



MSc Graduation Thesis
Delft, July 2025

The Portable Backrest,

A Integrated Storage **Solution** For Armoured Infantry Vehicles

A Project By Isabel Segers

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A Integrated Storage **Solution**
For Armoured Infantry Vehicles

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Executive Summary

Assignment

As the project progressed, the assignment was further defined and refined, resulting in the following updated version:

"Design a **solution** to develop an **integrated gear storage system** in CV90 vehicles for each individual infantry soldier, specifically for **essential personal equipment** items (Tweede Lijn)."

Analysis

To address the assignment, the following three topics were analyzed:



Scenario



Storage



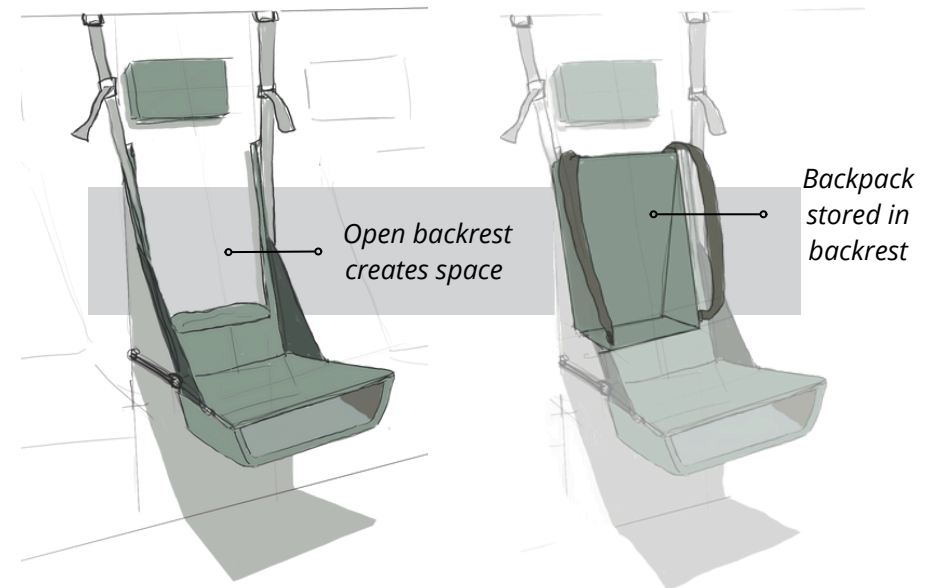
Equipment

Challenges During the Project

- **Limited vehicle space:** Minimal room for safe and secure storage.
- **Complex gear configuration:** Varying action needs make it difficult to define a fixed equipment setup.

Final Design

The final design is a portable backrest with a resized backpack holding essential personal gear for field use. A small space between the backrest and the vehicle wall allows the backpack to lean against the side and function as a stable backrest. Upon exiting, the backpack can be taken along or left in place, depending on the action.



Unique Selling Points



Secure Storage



Improved Entering and Exiting



Time Efficiency



Reduced Weight



Increased Mobility



Reduced Risk of Snagging

Further Development

The following points outline areas for further development of the concept:

- Conduct realistic testing before scaling up
- Compare portable backrest with current use
- Further testing on putting on the backpack
- Integrate the under-seat pouch
- Integration In Other Armoured Infantry Vehicles
- Integrate seatbelt into the portable backrest



Infantry Soldier Sitting Inside the CV90 With Portable Backrest

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Introduction

This report is part of my five-month graduation project at TU Delft within the Integrated Product Design program. The project focuses on the lack of space in armoured infantry vehicles, with a focus on the Combat Vehicle 90 (CV90). Due to the lack of storage space, equipment is often placed in unsuitable locations, which poses a risk to the occupants. This project investigates where space can be found, which items need to be stored safely and how the storage can be used optimally in this specific context. Despite the limited space, the project proposes an innovative solution that makes better use of currently underutilised space, while also improving entry and exit efficiency.



Figure 1: Infantry Soldier Entering the CV90

Project Partners



Graduation Project

This six-month graduation project was made possible through the collaboration between TU Delft and the Ministry of Defence's department COMMIT. Their support enabled access to relevant expertise, resources, and practical context. TU Delft provided academic supervision and methodological guidance, while COMMIT facilitated insights into real-world defence challenges and ensured the project aligned with operational needs. Their contributions were essential to the project's development.

TU Delft, Industrial Design

The knowledge that TU Delft has provided me with throughout my Industrial Design Engineering degree has enabled me to approach and tackle this project in this way. Furthermore, my supervisor Elmer van Grondelle and mentor Gianni Orsini provided helpful and critical feedback throughout the project that helped me get the most out of this learning experience.

Ministry of Defence's, COMMIT

Ministry of Defence's made it possible for me to carry out this project. My main supervisor, Ilse Kroesen, guided me through the project with great enthusiasm. Redmer Prins and Gerben van Huissteden provided me with the necessary information. Gerben also helped me to get in touch with the users and vehicles. Mark van Drunen showed me the way within the COMMIT department.

Glossary

Infantry soldier = A soldier who operates on foot.

Senior user = A military service member, either currently active or formerly in service, who has operated the vehicle extensively during missions and has gained deep practical knowledge over time.

Eerste and Tweede Lijn = Dutch terms used by the Ministry of Defence to refer to refer to specific group of equipment used in different circumstances.

Action = A military operation in which infantry soldiers operate dismounted from their vehicle.

*These grey bars with the eye icon highlight relevant **insights** related to the respective section.*





Problem

Soldiers operating in the CV90 do not have sufficient safe storage space for their equipment. As a result, gear is stored in unsafe locations, such as loose in the cabin or beneath the seat within the crumple zone. This poses a direct danger to occupants during abrupt movements or crashes.

The underlying cause is the vehicle's age. Designed in the late 1980s, the CV90's interior layout has changed little, while modern operations demand bulkier body armour, advanced optics, drone controllers and other mission-essential equipment. These items simply outgrow the stowage compartments engineered for an earlier generation of soldiers. Because the hull dimensions are fixed and no dedicated retrofit has been fielded, soldiers are forced to improvise, placing equipment wherever space is available.

Current storing place

Figure 2: Infantry Soldiers Sitting Inside the CV90

Context

CV90

The Combat Vehicle 90 (CV90) was developed in the 1980s by Hägglunds (now BAE Systems Hägglunds) for the Swedish Armed Forces. The aim was to design a modern infantry fighting vehicle that could operate effectively in the harsh Scandinavian environment and under extreme weather conditions (see Figure 1). Key requirements included high mobility, robust armour protection, effective firepower and the integration of digital systems. The vehicle had to be able to perform reliably in densely forested and snow-covered areas (BAE Systems, n.d.).

The Dutch variant of the CV90, the CV9035NL, introduced into Royal Netherlands Army service in 2008, is now employed in a far broader and more complex operational context. The platform has matured into a flexible combat system tailored to modern warfare: no longer limited to traditional battlefield roles, it is also deployed in hybrid conflicts where threats emerge from irregular tactics such as ambushes, drones and improvised explosive devices. In these environments, the CV90 has proven highly effective in both urban combat and open terrain (Army Technology, n.d.).

In order to operate successfully in such demanding conditions, the CV90 requires a robust and durable design. The environments in which these vehicles operate, as unpaved roads, rocky ground and damaged urban infrastructure, generate intense vibrations, shocks and structural stresses. Therefore, all internal components must be securely mounted inside the vehicle to keep the soldiers inside safe.



Figure 3, CV90 Operation in Extreme Weather Conditions
Screenshot taken from Gagadget (Kratiuk, 2025).



Figure 4, Kromhout Kazerne, Utrecht

Command for Materiel and IT

Within the Dutch armed forces, the Command for Materiel and IT (COMMIT) plays a key role in ensuring the operational availability of systems such as the CV90. COMMIT is responsible for the procurement, maintenance, and innovation of defence materiel and digital infrastructure. This means that the command ensures vehicles like the CV90 remain operational and are adapted to the needs of modern warfare. COMMIT facilitates developments in IT systems, weapon integration, and vehicle maintenance, directly contributing to the readiness, reliability, and deployability of combat vehicles (Ministry of Defence, n.d.-a).

1

Project

This chapter explains why this project was initiated, what the goal of the project is, and how the project was approached and which design method was used. Finally, it explains which stakeholders are involved in this project.

1.1 Assignment and Refinement

1.2 Methodology

1.3 Project Approach

1.4 Stakeholders

1.1 Assignment and Refinement

On 17 March 2025, the following assignment was agreed for this project:

"Design a prototype to improve the integrated gear storage system for military personnel in or around the Boxer and CV90 vehicles for a specific type of mission/operation."

This assignment was then refined to achieve the best possible final solution. Since a focused approach is crucial when designing for vehicles with limited space, the CV90 was selected as the main focus. This vehicle provides less storage space than the Boxer and therefore presents a greater design challenge. By concentrating on the CV90, the issue can be addressed more specifically, resulting in a solution that is not only more adapted to the current conditions but also easier to apply to the Boxer. See Appendix A and B for more information.

The updated assignment is as follows:

"Design a **solution** to develop an **integrated gear storage system** in CV90 vehicles for each individual infantry soldier, specifically for **essential personal equipment** items (Tweede Lijn)."

The word 'integrated' here means that the design must fit both within the vehicle and align with the soldier's full equipment.

1.2 Methodology

The Double Diamond method was used as a guiding framework during this project. Its four phases, in which divergence and convergence alternate, helped maintain an overview throughout the iterative design process. Although design is not a linear process, the model provided a clear structure for continuous reflection, adjustment and positioning of the approach within the project. In addition, the book *Product Design: Structure* by N. F. M. Roozenburg and J. Eekels, as well as the *Delft Design Guide*, were used to inform the application of more specific methods within this project.



Figure 5, Product Design



Figure 6, Delft Design Guide

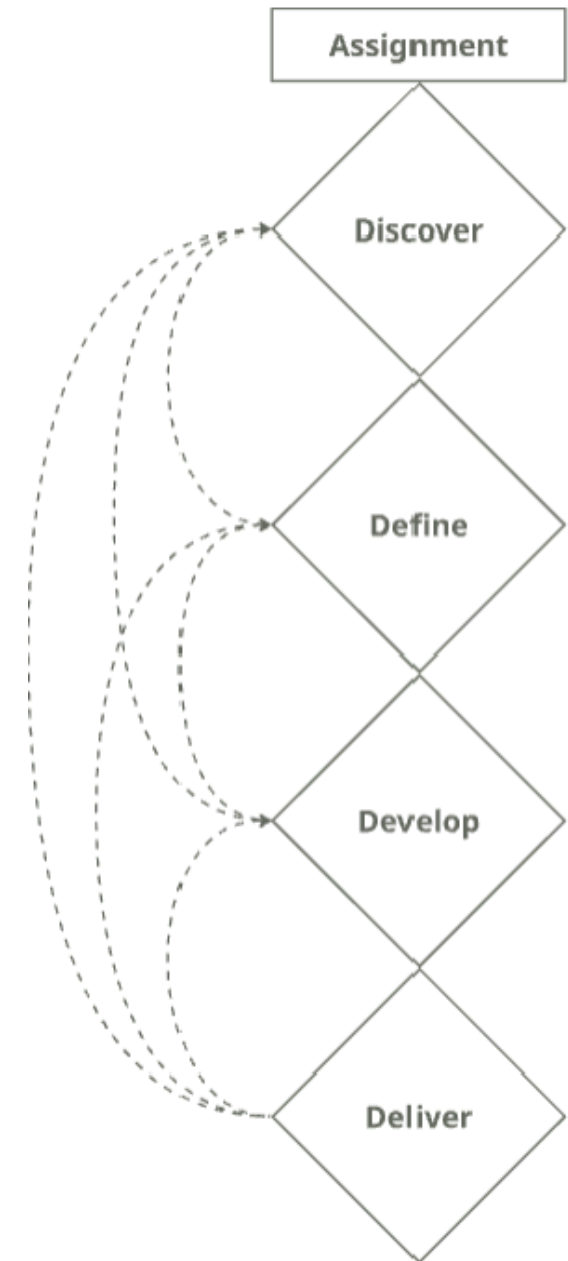


Figure 7, Double Diamond Method

1.3 Project Approach

This project explored three main topics: the layout and functioning of the vehicle, soldiers' equipment, and the operational context. Alongside practical observations, literature was consulted to validate specific aspects. Based on these insights, ideas were sketched, a clear direction was chosen, and design criteria were defined. Based on the identified possibilities, a concept was developed. This was followed by a program of requirements and wishes, validation through scale models and prototypes, and ultimately the delivery of a functional scale prototype.

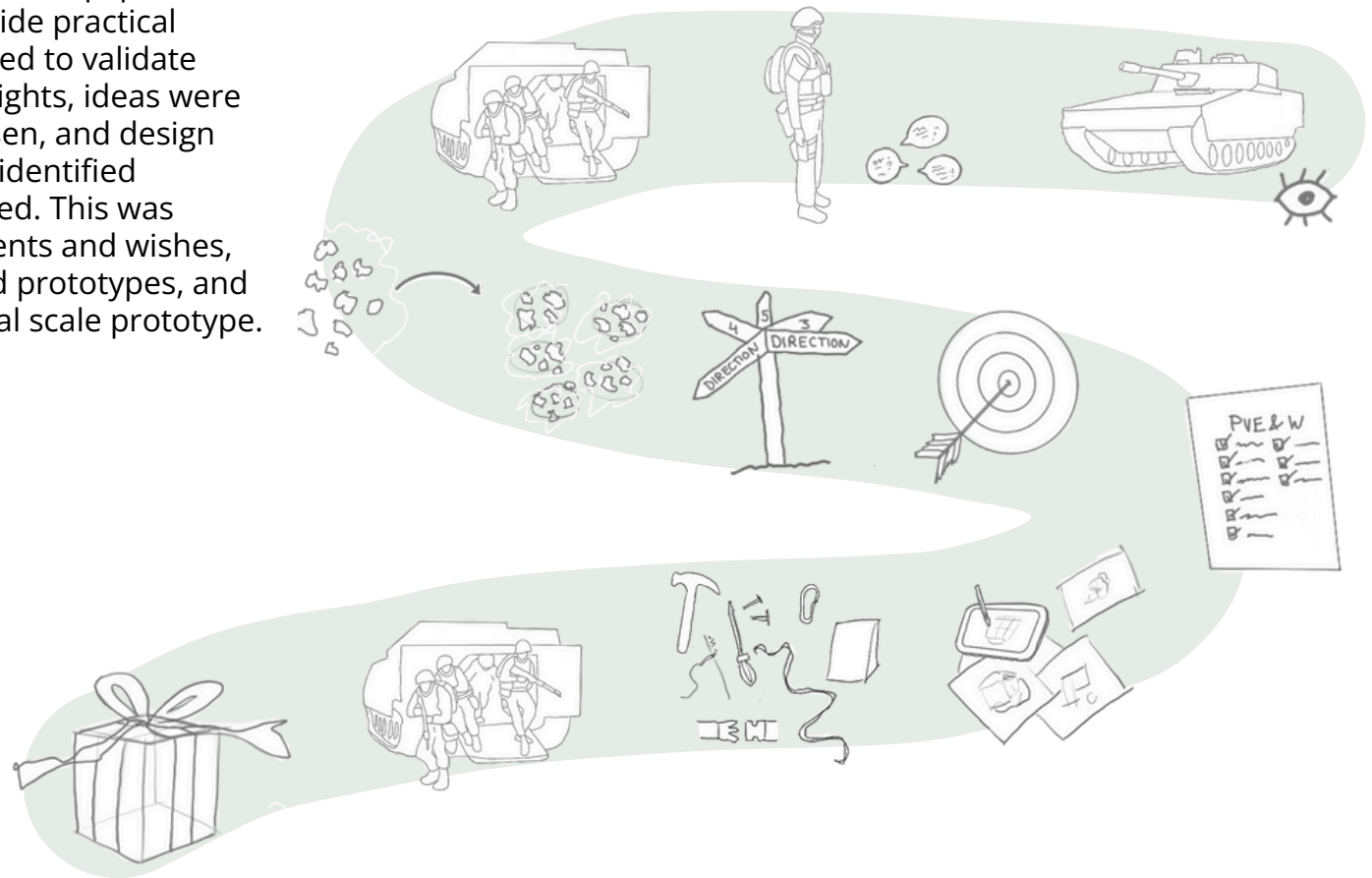


Figure 8, Visual Project Approach

1.4 Stakeholders

The core stakeholders in this project include the Ministry of Defence's COMMIT department. The project lead, Ilse Kroesen, and Redmer Prins, who provides technical support, are involved in the project directly and offer guidance. The project is being carried out by a team from TU Delft consisting of supervisor Elmer van Grondelle, coach Gianni Orsini and a master's student myself, who are responsible for executing, supervising and evaluating the project.

The primary end users are the infantry soldiers of the 43 Mechanised Brigade. Suppliers and manufacturers support the project by providing materials, and the logistics unit ensures integration into operational processes. Safety officers monitor compliance with safety regulations and warehouse managers are involved in the daily use and maintenance of the storage solution.

Indirect stakeholders include the Ministry of Defence, military certification bodies and infantry soldiers of the 13 Lichte Brigade, who may use a similar solution in future.

Stakeholder Map

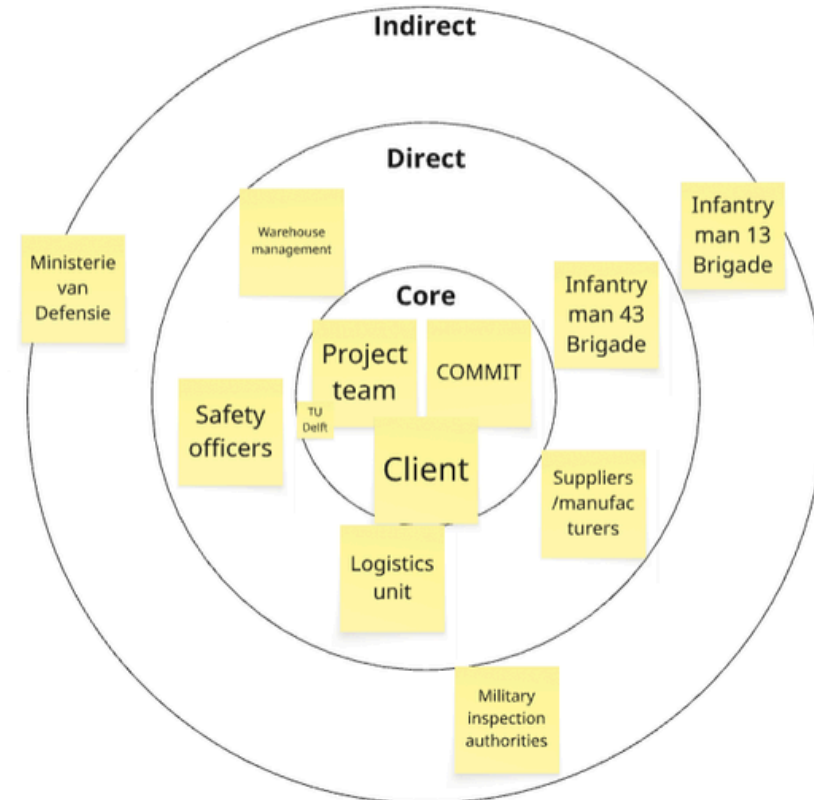


Figure 9, Stakeholder Map

2

Discover

This chapter outlines the current context in which the user operates, to better understand the situation and related challenges. It examines the gear that must be carried and the available secure storage space within the vehicle. All gathered information has been translated into drivers, which are organised into categories to form a structured foundation for the *Define* phase.

