first iteration this will be a description of the how the system operates.
Use Cases focus on functional requirements and specific system behaviour.

USE CASE	1	Using the AR Vehicle Maintenance System
Brief Description of Goal in Context	Provide real-time, augmented reality assisted guideance, to technicians, for vehicle maintenance, repair and diagnosis. Display 3D models, technical diagrams and step-by-step instructions on a live view of the vehicle to help them complete maintenance tasks with precision and accuracy. Reduce the need for paper manuals, increase error detection and improve the troubleshooting process.	
Preconditions	- Have the app on a compatible device - The device's camera is working properly - The vehicle is present and accesible	
Post Conditions, Success End Condition	- The vehicle's mechanical issues have been fixed - The maintenance task is successfully completed - The vehicle is in good condition	
Long DESCRIPTION of Scenario	The system provides interactive, real-time maintenance assistance directly on a mobile device or smart glasses. The primary goal is to improve the efficiency, accuracy and safety of maintenance tasks. The system will use the device's camera to detect and identify the vehicle model and will retrieve up-to-date technical information, wiring diagrams and relevant maintenance history from the database. The user can select the specific maintenance task they want to perform, such as inspecting the engine, performing a wiring diagnostic, or changing parts. The system will then display 3D representations of the vehicle's components onto the live camera feed, highlighting specific areas the user needs to focus on. Step-by-step instructions will be provided guiding the user on what to do next. The system will respond to the user's actions, confirming correct procedures and issuing alerts if something is not properly done. The system offers remote support for technicians who encounter issues they cannot solve. The technician can connect with remote experts who can see the live-view. During and after task completion, the system will capture key performance data such as parts replaced and errors encountered. This data is later used for developing a maintenance report. If internet connectivity is lost, the system switches to offline mode, allowing the user to continue their tasks but using static models and information.	

Main Flow		
Step	**Action**	**Alternate**
1.1	The user points their device at the vehicle	
1.2	The system recognizes the vehicle’s model	E.F. 1.2
1.3	The system retrieves necessary technical data	E.F. 1.3
1.4	The user selects the task to perform (maintenance, diagnosis, ...)	
1.5	The system generates a 3D model and displays intructions	
1.6	The user follows the real-time instructions	
1.7	The system tracks the user’s progress	
1.8	The system constantly monitors for errors	
1.9	The system offers posibility to initiate support session	
1.10	The user finishes all the steps	E.F. 1.10
1.11	The system generates a report about the task	
1.12	The system updates vehicle’s information	
EXCEPTIONS or ERROR Flow Description **E.F. 1.2:** Error flow at step 2 of Use Case 1: Vehicle not recognized		
Step	**Branching Action**	**Alternate**
1.2.1	The system indicates to the user it was unable to identify the vehicle	
1.2.2	The user inputs the vehicle model manually	
1.2.3	Go to Main Flow step 1.3	
EXCEPTIONS or ERROR Flow Description **E.F. 1.3:** Error flow at step 3 of Use Case 1: Data retrieval failed		
Step	**Branching Action**	**Alternate**
1.3.1	The system indicates to the user there was an error loading data	
1.3.2	The system will notify when data is retrieved	
1.3.3	Go to Main Flow step 1.4	
EXCEPTIONS or ERROR Flow Description **E.F. 1.10:** Error flow at step 10 of Use Case 1: User unable to complete a task		
Step	**Branching Action**	**Alternate**
1.10.1	The user notifies to the system it is unable to complete a task	
1.10.2	The system offers to connect the user to an specialist remotely (remote assistance)	
1.10.3	The user completes the task	
1.10.4	Go to Main Flow step 1.11	
ALTERNATIVE or VARIATION Flow Description		
Step	**Branching Action**	**Alternate**

Non Functional Requirements

Non-functional Requirements for each use Case can be added in the Table below.

Consider 2 or 3 non-functional requirements, related to the use case, from the list of options and add them to the table. Non-functional requirements, management issues and decisions required to be made, can be identified in the following table.

From the table below, **choose a limited number of appropriate non-functional requirements** relevant to the Use Case.