2.1 Scenario

2.2 Storage Inside the CV90

2.3 Equipment and Gear

2.4 Key Takeaways and Drivers



Figure 10, Discussing With Infantry Soldiers, Havelte

2.1 Scenario

This subchapter describes the vehicle involved, the users engaged in the operation, what a typical operational action may entail, and the specific scenario that forms the focus of this project.

Vehicle: CV90

This project focuses on the armoured infantry vehicle, the CV90. Operated by the 43 Gemechaniseerde Brigade, it is used to transport infantry safely from one location to another during military operations. As a tracked vehicle, the CV90 is powerful and capable of maneuvering through rough and challenging terrain.

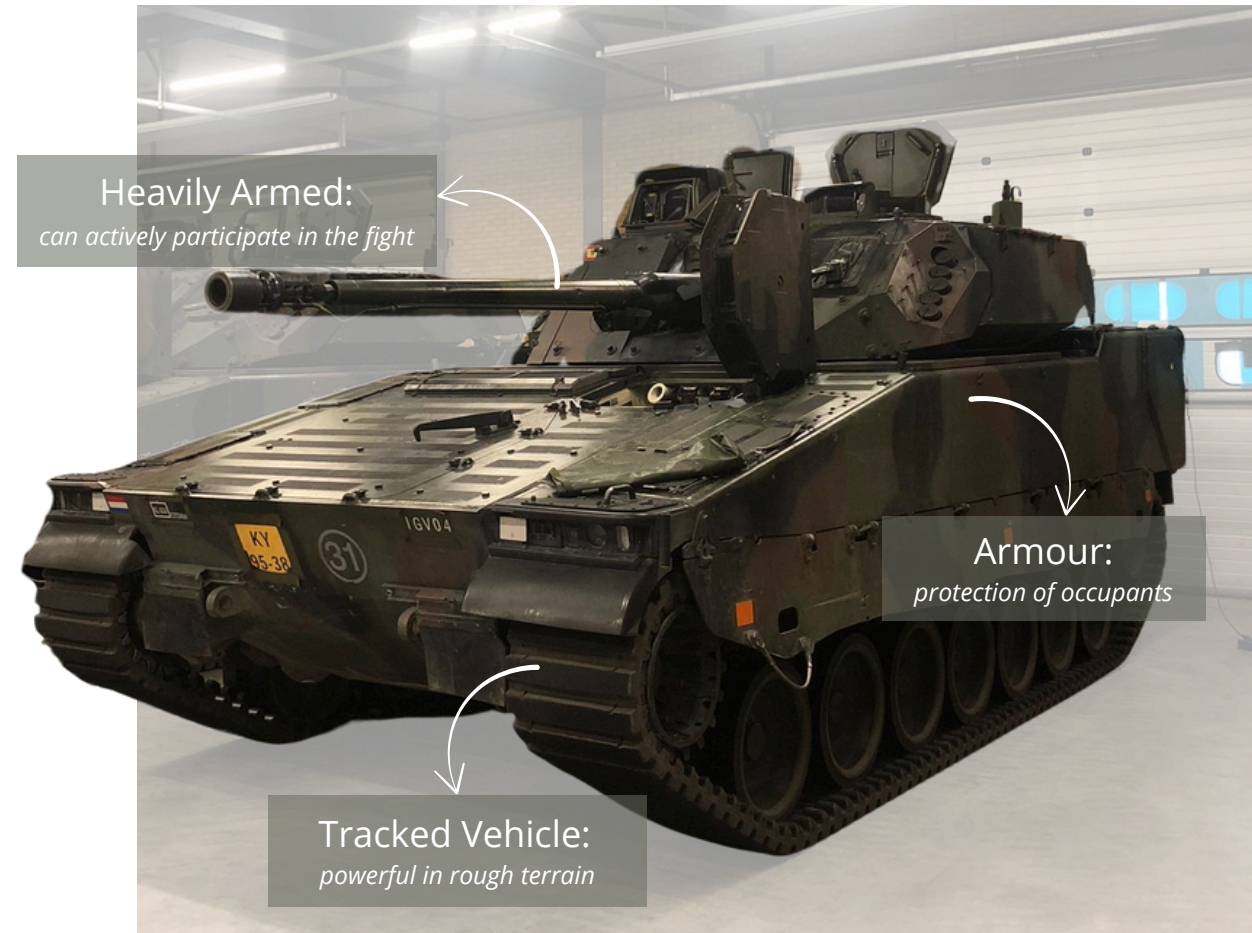


Figure 11, CV90

Vehicle Occupants

The vehicle accommodates ten people: the driver, gunner, group commander, and seven infantry soldiers. The interior is divided into a front and back compartment, separated by a bulkhead. See the Figure below for a schematic representation. Additionally, there is space along the sides of the vehicle where the tracks are located.

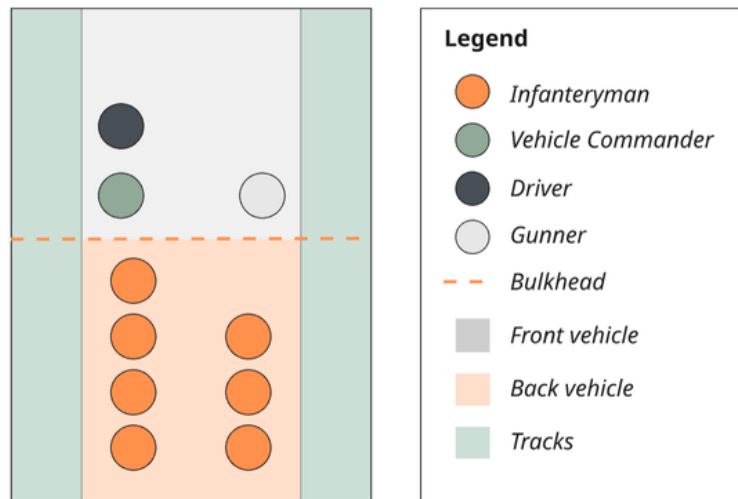


Figure 12, Schematic Representation CV90 - Top View

This project focuses on the back section of the vehicle, where seven infantry soldiers are seated (see Figure X). Among them is one group commander, who leads the group and gives instructions. The infantry soldiers sit facing each other in a confined space on fixed seats.

According to a senior user of the CV90, depending on the operation, personnel may have to remain inside the vehicle for up to eight hours without a break (personal communication, February 2025).



Figure 13, In the Back of the CV90

To better understand the user, a persona was developed focusing on new recruits, with attention to their skills and personality (see Appendix C). Since 88.4% of professional soldiers in the Royal Netherlands Army are male (Ministry of Defence, 2025-e), the design takes into account the average physical dimensions and ergonomics of young men. Furthermore, as soldiers can enter service with lower secondary education (vmbo) (Ministry of Defence, n.d.-b), the solution must be intuitive and easy to use. Given that operations often take place under high pressure and in stressful environments, it is essential that the system minimises cognitive load and supports quick and easy interaction.

Operational Deployment and Focus

During training exercises and deployments, infantry soldiers undertake missions consisting of various actions. Equipment of both the Eerste Lijn and Tweede Lijn is always brought in the vehicle. Eerste lijn gear is always worn on the body, while Tweede Lijn equipment is taken into the field only when required by the action. The specific items classified as gear of the eerste and Tweede Lijn are detailed in subsection 2.3, *Equipment and Gear*.

According to a senior user of the Boxer, the choice of which equipment to bring depends on the threat level and the duration of the mission. A higher threat level requires carrying as little gear as possible on the body to allow infantry to remain mobile and respond quickly in the field, as during offensive action. In contrast, longer actions require more equipment to ensure that tasks can be completed independently without experiencing logistical shortages. Examples of these actions are a combat patrol or social patrol. (personal communication, March 2025).



Figure 14, Examples of Actions

Offensive actions involve dismounting without taking Tweede Lijn equipment from the vehicle. During combat and social patrols, however, infantry take their Tweede Lijn gear into the field upon dismounting.

Whether Tweede Lijn equipment is brought into the field depends on the type of action.

Action-Equipment Overview

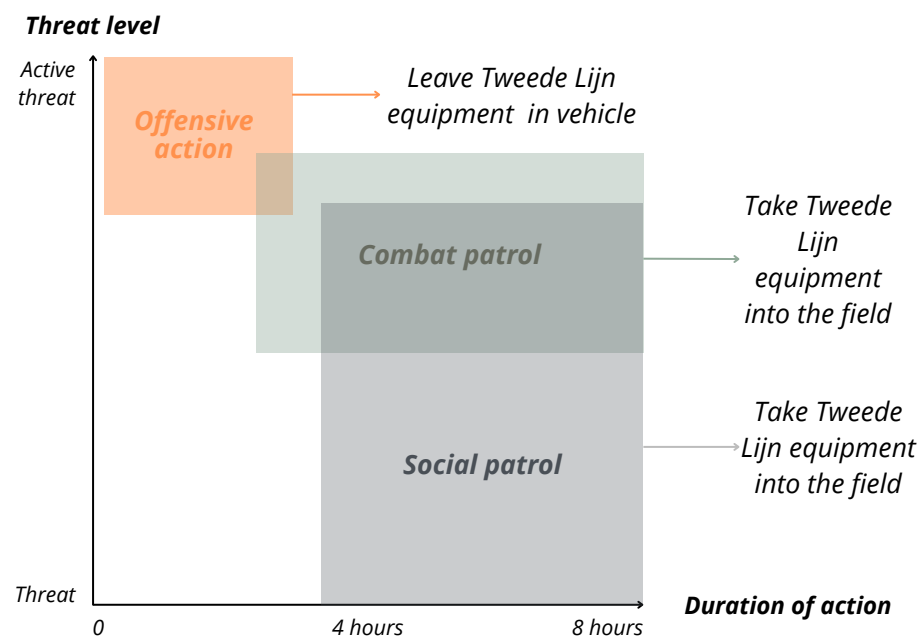


Figure 15, Action-Equipment Overview

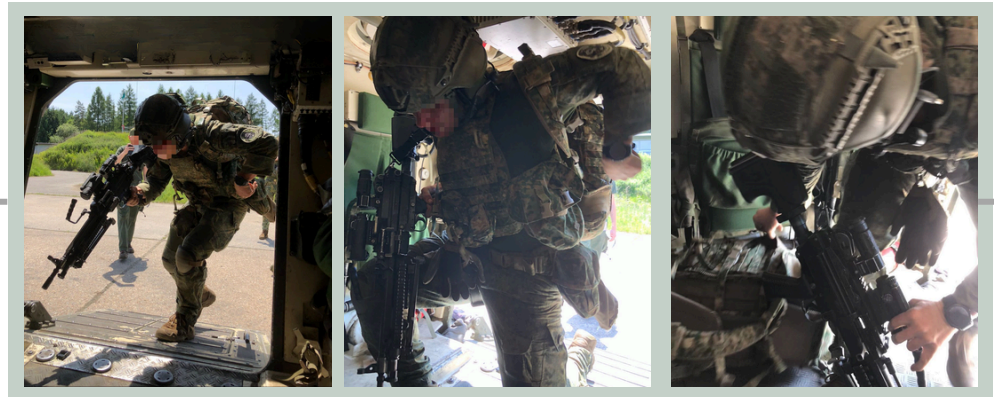
Current Scenario: Enter and Exit the CV90

In the current situation regarding vehicle entry and exit, the process is as shown in.

The current backpack in use is a 37L model, intended for storing equipment that must be carried during specific field operations. More details on this can be found later in Chapter 2.3 Equipment and Gear.

To provide an indication of the duration: both entering and exiting the vehicle individually take only a few seconds.

Entering



Enters vehicle with backpack

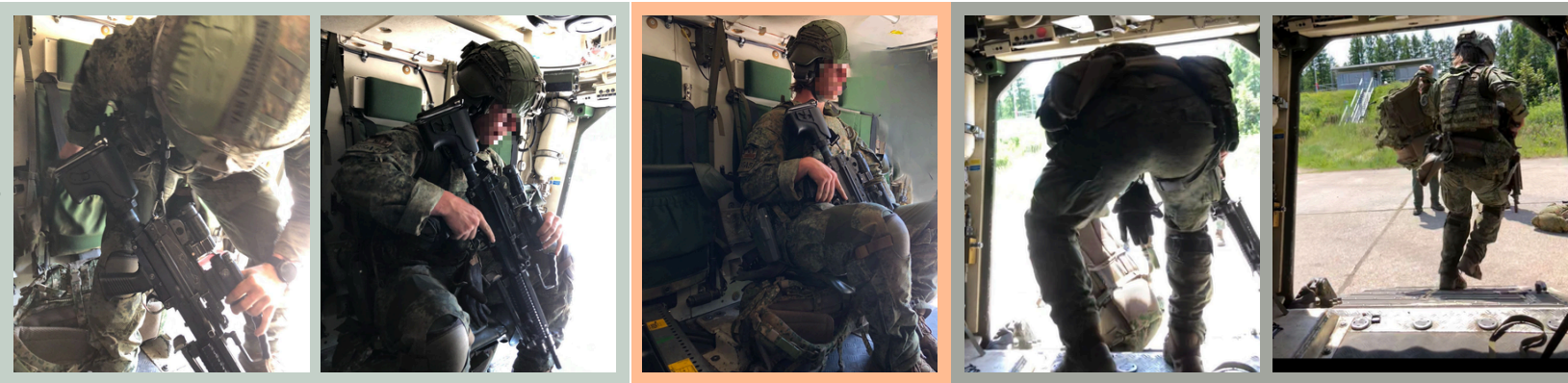
Takes off the backpack

Slides backpack under seat

Entering

Sitting

Exiting



Unfolds seat

Takes seat

Sits down



Exits vehicle with backpack

Swings backpack over shoulder

Painpoints Current Scenario

On April 23, 2025, a simulated exercise was held at the 43 Gemechaniseerde Brigade in Havelte to observe this process in practice. During the simulation, key observations were made, and the following pain points were identified. These pain points indicate that putting on and taking off the 37L backpack is especially problematic.

Exiting the CV90

Situation	Observation	Painpoint
	Backpack is carried in hand	One hand is occupied, making it unavailable for other tasks
	Backpack is put on in the field	Time-consuming and requires full attention, diverting infantry from other tasks

Entering the CV90





Situation	Observation	Painpoint
	Backpack gets caught on the top of the vehicle	Hinders the infantryman from entering the vehicle
	Backpack is thrown into the vehicle	Gear can be damaged, wear out faster
	Backpack gets caught on the infantryman's arm	Hinders the infantryman from boarding the vehicle
	Equipment is stored under the seat	Unsafe place to store equipment; it can pose serious risks for the occupants

Figure 17, Enter and Exit Scenario - Current Situation, Havelte

Key Takeaways 2.1

1. The CV90 operates in rough terrain (shocks, vibrations, mud, etc.).
2. Space inside the CV90 is limited; soldiers can barely turn or rotate their bodies.
3. Bags are individually placed around each seat, allowing soldiers to quickly grab them when exiting the vehicle.
4. Putting on and taking off the 37L backpacks is a pain point during vehicle entry and exit.
5. The vehicle is used for extended periods without breaks (up to 8 hours), under heavy operational load.
6. The end users are young, often under pressure, and frequently less experienced.
7. Items stored in the 37L backpack must be accessible within 2 minutes, highlighting the need for quick and easy access during operations.

2.2 Storage Inside the CV90

This subchapter highlights the key aspects of the vehicle to gain a better understanding of the available safe storage space and its limitations. These limitations form the boundaries for design decisions within the project.

Importance of Safe Storage

For the safety of infantry soldiers, it is essential that all equipment is properly stored. Loose items can be thrown around the vehicle during abrupt maneuvers or a crash, potentially causing serious injuries or even fatal wounds.

In addition, a limitation of the CV90 is the crumple zone: this is a buffer space of at least 12 cm from the floor, designed to absorb the force of mine explosions beneath the vehicle. This zone prevents the floor from directly impacting the occupants during an explosion. It is therefore crucial that this space remains clear, according to R. Prins (personal communication, 2025).

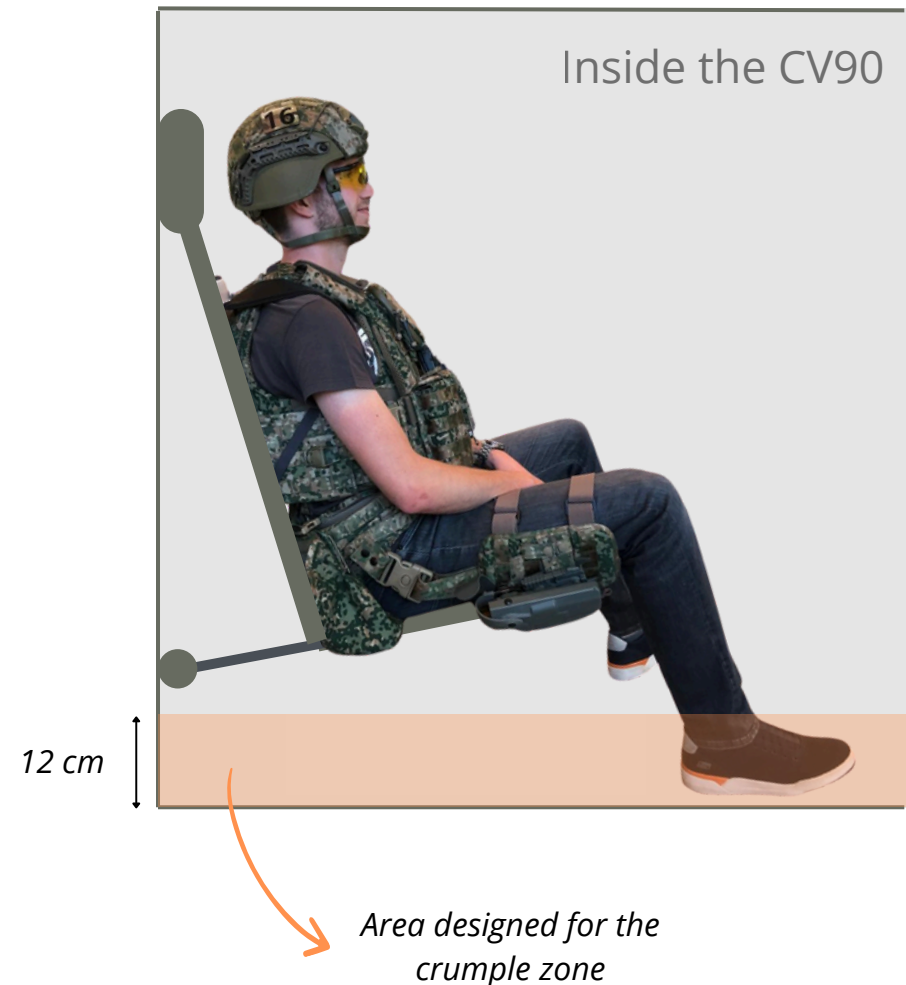


Figure 18, Crumple Zone

Current Storage Space

According to a senior user of the CV90, the storage space at the back of the CV90 is limited. Inside the vehicle, there are a limited number of storage compartments in the rear section, where equipment and materials can currently be stored safely (personal communication, February 2025). However, this storage space is too small to accommodate the 37L backpack.

Figure 19 shows a simplified schematic representation of the back of the vehicle, indicating the current storage locations. The image illustrates where certain materials are generally stored, although this may vary per CV90 vehicle, as each operation with the vehicle differs, according to conversations with users.

Insights From Analysing the CV90:

- The storage pouch located beneath the seat is only partially utilised, resulting in unused available space.
- The storage pouch integrated into the backrest of the seat is a large compartment intended for storing items;
- The pouch behind the seat is spacious, but a seated soldier cannot reach its contents.

Schematic Representation Storage Space

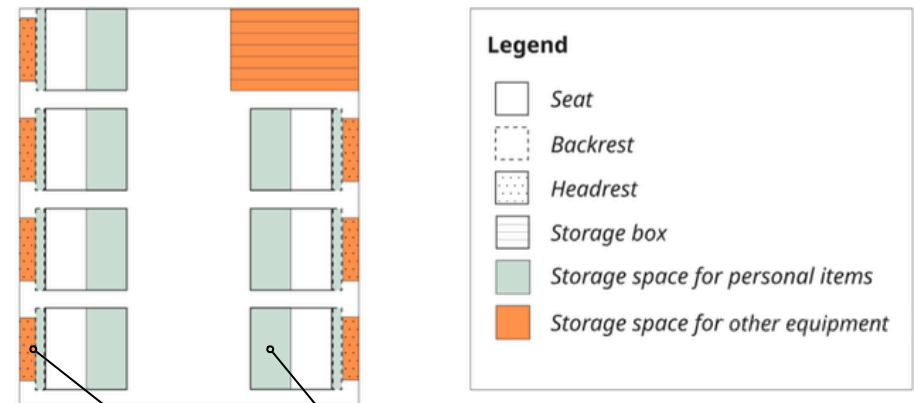


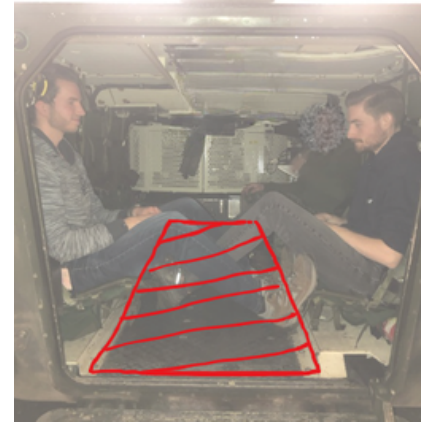
Figure 19, Current Storage Space

Potential Storage Locations

As part of this project, an vehicle space analysis was conducted to identify feasible storage options within the rear of the vehicle. This exploration was necessary due to the vehicle's spatial constraints, which complicate the safe stowage of equipment. Each location has been evaluated for its safety and usability under operational conditions.

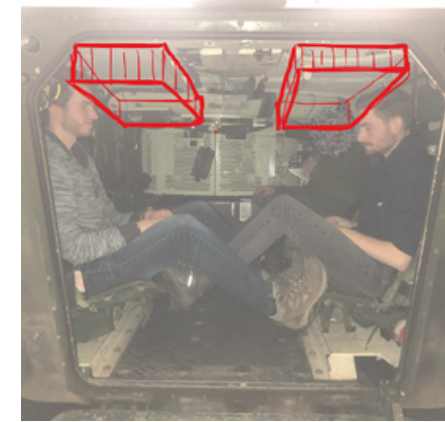
In this section, each option is explained along with the reasoning for selecting or rejecting it. Red indicates a rejected option; green indicates a potential storage option location.

Floor/Gangway



Infantry soldiers must not be obstructed when exiting the vehicle for safety reasons.

In Front of Heads



Infantry soldiers must not be obstructed when exiting the vehicle for safety reasons.

Beneath Seat



This space is already used for personal equipment storage.

Roof Center



Infrastructure is present at this location place.

Center



Infantry soldiers must not be obstructed when exiting the vehicle for safety reasons.

On the Floor Under the Chair



A space of 12 cm from the floor must be maintained for the crumple zone.

In front of Bulkhead



Infantry soldiers must not be obstructed when exiting the vehicle for safety reasons and not all infantrymen can access their gear independently.

Above Heads



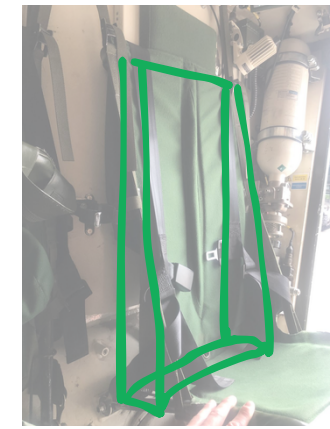
There must be sufficient space above the head to minimise the risk of neck injury in the event of sudden movement.

Between Heads



Infrastructure is present at this location place.

Behind Backrest



This space will be available when the seat is unfolded.

Figure 20, Exploring Potential Storage Locations



A storage system outside the vehicle is not desirable, as infantry personnel want to keep the items stored in the 37L backpack within reach.

The space analysis identified two locations as both safe and potentially suitable for storage (zie Figuur X):

- Behind the seat backrest
- Beneath the seat base

These two options will be further developed and explored.

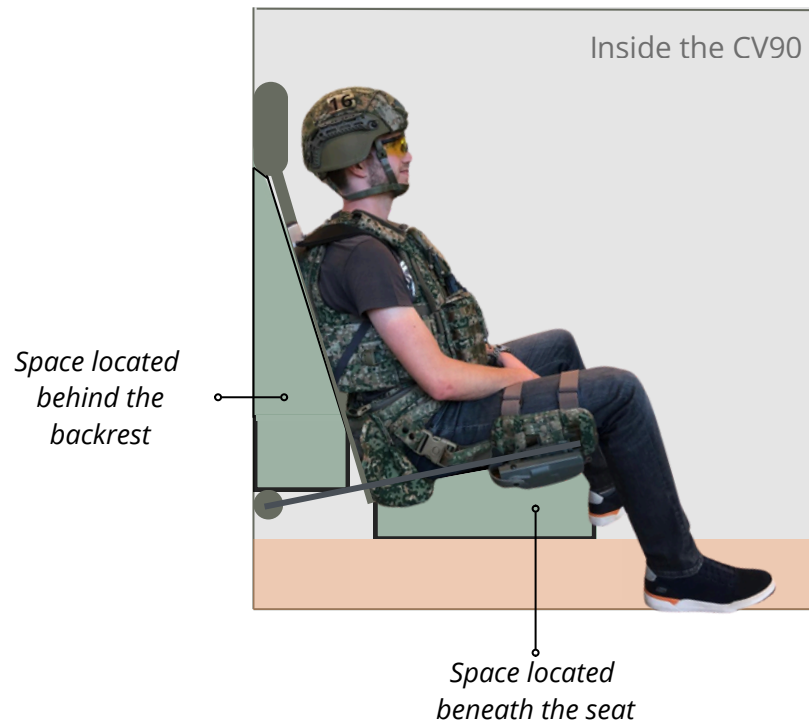


Figure 21, Potential Space Locations

Seat Dimensions

In the Figure below, the values shown in **green** are measurements taken directly from the CV90. The image itself was provided by the client. The 12 cm (120 mm) crumple zone should be kept in mind.

Seat Dimensions CV90 [mm]

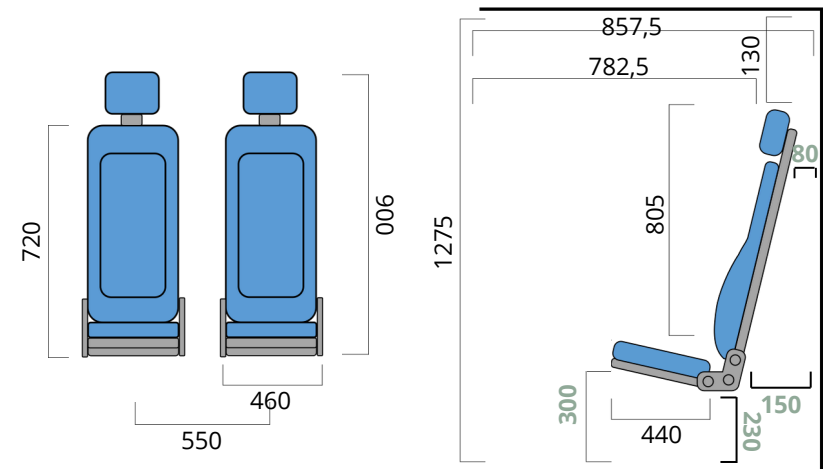


Figure 22, Seat Dimensions CV90

Key Takeaways 2.2

- 1.** The space behind the seat is currently unused when the seat is unfolded.
- 2.** The storage pouch beneath the seat is currently only partially utilised.
- 3.** The storage compartment in the seat backrest is spacious but difficult to access from the seated position.
- 4.** Loose items pose a serious risk during sudden movements or a crash.
- 5.** The 12 cm crumple zone from the floor must remain clear to absorb the impact of explosions.

2.3 Equipment and Gear

This subchapter highlights the importance of gear, what equipment soldiers carry, the types of items involved, and the distinction between items based on their level of essentiality.

Importance of Gear

In military operations, it is essential that all personal equipment and basic necessities are transported within the vehicle. This includes individual items such as protective clothing and communication devices, as well as mission-specific tools for field activities, maintenance, and survival. Additionally, sufficient provisions, such as water, food, and ammunition, must be available to support maximum 48 hours of autonomous deployment. These requirements place significant pressure on the limited storage capacity of compact vehicles like the CV90.

Given the unpredictable nature of missions, including extended duration or sudden tactical shifts, military personnel tend to bring more equipment than strictly necessary. This illustrates that if space is available, additional equipment will be carried.

An additional layer of complexity arises from the fact that not all items serve purely functional purposes. As emphasised by R. Stuivenwold, a representative of the Expertise Centre for Military and Equipment, some objects carry symbolic or emotional significance, contributing to identity, tradition, or unit cohesion. These elements are crucial for psychological resilience in high-stress environments. Therefore, leaving items behind is rarely an option from the soldier's perspective (personal communication, 2025).

Also research shows that these personal or symbolic objects, can strengthen identity, cohesion, and psychological resilience in military contexts. These items support mental stability under stress and are therefore considered essential by many soldiers. As a result, items cannot simply be omitted from storage considerations (Greene et al., 2024; Meredith et al., 2011).

Focus on Current Equipment

The 37-liter backpack is an essential part of the Improved Operational Soldier System (VOSS) of the Dutch armed forces. The first official issue took place on January 28, 2021 (Joint Forces, 2021). Each of the seven infantry soldiers seated in the rear compartment of the CV90 is issued an individual 37-liter backpack. The backpack contains multiple compartments, including space for a CamelBak hydration system. At the top, there is an opening that allows the drinking tube to be used easily while wearing the backpack. The design also allows integration of the CamelBak from the equipment of the Eerste Lijn.

Optional Daypacks of 10 to 15 liters can be attached to both sides of the backpack using zippers, allowing the storage capacity to be expanded as needed. Additionally, the bag is equipped with MOLLE-webbing, a durable woven attachment system that allows soldiers to add extra pouches or equipment based on personal preference and mission requirements.



The Combat Vest prevents direct contact between the backpack and the skin, acting as a comfortable buffer that absorbs friction and rubbing.



Figure 23, Explanation Current Used Equipment

Configuration Options

The configuration of equipment carried by infantry soldiers is inherently complex and shows significant variation in practice. Firsthand analysis and systematic mapping of current practices reveal that there is no universal or standard loadout. What a soldier carries depends on a combination of interrelated factors: location, duration and timing, type of operation, and individual role. These variables are often fluid and can shift rapidly in dynamic environments.

This complexity highlights the need for modular systems that can adapt to changing operational requirements and support a wide range of gear configurations.

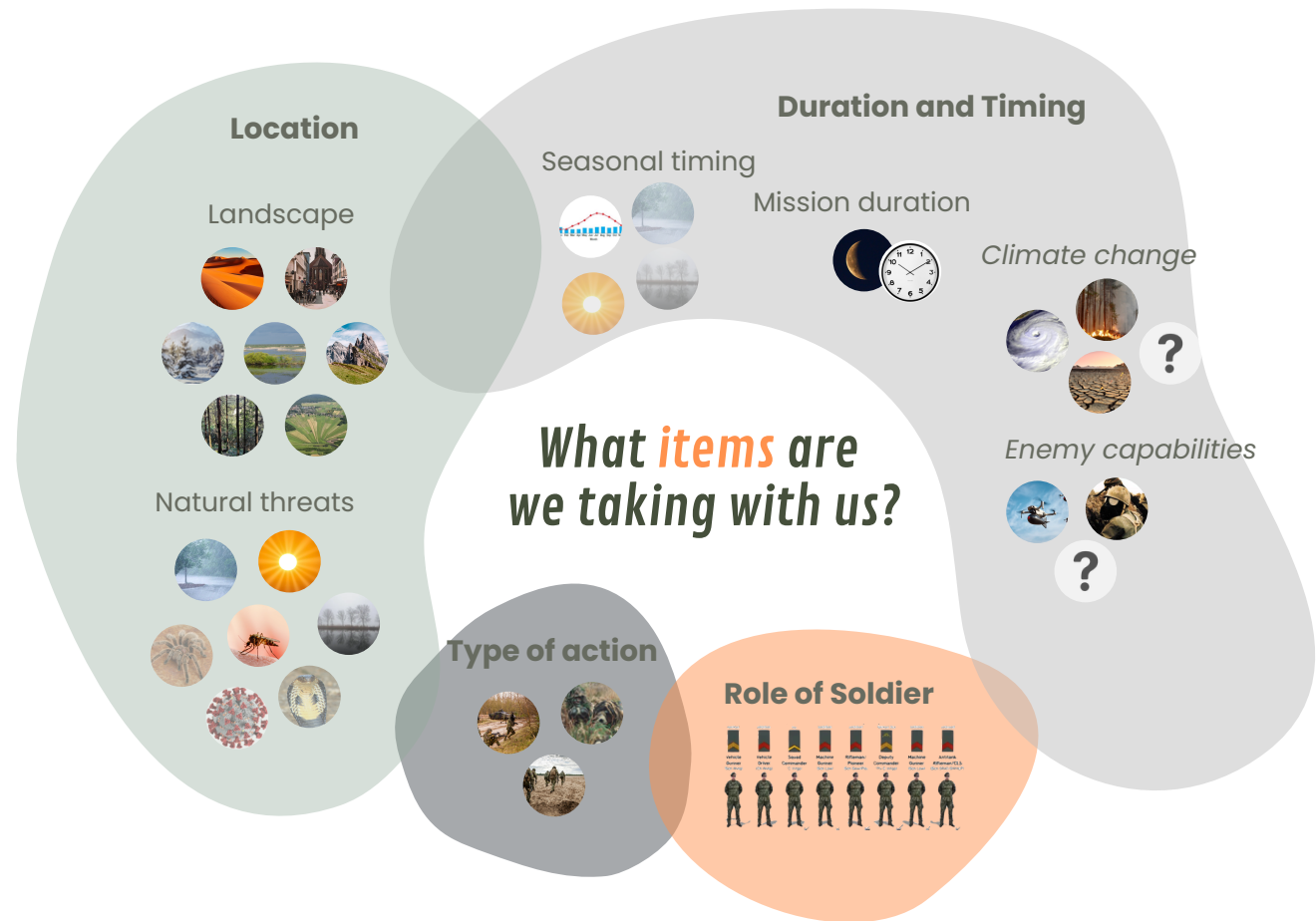


Figure 24, Operational Equipment Configuration Complexity

Determining Equipment

To determine the required volume for the storage system, it was first necessary to identify which items need to be stored. A standard set of equipment is carried during an operation, agreed upon in advance as essential for every infantry soldier. This standard set is based on the Handboek Militair en Uitrusting (Ministry of Defence, n.d.-c), and is supplemented with insights from the Defence Expertise Centre for Military Equipment. However, there is a distinction in how quickly certain items need to be accessible.

In Havelte, a group of seven experienced infantry soldiers discussed which items they need to have readily accessible within specific timeframes. To support the discussion, all relevant items were printed as images to provide clarity and structure. The outcome of the discussion identified three key timeframes for access: within 5 seconds, within 2 minutes, and within 5 minutes.

By categorising equipment based on required access time, storage locations can be assigned accordingly: items needed within 5 seconds should be carried on the body; those needed within 2 minutes should be stored inside the vehicle; and those needed within 5 minutes should be stored outside the vehicle. This approach keeps the limited in-vehicle space reserved for essential gear and reduces the risk of loose, potentially hazardous items.