Non Functional Requirements can be categorised as

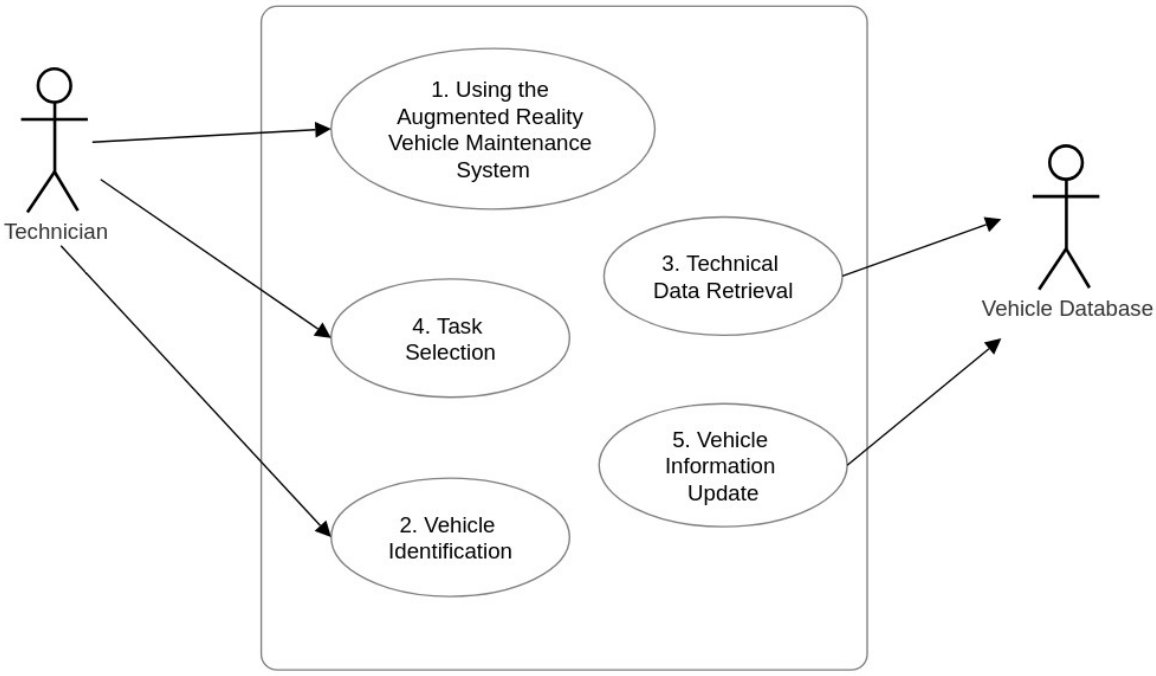
- Product related
- Organisation related, process and approaches set by the company
- External, imposed by outside bodies

RELATED INFORMATION	Use Case: 1	Using the AR Vehicle Maintenance System
Priority:	Highest, needed to use the system	
Product: Performance	- Process and memory capacity: high memory and processing power (handle large AR models, real-time 3D rendering and data retrieval) - Throughput: manage multiple sessions at the same time - Response time: instant recognition of vehicle parts and immediate display of instructions for smooth user experience	
Product: Efficiency	- Memory usage: optimize it to avoid crashes - Processor usage: balance resource consumption, high processing is required for rendering AR models	
Product: Reliability	- Highly reliable - Handle connection issues, camera errors and lags	
Organisation: Standards	- Follow company coding standards, security protocols and documentation procedures	
Organisation: Delivery	- Cloud-based or app store distribution - Regulaer updates must be delivered	
External: Legislation	- Privacy and data protection: comply with data privacy regulations like GDPR, ensuring user data is securly stored and protected. - Data retention: only necessary data - Safety standards: meet industry safety standards to ensure the instructions provided are accurate and safe	
External: Ethical	Designed for vehicle techniciand and trained	

	users. The use by untrained users could result in safety risks (warnings should be included)
Frequency	Frequent use
Channels to actors	- Interactive AR experiences with real-time instructions. - It may store data from static files and databases - Timeouts for internet or camera failure and retry options
OPEN ISSUES	- What happens if the models are outdated? - How to handle users with older devices? - How will customer support be integrated?
Due Date	Maybe link with market demand
...any other management information...	- Technicians may need training to use the app - Clearly state device requirements

More Systems Analysis

12. Open a new report document for the **Systems Modelling.**
Develop a second iteration in a separate word report consisting of 4 or 5 use cases.
Each use case requires a use case narrative describing the scenario analysis.
Each narrative requires to have at least 6 to 10 steps in the main flow.
Each use case should have 2 or 3 exception or alternative flows



Requirements Specification Matrix

13. From the requirements analysis identified with the use Case analysis identify key *functional* requirements.

    There should be 6 to 10 easily identifiable features or requirements that can be listed in this matrix.
    All the features (that will become use cases) identified previously need to be included, review section 7 for the additional features.