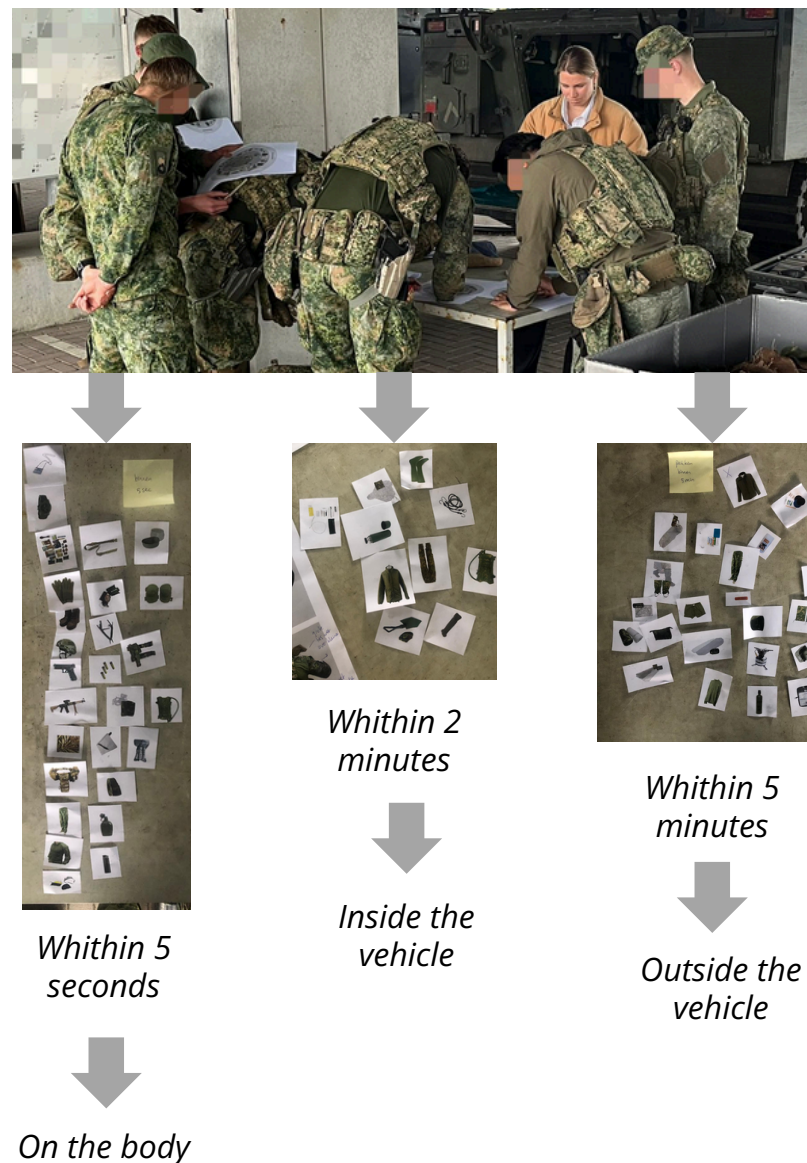


Figure 25, Sorting Current Used Equipment

'Lijnen Concept'

This categorisation of equipment is also known within the military as the Lijnenconcept. In this system, Eerste Lijn equipment is always carried on the person, gear of the Tweede Lijn is stored in the 37L backpack, and Derde Lijn gear is packed in the 65L backpack.

This section outlines which items fall under the Eerste Lijn and Tweede Lijn, based on the assumption that Derde Lijn equipment can be stored outside the vehicle.

However, the lists defining which items belong to each 'lijn' differ slightly between the Handboek Militair en Uitrusting, the Defence Expertise Centre, and the field research conducted in Havelte. For this project, the outcomes of the Havelte study have been chosen as the primary reference.

Eerste Lijn

Eerste Lijn refers to essential equipment that the soldier carries on their body at all times. This gear is stored in clothing pockets or attached to the combat vest. It is taken into the field during every action and remains immediately accessible, regardless of the type of action or duration.

Eerste Lijn Equipment



Figure 26, Eerste Lijn Equipment

Tweede Lijn Equipment

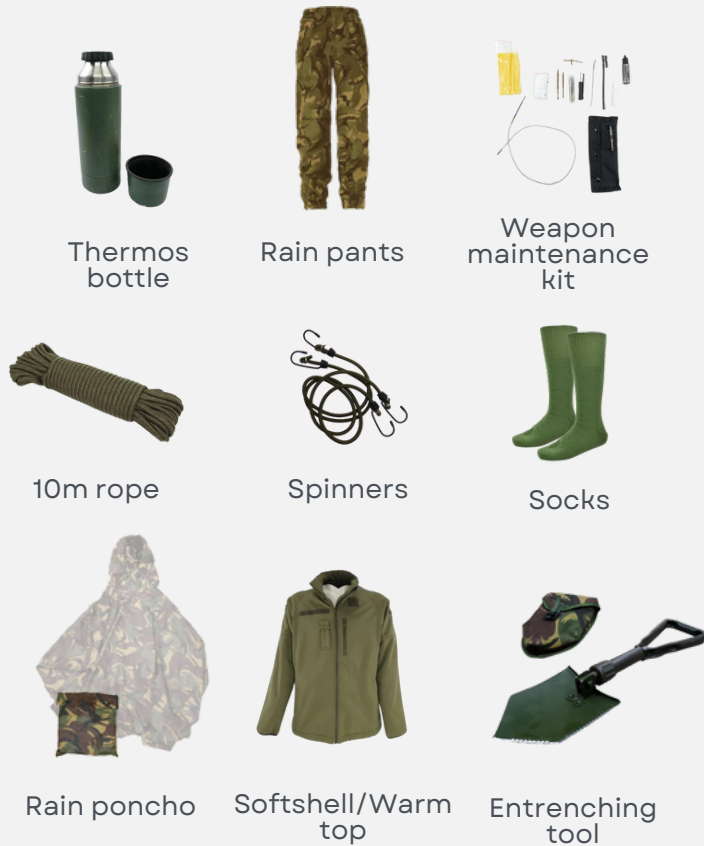


Figure 27, Tweede Lijn Equipment

Tweede Lijn

Tweede Lijn refers to additional equipment that is carried in a 37-liter backpack. This gear supports sustained operations and includes items not needed for immediate use, but still essential during longer actions. It is typically brought along for missions lasting between four and eight hours.

Dividing Tweede Lijn Equipment

The full 37L standard backpack, measuring approximately 23 cm in thickness (as measured during field analysis), does not fit behind or beneath the seats in the rear compartment of the CV90. The available storage spaces, behind and beneath the seat, lack both the volume and dimensions to accommodate the backpack as a single, intact unit.

Given these spatial limitations, the overall volume of stored Tweede Lijn equipment must be reduced. To assess whether this is feasible, two experienced users (both sergeant majors) were consulted. In this discussion, they explored how the contents of the backpack could be broken down and reorganised to match operational needs.

As a result, the gear of the Tweede Lijn was categorised into two groups: essential items and comfort items. Essential items must remain within immediate reach due to their critical importance during high-threat phases. Comfort items, while still transported in the vehicle, can be stored less accessibly and retrieved later when the operational situation allows for it. (personal communication, May 2025)



Figure 28, Dividing Tweede Lijn Equipment

Key Takeaways 2.3

1. Gear plays a crucial role in both the physical and mental readiness of soldiers.
2. The 37L backpack is the focus of this project and belongs to lijn 2.
3. The combat vest already contains all essential gear of the Eerste Lijn.
4. Within lijn 2, a distinction can be made between essential and comfort gear.
5. The full 37L backpack does not fit in current vehicle storage compartments.
6. Field research shows high variability in gear configurations.

2.4 Key Takeaways and Drivers

At the end of each chapter, key takeaways are identified. These takeaways represent challenges to be addressed. By reframing them as design drivers, a solution-oriented approach is enabled. Finally, the takeaways and drivers can be categorised. Table 1 presents an overview of the takeaways, their corresponding drivers, and categories.

#	Takeaway	Driver	Category
1	The CV90 operates in rough terrain (shocks, vibrations, mud, etc.).	The design must withstand these conditions to function reliably.	Technology
2	Space inside the CV90 is limited; soldiers can barely turn or rotate their bodies.	Items must be within arm's reach and 'easy' to grab without large movements.	Use
3	37L backpacks are individually placed around each seat, allowing soldiers to quickly grab them when exiting the vehicle.	Quick access to personal equipment is essential, without hindering others.	Use

Table 1, Takeaways, Drivers and Categories

#	Takeaway	Driver	Category
4	Putting on and taking off the 37L backpacks is a pain point during vehicle entry and exit.	The design must be user-friendly in confined or limited/small spaces.	Use
5	The vehicle is used for extended periods without breaks (up to 8 hours), under heavy operational load.	The design must be robust and capable of withstanding prolonged use without defects or loss of performance.	Technology
6	The end users are young, often under pressure, and frequently less experienced.	The system must be intuitive and error-tolerant, even under stress.	Use
7	Items stored in the 37L backpack must be accessible within 2 minutes, highlighting the need for quick and easy access during operations.	There is a need for additional or alternative storage solutions to provide sufficient capacity.	Volume
8	The space behind the seat is currently unused when the seat is unfolded.	There is unused space behind the seat that can be optimised for storage.	Volume
9	The storage pouch beneath the seat is currently only partially utilised.	There is unused space beneath the seat that can be optimised for storage.	Volume
10	The storage compartment in the seat backrest is spacious but difficult to access from the seated position.	Storage solutions must prevent items from becoming loose and flying around.	Safety
11	Loose items pose a serious risk during sudden movements or a crash.	Gear must be assigned a fixed and clearly defined storage location.	Safety

Table 1, Takeaways, Drivers and Categories

12	The 12 cm crumple zone from the floor must remain clear to absorb the impact of explosions.	Designs must not encroach upon or block this safety zone.	Safety
13	Gear plays a crucial role in both the physical and mental readiness of soldiers.	Gear cannot be excluded.	Volume
14	The 37L backpack is the focus of this project and belongs to <i>lijn 2</i> .	The contents of the 37 L backpack must be within reach of the infantry soldier.	Use
15	The combat vest already contains all essential gear of the <i>Eerste Lijn</i> .	Additional capacity must be found elsewhere, outside of <i>lijn 1</i> .	Volume & Integration
16	Within <i>lijn 2</i> , a distinction can be made between essential and comfort gear.	Gear can be divided to reduce one large volume.	Volume
17	The full 37L backpack does not fit in current vehicle storage compartments.	Gear needs to be split up and spread over different storage places.	Integration
18	Field research shows high variability in gear configurations.	The storage solution must be able to accommodate different gear configurations.	Integration

Table 1, Takeaways, Drivers and Categories

3

Define

After conducting research and gaining a deeper understanding of the topic, a clear problem statement can now be defined. This chapter also outlines the design criteria and goal, based on the drivers, categorised in the previous chapter. Additionally, a list of requirements and wishes is established to serve as the backbone for the next Develop phase, along with my personal design vision that will guide the design process moving forward.

3.1 Design Criteria and Goal

3.2 Program of Requirements and Wishes

3.3 Design Vision



3.1 Design Criteria and Goal

Following the research conducted during the Discover phase, the takeaways were translated into design drivers, which can be grouped into five categories. These categories form the design criteria for this project.

Based on this, the design goal is defined as:

"Develop a **safe**, **robust**, and **compact** storage solution for military equipment that is **easy to use** and **integrated** within the operational context of armoured infantry vehicles."

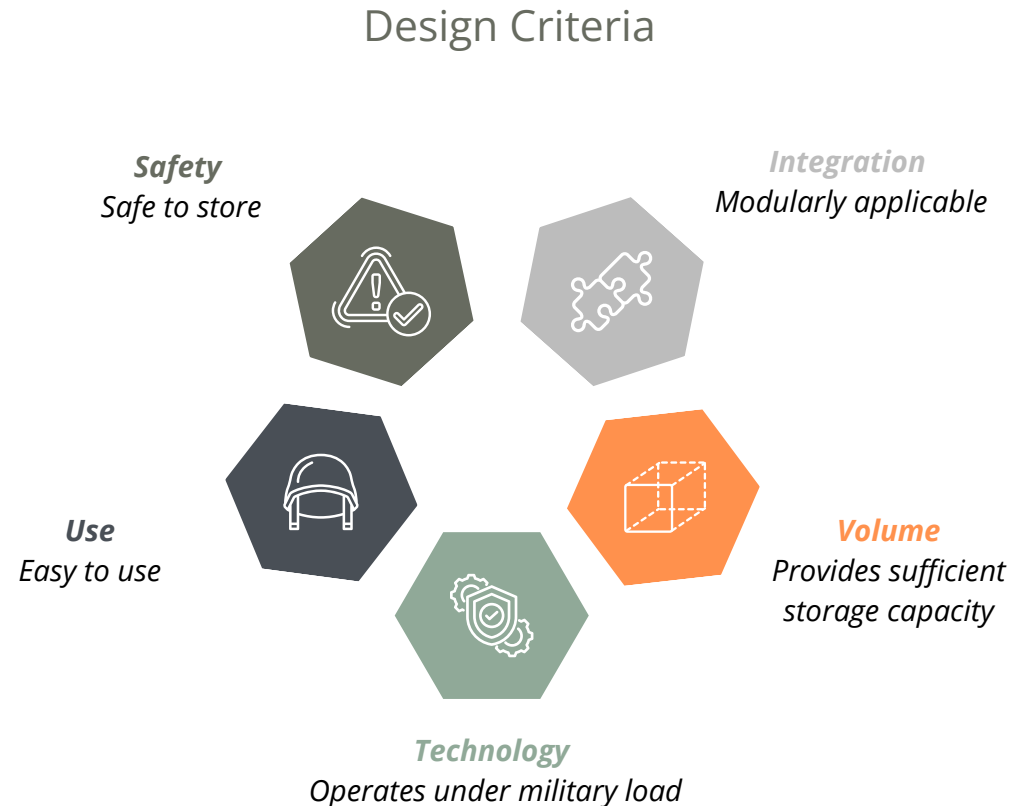


Figure 29, Design Criteria

3.2 Program of Requirements and Wishes

The following Program of Requirements and Wishes was created to provide guidance throughout the project. It was developed in collaboration with the client, two senior users, and two experienced end users (rank: Sergeant Major).

Use

Requirements

1. All gear of the Tweede Lijn must be accessible and retrievable within two minutes by each of the seven infantry soldiers seated in the rear compartment of the vehicle.
2. The storage must be reachable, removable, and carried outside the vehicle by the soldier within five minutes from the seated position, even under stressful conditions and with full gear.
3. The storage solution must be usable by both a P5 and P95 soldier.
4. The design must be simple and intuitive, allowing the soldier to reach and prepare the gear in no more than five actions.
5. If the storage solution is taken along during dismounting, it must be comfortable to carry.
6. The storage solution must not hinder the soldier's mobility in the field, for example by snagging on obstacles or restricting movement.

Wishes

7. The storage solution must be designed in such a way that it can be used independently and without assistance by up to seven infantry soldiers inside the CV90 vehicle.

Integration

Requirements

8. The storage solution must be integrable with the equipment of the *Eerste Lijn*; the equipment of the *Tweede Lijn* must not obstruct the equipment of the *Eerste Lijn*.
9. The storage solution must be safely integrated into the vehicle in seven positions, without affecting the operation of other vehicle systems (such as electronics, communication, or navigation).

Safety

Requirements

10. The system must not cause unsafe situations, such as obstruction of walkways or the buffer zone between head and roof.
11. A minimum of 12 cm of free space must be maintained under the seats for the designated crumple zone, measured from the top of the floor.
12. The space above the heads of seated personnel must remain clear to prevent head or neck injuries in the event of a collision.
13. The storage solution must not hinder infantry soldiers during rapid entry or exit of the vehicle.
14. The system must be tested under conditions such as a crash or mine explosion and must not pose additional safety risks to the user.

Technology

Requirements

15. The storage solution must be robust and durable, resistant to dust, sand, and soil, and remain functional under harsh environmental conditions during an operation.
16. The storage solution must be camouflaged in the NFP camouflage pattern when used outside the vehicle.

Wishes

17. The storage solution should preferably be securely attached to existing mounting points in the CV90 without requiring structural modifications, using standard mounting provisions (e.g., bolts, rails, or hooks).
18. The storage solution should contain as few active electronic components as possible that require external power during operational deployment.
19. The storage solution should, with minimal adjustments if necessary, also be applicable in the Boxer vehicle type, while maintaining the same functionality and mounting requirements as in the CV90.

Volume

Requirement

20. The storage solution must provide sufficient capacity to store and transport the complete equipment configuration of the *Tweede Lijn*, of a single infantry soldier, without requiring any components of the equipment to be carried separately.

Wish

21. The storage solution should only accommodate the equipment configuration of the *Tweede Lijn*, and the unintended storage of non-operational items, such as cigarette packs or soft drink cans, should be discouraged.

3.3 Design Vision

In my view, a design vision serves as a personal guide that provides direction throughout the design process and supports well-considered decision-making during the project.

I believe the user should be at the center of the design process. Active involvement, asking the right questions, and open, honest communication are essential to uncovering the user's true needs. Collaboration with people from different backgrounds enriches the process by introducing new perspectives and revealing blind spots. I am also convinced that making concepts tangible is a powerful way to encourage dialogue, it helps translate abstract ideas into concrete form, invites feedback, and stimulates shared reflection and development.

This vision was applied from the earliest stages of the project. End users were involved early, the interior of the CV90 was analysed, and full-scale mock-ups were built to explore spatial constraints, test the fit of the equipment, and evaluate form and volume. The mock-ups also helped make spatial challenges tangible, facilitating discussion with both users and the client. These activities ensured that design choices remained grounded in real dimensions and operational needs.