Req ID	Name of Req	Description	Priority	User Contact
1	Vehicle Identification	Identify the vehicle make, model and year	H	Technician
2	Technical Data Retrieval	Retrieve the necessary technical data for a specific vehicle	H	Technician
3	Task Selection	Select a task from a given list of tasks	M	Technician
4	3D Model and Instruction Generation	Generate 3d models and instructions for a certain task given a specif vehicle	H	Technician
5	Support Session Initiation	Initiate a support session if assistance is needed when performing a task	M	Technician, Support Specialist
6	Task Completion	Mark and log completed tasks	H	Technician
7	Report Generation	Generate and save a report to summarize a task that has been completed	M	Technicia m, Manageme nt
8	Vehicle Information Update	Update the database with information after tasks are completed	H	Technician, Database Manager

System Modeling

From the systems analysis and the requirements table, identify additional features and actors.
Normally this would be done through additonal Use Case models (diagrams and narratives).
At this stage the aim is just to list what would be needed to complete the model in a list by reviewing the requirements table and the systems analysis models.

14. List all/most of the potential *actors* in this system.

- Technician

- Vehicle Owner

- Remote Support Specialist

- Vehicles Database

15. List many more of the potential *use-cases* in this system.

- Maintenance History Access

- Real-time Monitoring

- Scheduled Maintenance Reminders

- Part Replacement Assistance

- Fluid Refill Assistance

- Safety Check Guidance

- Battery Diagnostics

- Diagnostic Reports

Validation and Verification of Requirements

16. Test Case Planning.

    Develop test cases for the main use cases, the abstracted **high priority** functional requirements, identified in Iteration 2 or 3 of the Use Case Analysis.

    Develop at least 1 test case for the **most important** non-functional requirements for the highest priority Use Cases.

    Use the test case template to create initial Use Acceptance Test plans that will permit users and developers to agree the system will have been developed as specified by the requirements

    Consider the test plan as a user guide or user manual for non-technical novice users of the system

Test Case Number: 1
Test Case Name: Verify Vehicle Identification
Related Use Case Name: Vehicle Identification Number: **2**
Purpose: **Confirm that the system correctly identifies the vehicle model when the technician points their device at the vehicle.**
Procedure Steps: 1. Tester launches the maintenance app on their device 2. Tester points the device at a vehicle within the app's detection range 3. System scans the vehicle and attempts to identify its model 4. System displays vehicle model 5. Tester verifies the displayed model matches the actual vehicle
Expected Results: **System correctly identifies and displays the vehicle's model.** **All information matches the real vehicle details.**

Test Case Number: 2

Test Case Name: Verify Technical Data Retrieval

Related Use Case
Name: Technical Data Retreival
Number: **3**

Purpose:
Confirm that the system correctly retrieves and displays relevant technical specifications for the identified vehicle.

Procedure Steps:

1. Tester initiates vehicle identification
2. After vehicle identification, system retrieves technical data for the identified vehicle
3. System displays technical data
4. Tester views displayed data fields
5. Tester verifies the technical data is complete and accurate

Expected Results:
System correctly retrieves and displays all relevant data.
Data accuracy matches stored vehicle database records.

Test Case Number: 3

Test Case Name: Verify Task Selection

Related Use Case
Name: Task Selection
Number: **4**

Purpose:
Confirm that the system allows the technician to select a task.

Procedure Steps:

1. Tester initiates task selection screen after the vehicle is identified and data is retrieved
2. System provides a list of available tasks
3. Tester verifies the list is correct and appropriate for the vehicle identified
4. Tester selects a task
5. System confirms task selection and presents previes of the task
6. Tester verifies the correct task is selected and the preview provided

Expected Results:
System displays the task selection emnu with relevant tasks.
The chosen task confirms with the selected one.
The preview corresponds to the selected task.

Test Case Number: 4

Test Case Name: Verify 3D Model and Instruction Generation

Related Use Case
Name: 3D Model and Instruction Generation
Number: **8**

Purpose:
Confirm that the system generates a 3D model and provides clear step-by-step instrutions for the selected task.