4

Develop

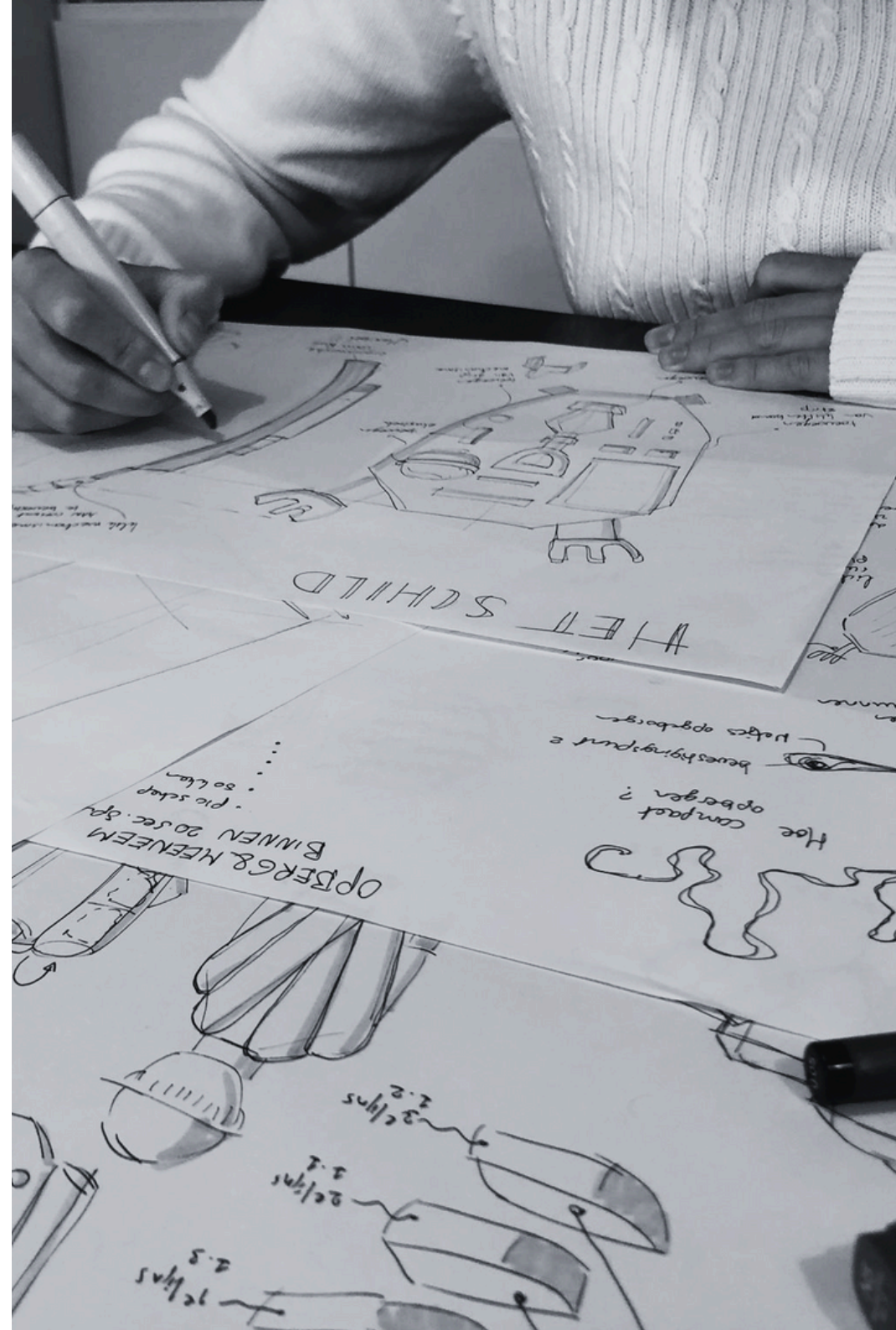
Having set the design criteria, direction and program of requirements and wishes this chapter turns to generating solutions. Ideation sessions produced a broad idea pool, later clustered by shared principles; select clusters were developed into concepts. It concludes with the choice of a single concept for refinement in the upcoming Deliver phase.

4.1 Ideation

4.2 Solution Directions

4.3 Concepts

4.4 Concept Choice



4.1 Ideation

Parallel to the Discover phase, initial directions for possible solutions were explored. This phase required an open mindset and a willingness to challenge conventional assumptions.

Idea generation began individually but was enriched by incorporating diverse perspectives through both informal and structured group sessions. One session involved a spontaneous brainstorming activity with a mixed group of individuals unfamiliar with the topic, allowing for free-flowing and uninhibited idea-sharing. Another session took the form of a more structured workshop using a tailored SCAMPER method. This involved participants with contextual knowledge from various disciplines.

This structured workshop is described in Appendix D.

Input from both sessions was reflected in my own ideation process, leading to a range of small sketches that captured the first glimpses of these ideas. These initial ideas formed the foundation for the clusters and directions discussed in the next section.



Figure 30, Ideation Workshop with Colleagues, Utrecht

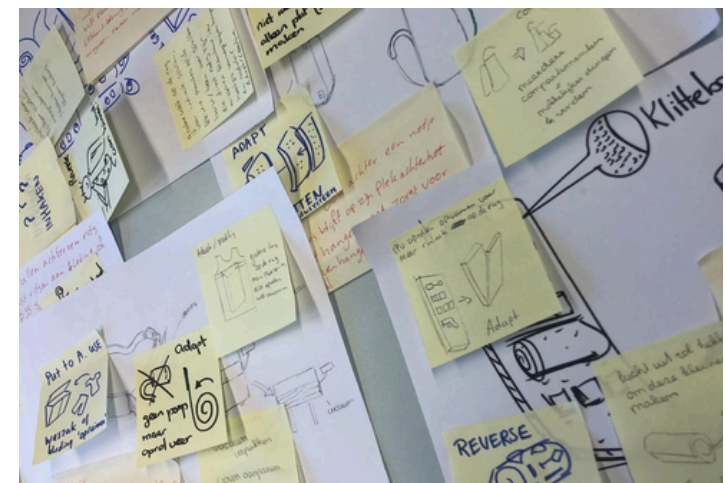


Figure 31, Outcomes Ideation Workshop

4.2 Solution Directions

As previously outlined, the generated ideas were grouped based on common themes, named solution clusters (see Appendix E). This ideation process led to six distinct clusters, each addressing a different opportunity to solve the storage challenge.

1. Reduce Gear

This cluster focuses on minimizing equipment to reduce storage needs. By carrying only the essentials, space becomes easier to manage, allowing for a clearer and more efficient system.



This option was not pursued, as all gear taken on an action is essential and cannot be left behind.

Figure 32, Reduce Gear

2. Seat Adjustments

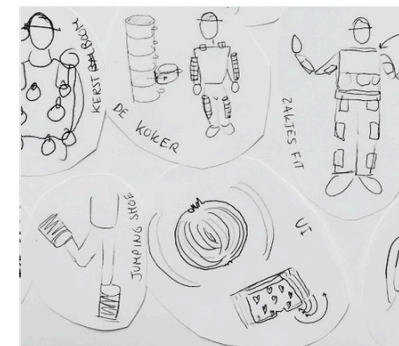
This direction explores how vehicle seating can serve dual functions. Integrating storage into seating maximises use of the available space inside the vehicle.



Figure 33, Seat Adjustments

3. Clothing Adjustments

This direction explores how military garments can double as gear carriers. Modifying or enhancing clothing allows it to serve not just for protection but also as a storage platform.



This option was not pursued, as adding extra items to the body leads to overload and reduced mobility.

Figure 34, Clothing Adjustments

4. Backpack Adjustments

Here, the focus is on redesigning the standard backpack to better fit within tight vehicle constraints, optimizing shape and volume while maintaining comfort and usability in the field.

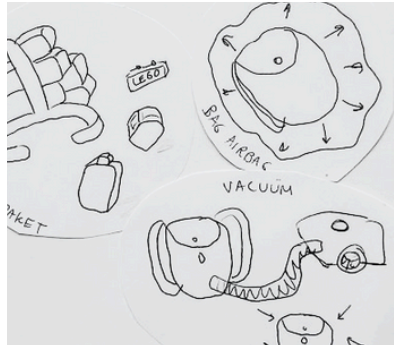


Figure 35, Backpack Adjustments

5. Vehicle Adjustments

This cluster looks into reconfiguring or redesigning the vehicle's interior to make optimal use of space for secure, logical, and easily accessible storage solutions.



This option was not pursued, as the vehicle remains limited, costs are high, and it introduces major new challenges that require safety validation.

Figure 36, Vehicle Adjustments

6. Outside the Vehicle

This cluster examines opportunities to use space around the vehicle. External storage solutions can add capacity without affecting the interior layout.



This option is not viable, as infantry soldiers must be able to access their Tweede Lijn gear within 2 minutes.

However, it could be a solution for Derde Lijn equipment.

Figure 37, Outside the Vehicle

Chosen Clusters

The clusters number 2: **Seat Adjustments** and number 4: **Backpack Adjustments** were selected because they offer complementary and feasible opportunities for solving the core challenge: safely and efficiently storing gear of the Tweede Lijn inside the vehicle.

Unused space beneath and behind the seat offers potential for integrated storage. However, the current backpack's shape and volume require adaptation. To ensure efficient and secure use, the seat will also need modification. Together, these clusters provide a realistic solution for safely storing gear of the Tweede Lijn inside the vehicle.

4.3 Concepts

Due to the limited available space, a practical, hands-on approach was chosen. Scale models were created to physically test volumes and proportions, to see whether the gear would fit and to make ideas tangible. This process is briefly illustrated in Appendix F.

The development of the concepts was an iterative process involving sketching, applying the HKJ method (see Appendix G), selecting two concepts: Behind the Seat and Under the Seat and then working directly with scale models.

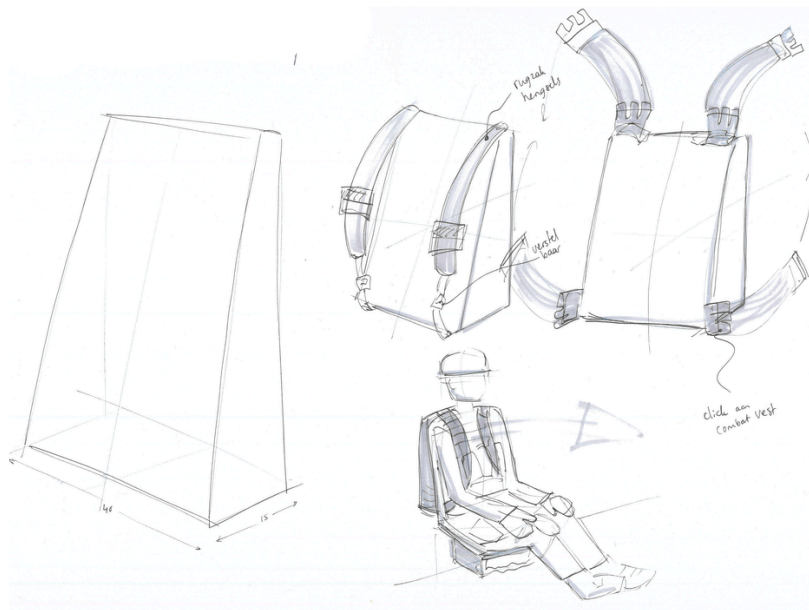


Figure 38, Behind the Seat Sketches

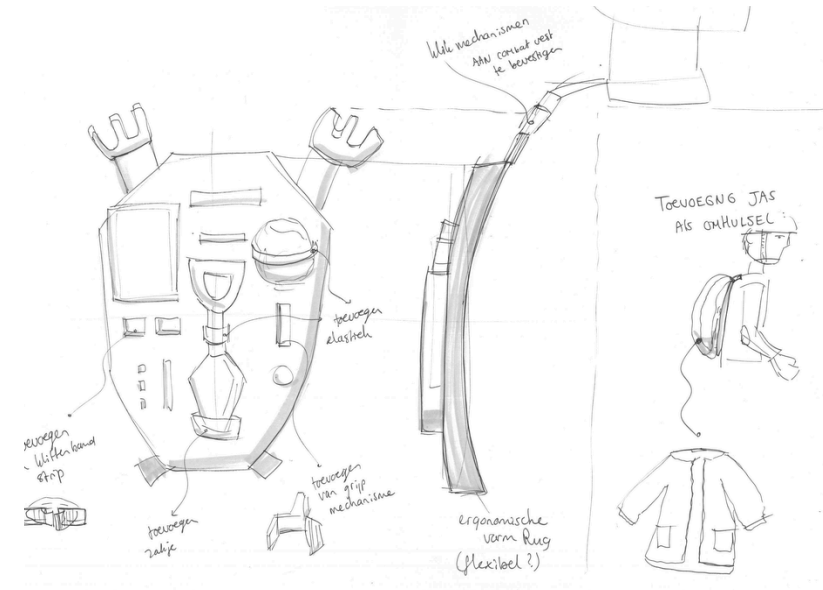


Figure 39, Under the Seat Sketches

Concept 1: Behind the Seat

In this concept, the backpack is integrated into the space behind the seat backrest, which becomes available when the seat base is folded forward. The backpack serves a dual function: it acts as both back support for the soldier while seated and as storage for essential gear. To fit within the available space, the backpack is shaped like a triangle, with the bottom edge limited to a depth of 15 cm. When dismounting, the backpack can optionally be taken along directly from its position and worn on the back, already aligned with the desired carrying position.



Figure 40, Mockup Details Behind the Seat

Concept 2: Under the Seat

In this concept, the backpack is placed under the seat and can be pulled forward for use. The hard back side of the backpack is mounted against the underside of the seat base and, within the available space of 10–15 cm, is used to store rigid equipment. Softer items, such as clothing, can be placed on the outer side of the bag and may deform slightly upon contact with the crumple zone, without compromising the soldier's safety, provided the setup is used correctly. The backpack is taken out manually during dismounting and worn outside the vehicle, as is currently standard practice.

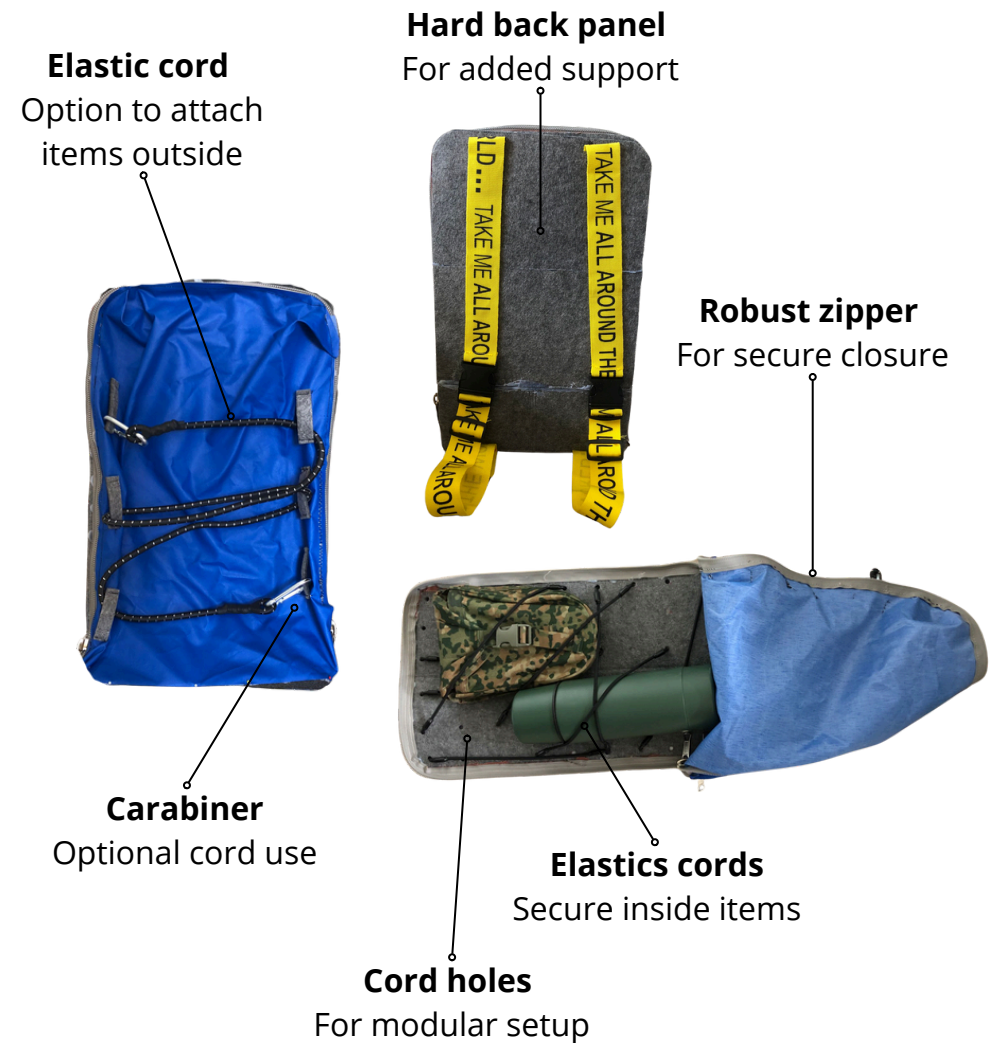


Figure 41, Mockup Details Under the Seat

4.4 Concept Choice

Weighted Objective Method

To evaluate the potential of different storage solutions, the two previously mentioned concepts, storing the backpack behind the seat and storing it under the seat, were compared. To complete the comparison and provide context, the current 37L backpack was also added as a reference point. This approach ensures that the evaluation captures both the potential of new ideas and how they perform in relation to the existing situation.

To decide with what concept to go further with, the weighted objectives method was used. The five previously defined design criteria were applied for this purpose (see section 3.2 Design Criteria and Goal).

Each criterion was assigned a weight based on input from the client, a senior user, and end users, with final decisions made in the design process.

The Behind the Seat concept scored 765 out of 100, Under the Seat 665, and the Current Backpack 540. Behind the Seat is the safest option for storing the backpack.

Comparison Criteria	Weight
Easy to deploy	20
Modularly stored	25
Safe to store	25
Functions under military-grade stress	15
Provides sufficient storage capacity	15

Total: 100

Behind Seat		Under Seat		Current Backpack	
Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
9	180	7	140	5	100
6	150	7	175	7	175
9	225	5	125	1	25
8	120	8	120	8	120
6	90	7	105	8	120
765		665		540	

Figure 42, Weighted Objective Method

Chosen Concept

After scoring the three concepts against these criteria, the concept '**Behind the Seat**' emerged with the highest score. This concept will therefore be further developed in the next phase of the project.



Figure 43, Behind the Seat Concept

User Insights of Scale Models

Before moving on to the next chapter, it is important to highlight the key insights gathered from the reviewed scale models. These were evaluated by two senior users (CV90 and Boxer operations) and two sergeant majors, with extensive operational experience using the CV90 in the field. Their feedback will be carried forward into the next phase and serve as guiding input during further development.

Key Insights User Feedback

- Loose external elastics are prone to snagging and should be avoided.
- Velcro is not recommended in field use due to noise concerns.
- A robust, high-quality zipper is preferred.
- External carabiners increase the risk of snagging and are discouraged.
- Attaching loose items to the exterior is not advised due to snagging risks.

Seat Adjustments

To integrate the backpack into the seat backrest, structural adjustments to the backrest are required. Iterative sketches were created to explore several design options. In consultation with the client, a final concept was selected, highlighted in green. The choice was based on the following considerations:

- **Large Insertion Area**

Allows for smooth and easy placement and removal of the backpack, ensuring quick usability under operational conditions.

- **Preserved Lumbar Support**

The ergonomic support in the lower back area is maintained, which is crucial for user comfort during prolonged seating (based on client input).