Procedure Steps:

1. Tester selects a task
2. System generates a 3D model of the vehicle with highlights on relevant components
3. System displays step-by-step instruction overlaying the 3D model
4. Tester follows the on-screen instructions to complete the task
5. Tester verifies that each step is clear and the 3D model corresponds to the instructions

Expected Results:
System generates an interactive 3D model.
Instructions are clear and interactive elements correspond accurately with vehicle components.

Test Case Number: 5

Test Case Name: Verify Support Session Initiation

Related Use Case
Name: Support Session Initiation
Number: **7**

Purpose:
Confirm that the system allows to initiate a support session when assistance is needed.

Procedure Steps:

1. Tester begins a task and encounter a step requiring assistance
2. Tester taps the “Support” button on the screen
3. System initiates a support session, connecting the technician with support specialist
4. Support specialist provided real-time assistance
5. Tester verifies the support session is responsive and effective

Expected Results:

Support sessions initiates within 10 seconds of the request.

Support specialists can see technician’s task context and provide assistance.

Test Case Number: 6

Test Case Name: Verify Task Completion

Related Use Case
Name: Task Completion
Number: **9**

Purpose:

Confirm that the system logs completed tasks and updates vehicle information.

Procedure Steps:

1. Tester completes a task following the step-by-step instructions
2. After completion, system prompts the tester to comfirm task completion
3. Tester confirms
4. System verifies completion
5. System logs the task as complete
6. System updates vehicle records
7. Tester checks logs and verifies the task completion is logged accurately and vehicle records are updated

Expected Results:

Task is logged as complete and vehicle records have been updated.

Task history shows the completed task with accurate timestamps.

Test Case Number: 7
Test Case Name: Verify Report Generation
Related Use Case Name: Report Generation Number: **6**
Purpose: **Confirm that the system generates a summary report for completed tasks.**
Procedure Steps: 1. Tester completes a task 2. System generates a report for the completed task 3. System displays the report 4. Tester reviews the report 5. System saves the report 6. Tester checks the report has been saved and is accesible
Expected Results: **The report is generated with correct and accurate information.** **The report is saved and can be accessed.**

Non-functional

Test Case Number: 8
Test Case Name: Verify Response Time for 3D Model Generation
Related Non-Functional Requirement 3D model generation response time should be under 5 seconds
Purpose: **Confirm that the system meets the response time requirement for generating 3D models.**
Procedure Steps: 1. Tester selects a task requiring 3D models 2. System initiates 3D model generation 3. Tester times the time taken for the model to displays 4. Tester repeats the test 10 time for accuracy
Expected Results: **The system generates the 3D model within 5 seconds.**

Test Case Number: 9
Test Case Name: Verify Processor Usage During Real-Time Intructions
Related Non-Functional Requirement Processor usage should not exceed 20% CPU load while providing real-time interactive instructions
Purpose: **Confirm processor usage remains within acceptable limits to avoid lag or delays during task execution.**
Procedure Steps: 1. Tester selects a task with interactive real-time instructions 2. Tester begins the task following the instructions 3. Tester monitors CPU usage using diagnostic tools 4. Tester record the peak CPU load
Expected Results: **CPU load remains at or below 20% throughout the real-time instruction phase.**

Test Case Number: 10
Test Case Name: Verify Responsiveness Under Concurrent Task Completion
Related Non-Functional Requirement The system should support up to 50 concurrent task completion log entries
Purpose: **Confirm that the system can handle multiple users logging completed tasks simultaneously without performance loss.**
Procedure Steps: 1. 50 simulated users complete tasks and log their completion concurrently 2. Tester monitors system response times for each logged entry 3. Tester evaluates the system performance under concurrent load
Expected Results: **Task completion logs are recorded within 5 seconds for each user entry.** **System response time remains within acceptable limits without delays.**

Completing the Feasibility Study

Review Previous Versions

17. Before you complete the final submission of a feasibility report, review and update the non-functional requirements, if necessary.

18. Review and, if necessary, Update the requirements Specification Matrix, section 13, and identify the high level (abstract) core system features.

Update Requirement Specification (RS) & set of Use-Case Diagrams (UCD) with narratives

19. Consider the Use case Model to ensure that core/key functionality has been addressed in the analysis and modelling process.

    Add comments here on what might need to be done to address any omissions or corrections.