- **Durable Zipper Closure**

Zippers are used to provide a secure and robust closure solution, capable of withstanding repeated use in the field.

- **Reversible Opening**

The system can be closed when backpack integration is not required, offering flexibility and maintaining seat integrity when used conventionally.

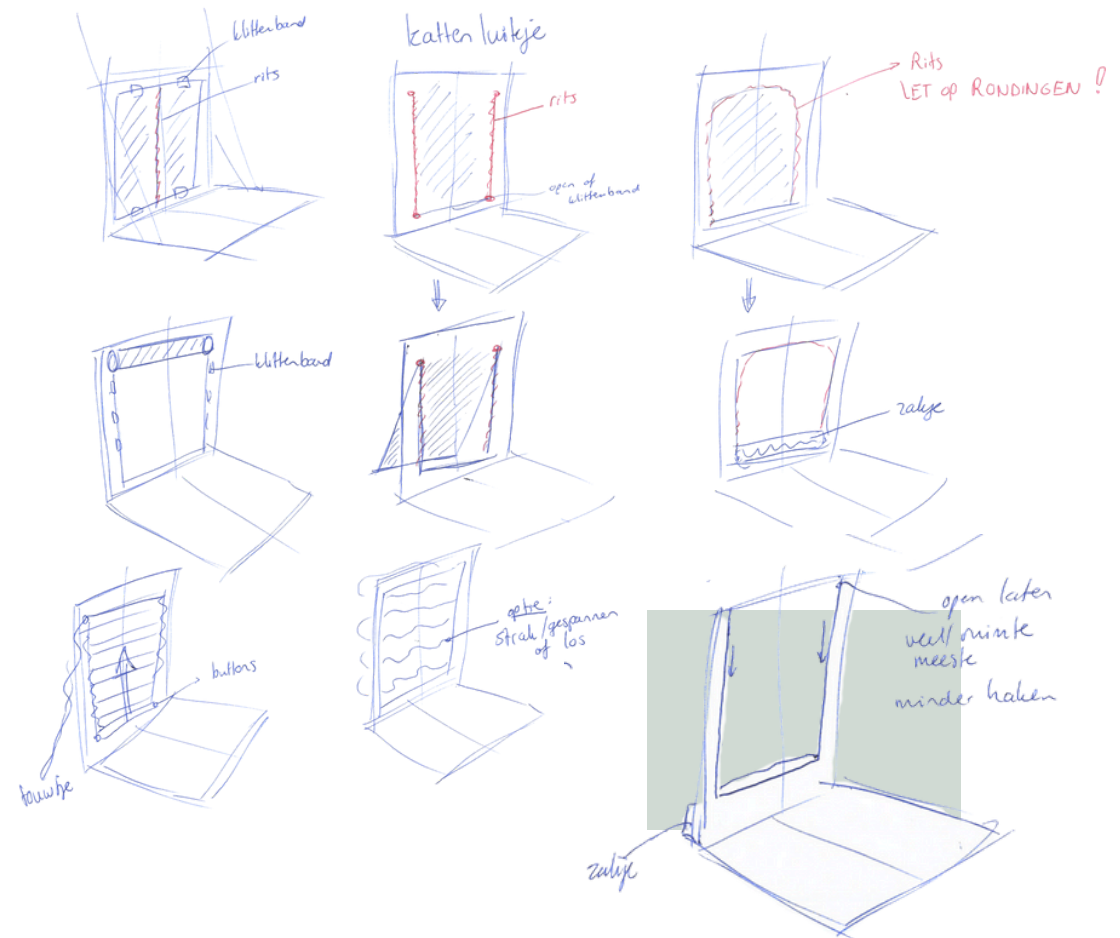


Figure 44, Iterative Sketching Seat Adjustments



A similar concept is already used in firefighting vehicles, where oxygen tanks are integrated into the seat backrest. These tanks can be worn while seated and are immediately accessible when exiting the vehicle. This system combines storage, accessibility, and rapid deployment in a single integrated solution.

Although the context differs from that of an infantry vehicle, both share the same needs: fast dismounting and immediate access to essential equipment. This confirms that functional integration into the seat, such as the proposed backpack concept, is a proven and effective approach.

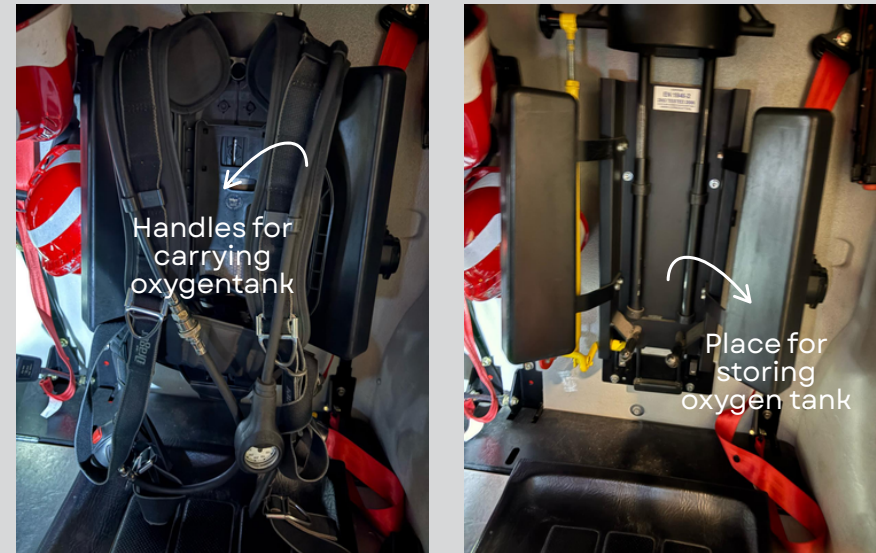


Figure 45, Integration of Oxygen Tank in Firefighting Vehicles
Photo taken by T. Boersma, Firefighter

5 Deliver

With the Behind the Seat concept selected, this chapter outlines the concept, how it is used, and how it should be integrated into the vehicle. It also covers the prototype, the test performed, the results, and points for improvement.

- 5.1 Concept and Application*
- 5.2 Technical Implementation*
- 5.3 User Test and Results*
- 5.4 Improvements*



Figure 46, Infantry Solder Sitting inside CV90 with Adjusted Backpack and Backrest, Bergen-Hohne

5.1 Final Concept and Application

A Portable Backrest

The concept is designed as a portable backrest: a backpack that functions both as a storage system for essential Tweede Lijn gear and as a backrest while seated. While seated against the side of the CV90, the backpack remains in place and does not need to be removed. Upon exiting, the soldier can choose whether or not to take the backpack, depending on the vehicle commander's instructions.

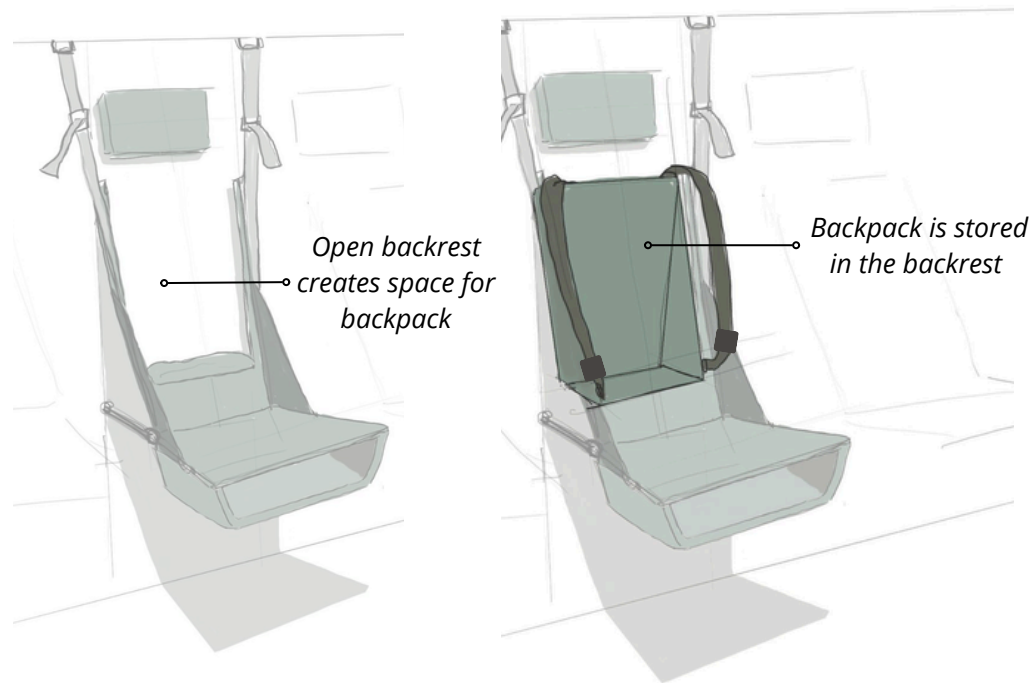


Figure 47, Portable Backrest Concept

Quick-Release Clip System

The quick-release clip system is designed to allow the infantry soldier to exit quickly without the backpack, preventing them from getting caught on the bag's straps.

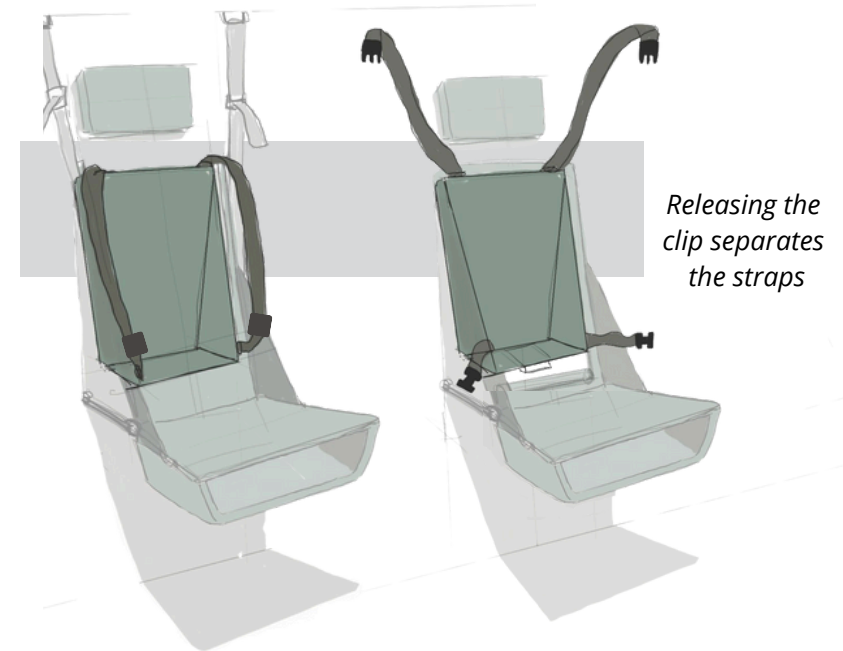


Figure 48, Quick-Release Clip System

Enlarged Pouch Under Seat

The pouch beneath the seat needs to be enlarged to accommodate equipment that must be carried in the vehicle. This storage is intended for items that are important to have inside the vehicle but do not need to be taken outside immediately during certain actions, such as the configured set of comfort gear.

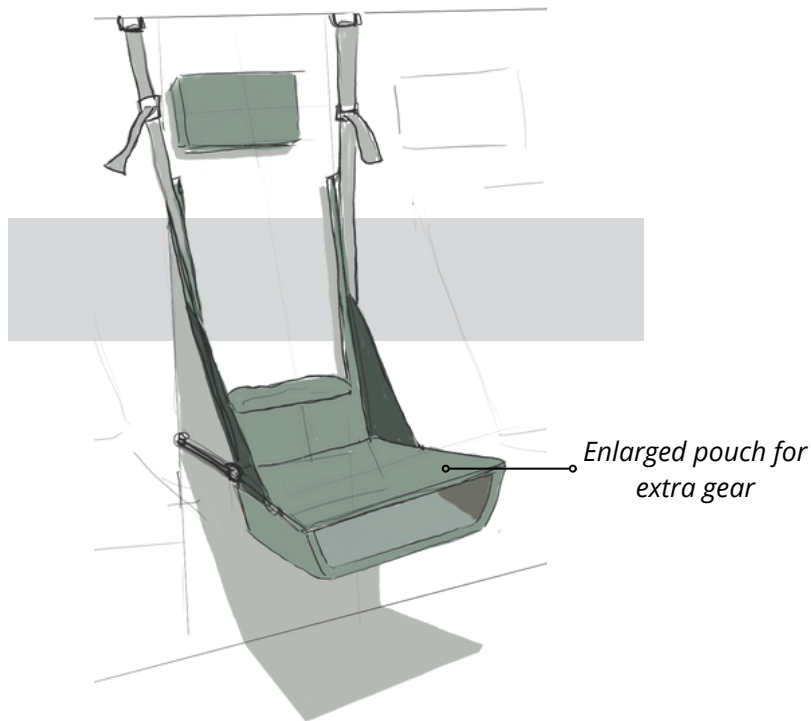
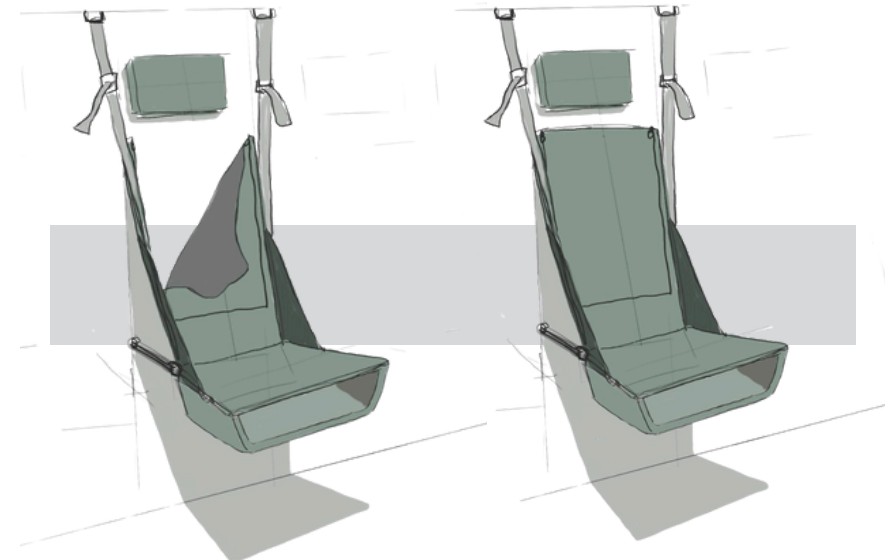


Figure 49, Enlarged Pouch Under Seat

Restoring if Needed

In rare cases where no backpack is worn and the seat must be used in its conventional form, the backrest can be closed using a zipper. This allows the user to restore the seat to a standard configuration, providing back support without the integrated backpack opening.



Zipper allows the backrest section to be closed when no backpack is present, allowing for normal seating

Figure 50, Reversible Opening

Use Scenario, Flowchart

The following flow illustrates the designed procedure when entering the vehicle.

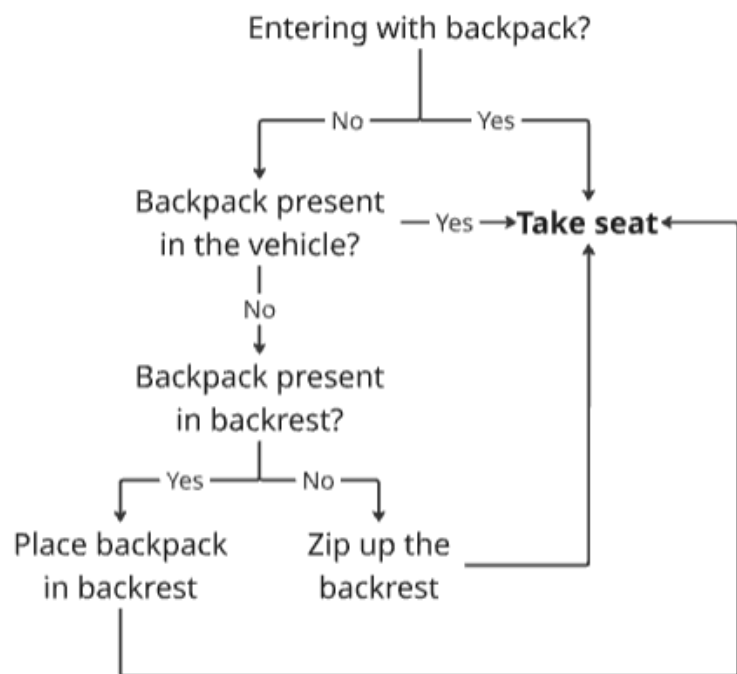


Figure 51, Flowchart for Entering the CV90

Although the backpack is almost always brought along, in the rare case it is absent, the backrest must still function in its original form to prevent the soldier from falling into the designed gap. Therefore, a zipper has been integrated into the backrest to restore it when needed.

The following flow illustrates the designed procedure when exiting the vehicle.

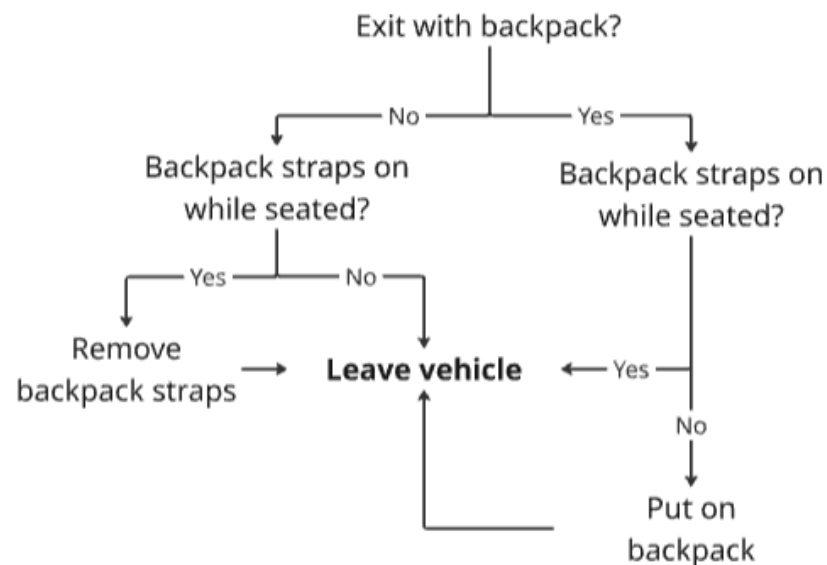


Figure 52, Flowchart for Exiting the CV90

The actions required to enter the vehicle, sit down, and later exit and leave the vehicle are minimal, regardless of whether the backpack is worn. This supports the objective of enabling fast and efficient entry and exit procedures.

Use Scenario, Enter and Exit

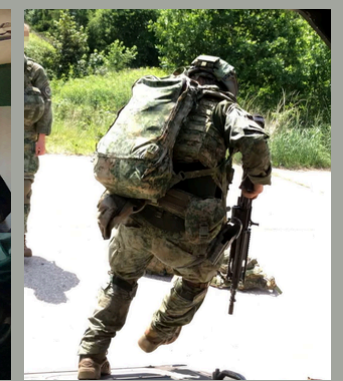
In the designed scenario, infantry soldiers enter and exit the vehicle while wearing full Eerste Lijn equipment and a modified backpack containing essential Tweede Lijn items. This setup allows them to sit down without removing the backpack or placing it in an unsafe position.

Scenario with backpack:

Entering



Sitting



Exiting

Infantry soldier enters the vehicle with backpack.

Infantry soldier unfolds the seat.

Infantry soldier takes seat with the backpack on his back.

The backpack fits into the gap in the backrest as the soldier sits down.

Infantry soldier exits the vehicle with backpack.

Infantry soldier leaves the vehicle and initiates their operation.

Figure 53, Enter and Exit Scenario - Designed Situation, Bergen-Hohne

In the designed scenario, the infantry soldier is seated inside the CV90 while wearing a modified backpack that integrates essential Tweede Lijn items into a reconfigured backrest. This allows the soldier to remain seated comfortably and safely without needing to remove the pack.

Scenario without backpack:

Entering



Infantry soldier enters the vehicle without backpack.



Infantry soldier unfolds the seat.



Infantry soldier takes seat.

Sitting



The soldier leans into the backpack as the soldier sits down.

Exiting



Infantry soldier exits the vehicle without backpack.



Infantry soldier leaves the vehicle and backpack stays in the vehicle.

Figure 53, Enter and Exit Scenario - Designed Situation, Bergen-Hohne

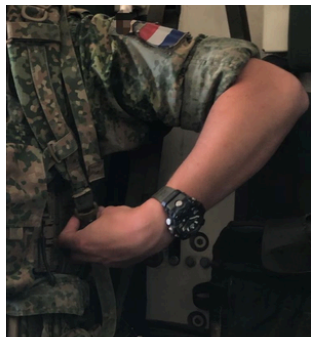
Backpack Handling

The following four scenarios illustrate how the backpack is handled before, during, and after dismounted operations. Each situation highlights how the design allows for easy stowage, access, and reattachment without obstructing movement inside the vehicle.



Option 1
Using shoulder straps

Removing backpack
When the backpack is not taken on an action, it is stored behind the seat. The soldier can remove it using either the shoulder straps or the quick-release system.



Option 2
Using quick-release system



Secured backpack
When the backpack is left behind, the seat automatically folds closed, holding the backpack securely in place.



Returning from the operation
After returning, the soldier uses the backpack as a backrest again while seated.



Reattaching the backpack
The soldier can put the backpack back on either by putting on the shoulder straps or by reattaching it using the quick-release system.

Figure 54, Backpack Handling While Seated, Bergen-Hohne

Fitting Backpack Configurations

Due to constant changes in carried equipment, storage solutions must remain flexible. Infantry soldiers need the freedom to decide what gear is essential for each action. The backpack supports this by allowing them to compose their own loadout, within a fixed volume.

The modified backpack has a 16L capacity. This capacity was verified through a water-fill experiment, as documented in Appendix H. This limitation forces soldiers to prioritize and make practical decisions. As a result, only the most essential items, based on the specific action, are taken into the field.

For example, in the gear configuration, the thermos bottle from the essential gear was replaced with a CamelBak from the Eerste Lijn equipment. This adjustment was proposed during a discussion in Bergen-Hohne with two infantry soldiers who operate with the CV90.



Figure 55, Example Fitting Gear Configuration

5.2 Technical Implementation

Integration in the vehicle

The modified CV90 seat has been designed for easy integration into the existing interior of the vehicle.

The original seat consists of a fabric component suspended using straps that are routed through attachment points on the ceiling and sidewall of the vehicle. These straps can be easily removed by unclipping the fasteners. The seat cushion is made of fabric that is slid over a metal frame, which is permanently mounted to the vehicle wall.

The wall-mounted attachment points and metal frame remain in place and are reused. The modified seat is slid over the existing frame, and the new straps are secured with clips to the side and top of the vehicle interior. Installation takes approximately ten minutes and requires no permanent modifications to the vehicle.

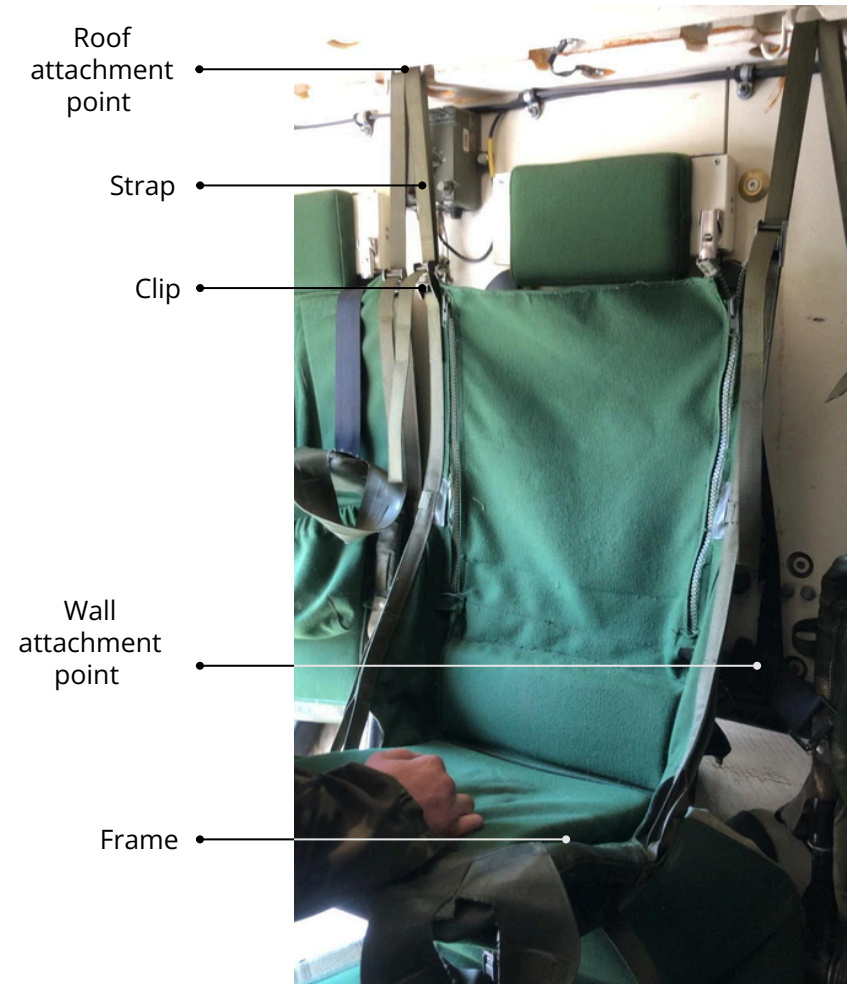


Figure 56, Installing Adjusted Seat Inside the CV90

Adjusted CV90 Seat

To make it possible to integrate the backpack into the seating arrangement, several adjustments were made to the existing backrest of the CV90 seat. These adjustments include the following:

1. Zippers on both sides of the backrest

Zippers have been added on both sides of the seat, running from top to bottom. These allow the back panel to open, creating space to insert the backpack behind the seat.

2. Retention of existing lumbar support

The original lumbar support has been maintained to ensure ergonomic comfort and posture support. According to Cornell University Ergonomics Web (2021), effective lumbar support should be positioned at least 15 cm above the seat surface.

3. Material removed from the backrest interior

Internal material has been removed to provide extra space for backpack integration. Full back support is deemed non-essential, as soldiers wear combat vests that offer sufficient structural support when seated.

4. Integrated storage pouch for backrest panel

A small pouch has been added behind the lumbar support to store the unzipped backrest panel. It also acts as a support base when the panel is reinserted.

5. Removal of rear seat pouch

The original pouch located behind the seat has been removed to further optimise the available internal space.

6. Enlarged pouch under the seat

The storage pouch beneath the seat is enlarged to maximise the safe stowage of equipment within the available space.

Zipped Backrest



Unzipped Backrest



Figure 57, Seat Adjustments

Adjusted 37L Backpack

To enable integration of the backpack into the backrest of the seat, several modifications were made to the standard 37L military backpack. These changes were driven by the limited available volume behind the seat, requiring the backpack to be more compact while still maintaining essential functionality. Based on fitting essential items, the required volume was determined to be 16 liters.

1. Side Zippers for Compression

The existing side zippers, originally meant for daypacks, are now used to compress the backpack. This allows it to fit behind the seat. When full volume is needed, the zippers can be opened.

2. Quick-Release Clip System

A quick-release clip on the shoulder straps allows the backpack to be detached rapidly when not needed, enabling faster vehicle exit.

3. Removal of MOLLE Webbing

Side and front webbing have been removed to prevent pouch attachments, keeping the backpack slim, lighter, and less prone to snagging.

4. Simplified Layout with Fewer Pouches

Front pockets have been removed to enforce gear prioritisation and reduce weight and bulk.



Figure 58, Backpack Adjustments

Materials and Methods

To ensure a robust and reliable design, existing materials and components from current military gear were reused, chosen for their proven durability and resistance to sand, dust, and wear. Familiarity with these materials also supports user acceptance and seamless integration.

Modifications were carried out using a Lewenstien Super 904E sewing machine with heavy-duty thread. A topstitching technique with parallel straight lines was applied to reinforce the structure and ensure long-term durability under field conditions. Thick fabrics and the original MOLLE system were cut and adjusted using a Stanley knife and heavy-duty fabric scissors, enabling precise work through dense, rugged material.



Figure 59, Using a Sewing Machine for Prototyping, Rotterdam

Maintenance and Durability

Because the concept makes use of existing components, maintenance procedures remain largely the same. This is a key advantage, as repairs and replacements follow the same process as the current system. Disassembly and reassembly of the seat remain identical to the original design. Based on current usage, the expected lifespan under intensive use is estimated at approximately 10 years. Wear is most likely to occur at the zipper, but this component is relatively inexpensive and easy to replace.

As for the backpack, it is expected to experience less wear than the current 37L version, as it is no longer stored loosely in the vehicle. The fixed placement behind the seat reduces friction and impact. For this reason, the backpack is also assumed to last 10 years under intensive use.

Scalability and Repeatability

The Portable Backrest concept is highly scalable and easily repeatable within existing logistical and production processes. The seat can be modified relatively easily using available tools and materials. However, in the case of the backpack, it is likely more cost-effective to produce a new version rather than modify existing ones, due to the time and resources required for adjustment. This makes large-scale implementation feasible, with minimal impact on current workflows and training.

5.3 User Test and Results

User Test

A qualitative user test was conducted to gain insight into the practical usability of the prototypes. The test took place on June 17, 2025, at the Bergen Hohne training area in the back of the CV 90. The adjusted CV90 seat was installed in the vehicle to enable a realistic and representative evaluation.



Figure 60, Test Setup, Bergen-Hohne

Objective

The objective of this test is to evaluate whether the adjusted backpack could be correctly placed into the backrest, whether any difficulties arose during entry and exit, how the backpack was experienced during use, and how well the shoulder-strap clip system functioned.

Sample

The test involves seven man infantry soldiers. Two of the participants are experienced users, each having operated in the rear compartment of the CV90 for approximately nine months during training exercises. The remaining five participants are CV90 crew members, including drivers and gunners, who are familiar with the vehicle's interior and operational context.

Participant heights range from 175 cm to 203 cm, providing a representative range of body sizes for evaluating ergonomic and spatial aspects of the prototype.

Stimuli

- CV90
- Eerste Lijn equipment
- Prototype adapted CV90 seat
- Prototype adjusted backpack
- Tweede lijn equipment
 - Entrenching tool
 - Thermos bottle
 - 2x spinners
 - Rope
 - Rain poncho
 - Rain pants
 - Soft shell/warm top
 - Wapen maintenance kit
 - Socks
- Mobile phone (for camera, timer, and audio)
- Printed interview forms

Procedure

1. Simulation of Current Situation

- On command: enter and exit the vehicle using the current procedure.

2. Instruction and preparation

- Demonstration of entering and exiting the vehicle with the adjusted backpack.
- Unzipping the backrest to prepare the seat for backpack storage.

3. Test Round 1, Entering With Adjusted Backpack

- On command: enter the vehicle with the adjusted backpack.
- Sit in the adapted seat and stow the backpack.
- Remain seated for approx. 1 minute (transport simulation).
- Remove the adjusted backpack, with optional use of the shoulder-strap clip system.
- On command: exit the vehicle without the adjusted backpack.

4. Test Round 2, Exiting With Adjusted Backpack

- On command: enter the vehicle without the adjusted backpack.
- Sit in the adapted seat.
- Remain seated for approx. 1 minute (transport simulation).
- Put on the adjusted backpack.
- On command: exit the vehicle with the adjusted backpack.

5. Additional, Field Use With Adjusted Backpack

On command: 'contact drill' exercise with adjusted backpack worn outside the vehicle. This involved quickly dropping to the ground and executing immediate actions as trained, in order to evaluate freedom of movement and overall mobility during field use.

At the end of the practical rounds, each participant completed a short interview to evaluate comfort, usability, and perceived safety related to both the prototype seat and backpack system.

Results

Test 1, Entering With Adjusted Backpack

Placing Backpack Inside the Backrest

All seven participants were able to place the adjusted backpack into the seat backrest without difficulty. No obstacles or discomfort were reported while entering the vehicle, sitting down, or storing the backpack.

The adjusted backpack was even perceived as more favorable, as it protrudes less, reducing the chance of getting caught on parts of the vehicle during entry.

Success Rate of Placing Backpack

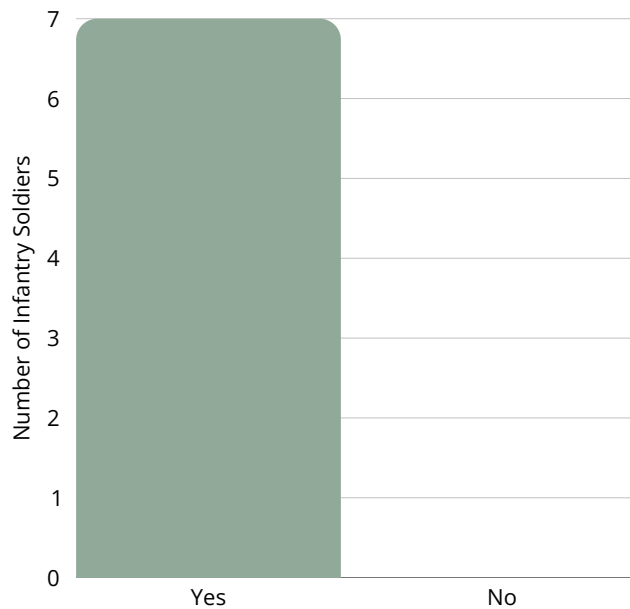


Table 2, Success Rate of Placing Backpack

Seated with Backpack

Seated comfort was rated while sitting in the modified CV90 seat with the backpack on. Participants used a 7-point scale, where 1 indicated very uncomfortable and 7 indicated very comfortable.

Three participants rated the experience as somewhat comfortable (score 5), while four rated it as comfortable (score 6).

"It feels like you're leaning against a backrest, the backpack supports your back."

Seated Comfort Rate

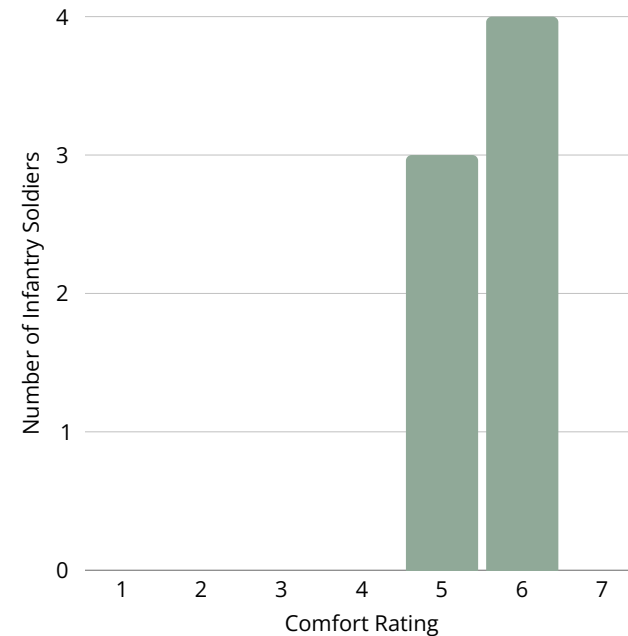


Table 3, Seated Comfort Rate

Removing the Backpack

All participants were able to remove the backpack independently while seated in the adjusted CV90 seat. Four participants chose to use the shoulder-strap clip system for this step, which was generally perceived as convenient.

Using Quick-Release Clip System

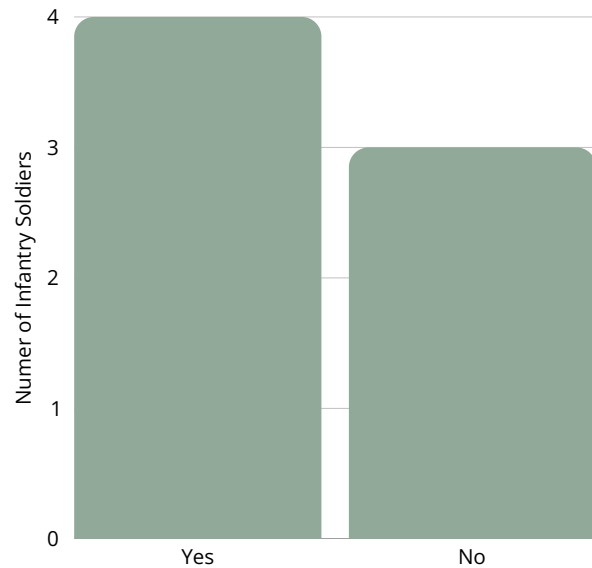


Table 4, Using Quick-Release Clip System

Clip System Detach

The four participants who used the shoulder-strap clip system rated the action as pleasant (score 6) on a 7-point scale, where 1 = very unpleasant and 7 = very pleasant.

"It comes off quickly without snagging, that makes getting out much easier."