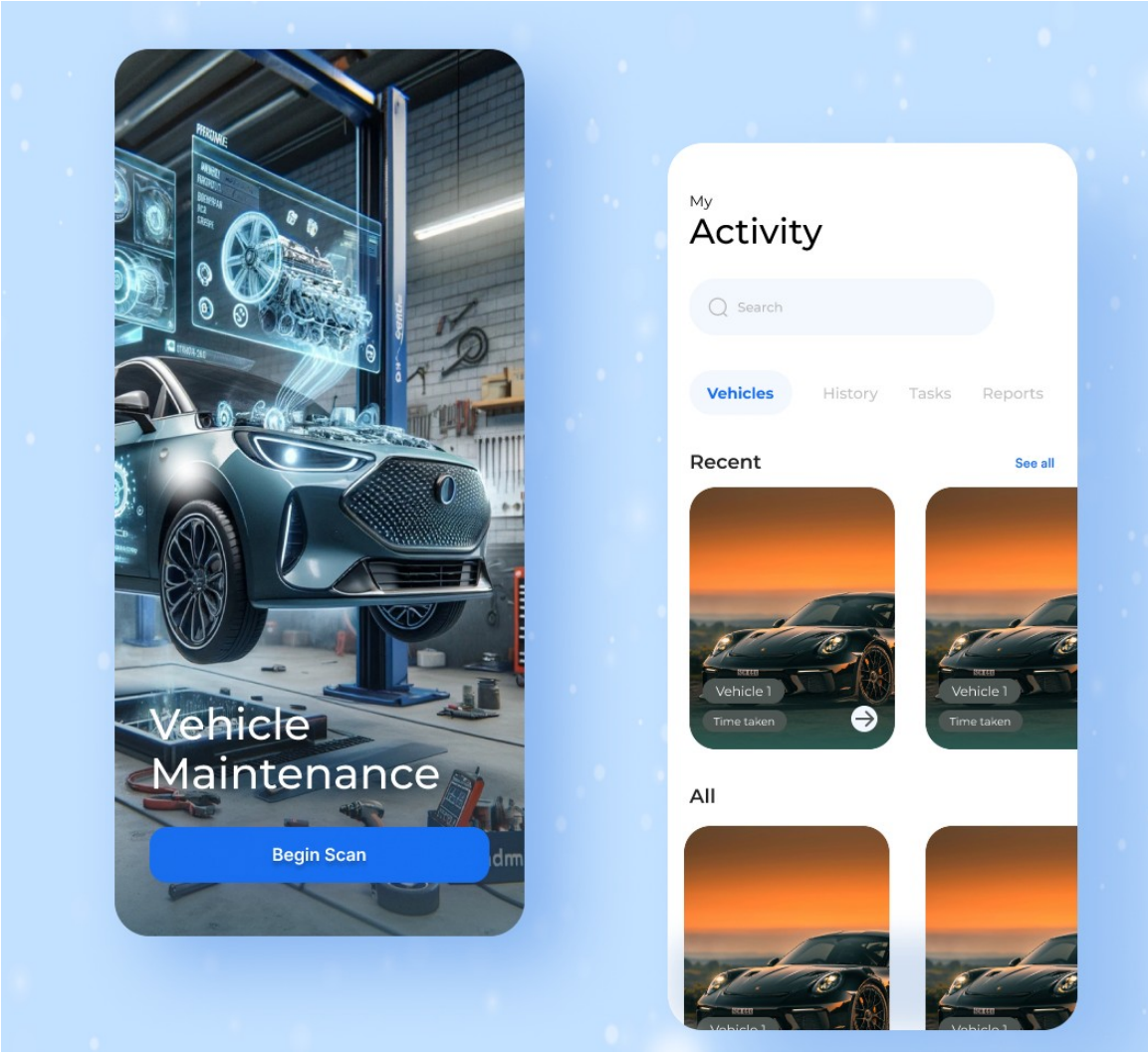
    a. Do any of your use-cases need to be broken down further i.e., is there is too much functionality in one use-case? No
    b. Update the potential Use Case list in section 15 as necessary.
    c. Update the Requirement Specification table with additional requirements as necessary.

Prototype

20. Create an initial prototype of the proposed system.

    Such as: sketch the home page/starting page of the system. Then take a photo of it and insert the photo into the document.

    Alternatively use a drawing tool to design the prototype view of the home page of the app.



Functional & Non-Functional Test-Cases

21. Write 3 additional test-cases (using the test-case template) for each of three abstracted **high priority** *functional* requirements (one test-case per requirement/use case).

Question 16

22. Write 2 additional test-cases (using the test-case template) for each of the two **most important** *non-functional* requirements (one test-case per requirement).

Question 16