Detach Quick-Release Clip System

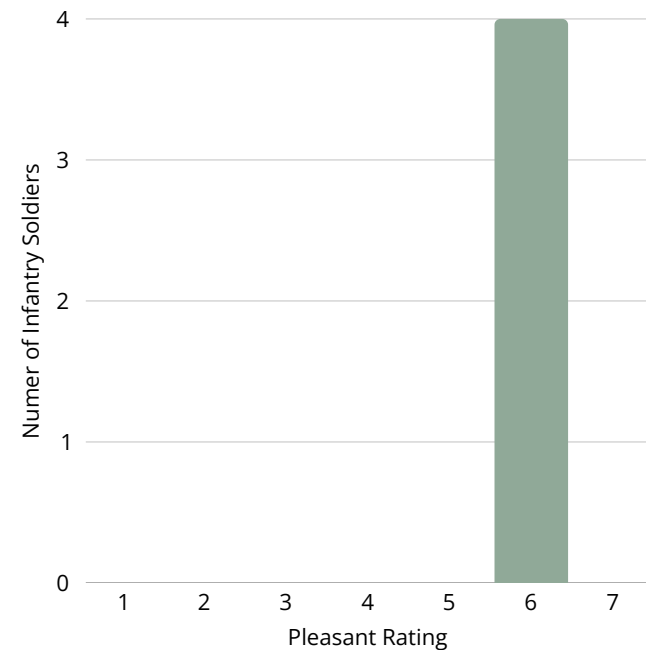


Table 5, Detach Quick-Release Clip System

Test 2, Exiting With Adjusted Backpack

Putting On the Backpack

Six out of seven infantry soldiers were able to put on the adjusted backpack independently while seated in the adjusted CV90 seat. One soldier required assistance from a fellow infantry member to complete this step from the seated position, specifically to help hand over the backpack strap.

Success Rate of Putting On Backpack

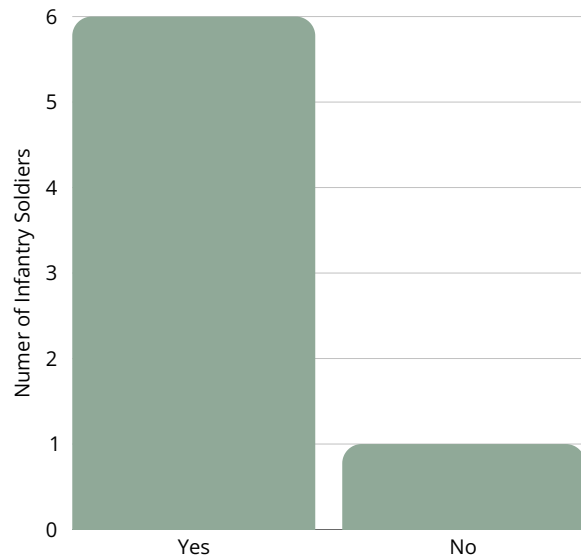


Table 5, Success Rate of Putting On Backpack

Clip System Reattach

While seated with the backpack stored behind, the four participants had to reattach the backpack using the shoulder-strap clip system. Several participants indicated that the straps were difficult to locate and grasp due to limited reach and interference from worn gear.

On a 7-point scale, where 1 = very unpleasant and 7 = very pleasant, three participants rated the action as somewhat unpleasant (score 3), and one as very unpleasant (score 1).

"Finding the clips again is hard, and the movement needed doesn't work well with all this gear on."

Reattach Quick-Release Clip System

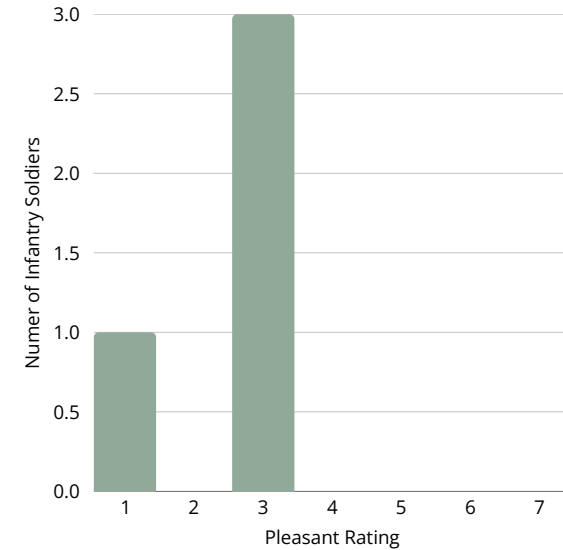


Table 6, Reattach Quick-Release Clip System

Taking Backpack with Exiting

All seven participants were able to take the adjusted backpack out of the vehicle without difficulty. No obstacles or discomfort were reported while exiting the vehicle.

“The slimmer shape makes it less likely to get caught than the current 37L backpack.”

Success Rate of Removing Backpack

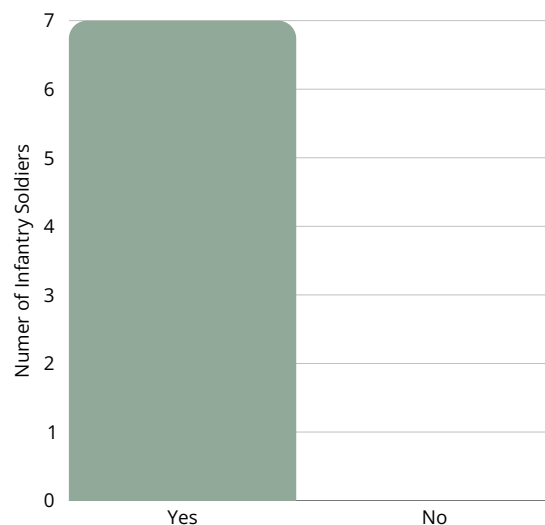


Table 7, Success Rate of Removing Backpack

Additional, Field Use With Adjusted Backpack

Mobility During Field Exercises

Mobility was rated during a standard contact drill, which involved quickly dropping to the ground and executing immediate actions as trained.

The exercise was performed while wearing the adjusted backpack outside the vehicle, in order to evaluate freedom of movement during field use. Participants used a 7-point scale, where 1 indicated very difficult and 7 indicated very easy. Six participants rated the mobility as easy (score 6), while one participant rated it as very easy (score 7).

“The current backpack shoots up into your neck when going to the ground fast. That doesn’t happen with the new one.”

Mobility Ease Rate

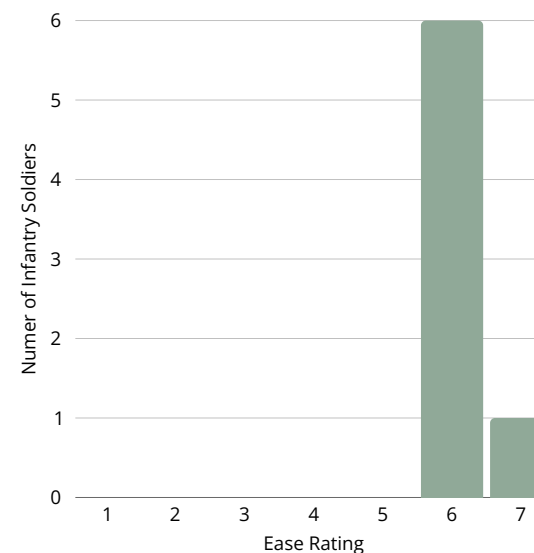


Table 8, Mobility Ease Rate

Compatibility with Eerste Lijn Gear

All seven participants were able to carry their Eerste Lijn gear while wearing the adjusted backpack. None of them reported that the adjusted backpack did interfere with their Eerste Lijn equipment.

"This adjusted backpack looks like the backpack we already use; the Cargo Panel. But it doesn't hold much gear and also gets in the way when sitting, that is nice."

Interfacing with Eerste Lijn Gear

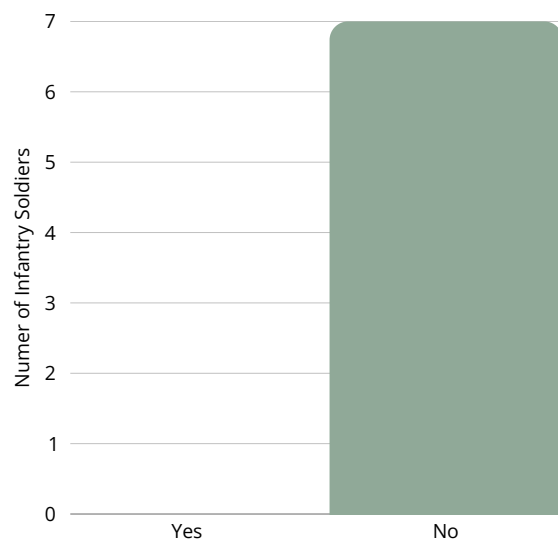


Table 9, Interfacing with Eerste Lijn Gear

Additional Observation

When disembarking without the backpack, the infantry soldier may unintentionally dislodge the bag. In some cases, it becomes entangled and drops to the ground, or shifts into an unstable, tilted position behind the seat.



Figure 61, Backpack On the Ground

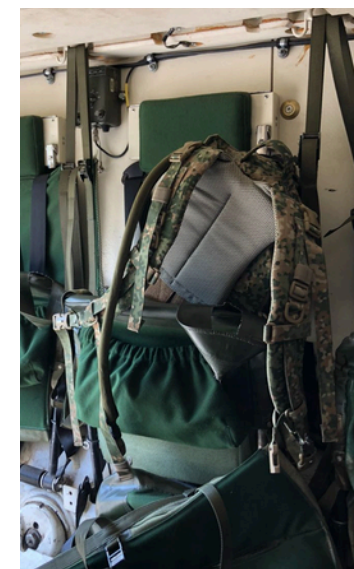


Figure 62, Backpack in Tilted Position

Additional Insight

"Sometimes I have small but important items I want to carry in the bag, but they get lost in the large compartment."

5.4 Improvements

The following points could improve the current prototype:

1. Adding Velcro

Velcro should be added to the front of the bag and the side of the vehicle to ensure the bag stays securely in place when an infantry soldier exits the vehicle without the backpack.

2. Adding Small Pocket

The adjusted backpack currently consists of a single large compartment. It would be useful to add an optional small pocket, for example on the side or back or straps of the backpack, as these areas offer small available space.

3. Expanding Clip System

Putting on the backpack is difficult after using the quick-release system. To make it more user-friendly and easier to locate, the clip could be designed larger.



Figure 63, Improvements After Testing

6

Evaluation

To conclude this project, the unique selling points and limitations of the Portable Backrest concept are presented, followed by the conclusion, recommendations for further development, and a reflection on the project.

6.1 Unique Selling Points

6.2 Limitations

6.3 Conclusion

6.4 Recommendation

6.5 Project Reflection

6.1 Unique Selling Points

The Portable Backrest offers several clear advantages over the current situation. Where the current 37L backpack is large, bulky, prone to snagging on vehicle parts, often in the way, and heavy to carry, the modified version is lighter, more compact, and better integrated into the operational workflow. These benefits occur at multiple stages of use: during storage inside the vehicle, while entering and exiting, and during dismounted actions. The following points highlight these unique selling points:



Secure Storage

The designed location, ensures the backpack to be stored safely. This prevents it from becoming a loose object that could pose a risk during crashes or mine blasts.



Improved Entering and Exiting

No loose gear on the floor and no need to handle the backpack during movement, resulting in smoother and unobstructed access in and out of the vehicle.



Time Efficiency

Soldiers no longer need to take the backpack on or off when entering or exiting the vehicle. This saves time, especially across a full squad of seven.



Reduced Weight

By carrying only mission-essential items, the backpack remains lighter, saving energy for the infantry soldier during dismounted actions.



Increased Mobility

The backpack fits closely to the body and near the soldier's center of gravity, enhancing balance, agility, and comfort during rapid movement.



Reduced Risk of Snagging

The compact design minimises the chance of getting caught on obstacles, enabling quicker movement and improved focus during actions.

6.2 Limitations

Not Tested During Transport

The Portable Backpack has not been tested in a moving vehicle. As a result, there is no insight into the impact on the user from vibrations during transport, prolonged sitting while wearing the backpack, or safety in the event of explosions or crashes.

Limited Number of Users Tested

The concept was tested with only seven infantry soldiers, of whom only two were actual end users. This limits the representativeness of the results.

Not Tested with Full Squad

No test was conducted with a full squad entering and exiting the vehicle during operational procedures. Therefore, the effects on flow, efficiency, and speed remain unknown.

Not Tested with Female Users

No data is available from female infantry soldiers.

Limited Height Range Tested

The test was conducted with individuals between 175 cm and 205 cm.

There is no information on how the concept performs for users outside this height range.

Equipment Configurations Limitations

The current backpack setup is tailored to a specific set of equipment.

In practice, these configurations vary, which may cause the backpack to be incompatible with other setups.

No Room for Comfort Gear

The comfort equipment designed to be stored under the seat may also be needed outside the vehicle. However, due to limited space behind the seat, there is no room to include these items in the adjusted backpack.

No Access to Backpack During Transport

While seated during transport, the user cannot access the backpack mounted on their back. As a result, it is not possible to retrieve or exchange items while the vehicle is moving.

6.3 Conclusion

With the design goal of this project:
"Develop a **safe, robust, and compact** storage solution for military equipment that is **easy to use** and **integrated** within the operational context of armoured infantry vehicles."

The storage solution is a modification of the current 37L backpack, integrated into the backrest of the modified CV90 seat. It serves as a portable backrest in which essential personal gear can be securely stored and quickly accessed.



Safety

Safe to store

The chosen location behind the seat is the safest option in the vehicle for a storage solution. However, it should still be tested under operational conditions, including scenarios involving shocks, impacts, and potential explosions.



Integration

Modularly applicable

The adjusted backpack features a large main compartment that supports a modular layout, allowing for dynamic gear configurations. Integrated into the seat's backrest, it combines storage capability with ergonomic back support.



Volume

Provides sufficient storage capacity

The modified backpack can store the most essential items that the soldier needs to take outside immediately. The enlarged storage compartment under the seat can hold other equipment that must be present in the vehicle but does not always need to be carried outside.



Use

Easy to use

The adjusted backpack is integrated into the seat's backrest to facilitate ease of use, allowing for quick removal, carrying, and reinsertion when exiting and re-entering the vehicle



Technology
Operates under military load

The adjusted backpack and adjusted backrest were both constructed using materials and components already in use during operational deployment. Additional modifications were made using similar materials. This indicates that the solution functions effectively under military load conditions.

6.4 Recommendations

For further development, several steps are recommended:

Conduct Realistic Testing Before Scaling Up

The prototype has not yet been tested under realistic conditions, such as vehicle movement or full squad boarding. A one-week field test with the adapted seat and backpack in a single CV90 is recommended. This will provide essential insights into ergonomics, safety, usability, and allow proper validation of the Program of Requirements and Wishes. Broader implementation should follow only after evaluation.

Compare Portable Backrest with Current Use

The Portable Backrest has been tested independently, without direct comparison to the current storage methods used in the CV90. This was due to limited availability of infantry soldiers who actively operate with the CV90. A direct comparison is recommended to better assess the added value and practicality of the new solution.

Further Testing on Putting On the Backpack

Additional testing is needed to identify a more efficient solution for soldiers to put on the backpack while inside the vehicle. Currently, securing the shoulder straps is difficult and time-consuming. This process should be improved to enable faster and easier use under operational conditions.

Integrate the Under-Seat Pouch

The under-seat pouch has not yet been implemented in the prototype. A larger version of the currently suspended pouch should be developed and added to optimise available space.

Integration In Other Armoured Infantry Vehicles

It is recommended to assess the feasibility of implementing the portable backrest concept in other infantry vehicles. This requires insight into seat types and interior dimensions. If soldiers operate in a similar way, entering and exiting the vehicle with their personal gear, this solution could enhance ease of use and improve operational readiness during dismount.

Integrate Seatbelt into the Portable Backrest

Currently, the standard seatbelt systems are not actively used. To ensure infantry soldiers are transported as safely as possible within the vehicle, it is recommended to explore the integration of the backpack shoulder straps with the seatbelt system into a single, combined solution. This approach could enhance safety, increase compactness, and improve overall efficiency.

6.5 Project Reflection

This graduation project was my first real experience in a company setting. Over the course of five months, I learned a lot, both personally and in terms of content. I gained deep insights into a subject I previously knew very little about.

That said, it wasn't always easy. I struggled with the sheer amount of new information and the challenge of translating complex theory into something practical and usable. I also found out that real-life practice often doesn't line up with theory, which was sometimes quite frustrating.

Still, one of my main goals was to build confidence, and I really feel I achieved that. I'm proud of what I've done, especially organising and building a full-scale prototype and testing it in a real CV90 with actual infantry soldiers in Germany, in a vehicle where almost everyone at the office said there was no space at all to create any kind of storage system.

The interactions with colleagues and military personnel, from casual coffee chats to interactive brainstorming sessions, were just as valuable. I also managed to build strong connections, which made the experience feel even more meaningful.

Looking back, it was intense and sometimes tough, but overall a great experience. I wouldn't have wanted to do any other project, and I'm truly grateful to the people around me who supported and inspired me throughout the process.



Figure 64. Holding the Adjusted CV90 Seat in Front of the Vehicle Used for Testing, Bergen-Hohne

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Appendix

A. Vehicle Consideration

The infantry armored vehicles Boxer and CV90 differ in type, role, armament, protection, and mobility. These characteristics influenced the original design of each vehicle and result in fundamental technical, functional, and structural differences between them (Ministry of Defence, n.d.-d; Ministry of Defence, n.d.-e). According to vehicle specialist G. van Huissteden, these differences mean that the two vehicles operate in distinct ways and cannot be directly compared (personal communication, 2025). To provide insight into these differences, the following table has been included.

Characteristic	Boxer	CV90	Difference
Type	Armoured wheeled vehicle (8x8)	Tracked vehicle	The CV90 uses tracks for off-road mobility; the Boxer is faster on roads and offers more comfort for passengers.
Role/Purpose	Troop transport	Troop transport and combat vehicle	The Boxer is designed for transporting infantry; the CV90 is built for firepower and combat deployment.
Armament	Lightly armed (.50 caliber machine gun)	Heavily armed (35 mm cannon)	The Boxer plays a supporting and evasive role; the CV90 is offensive and directly engaged in combat situations.
Protection	Modular armor, primarily against IEDs	Heavy armor + active protection system	The Boxer offers broader protection against explosives; the CV90 is more heavily armored for frontline engagement.
Mobility	Wheeled vehicle, fast and agile on roads	Tracked vehicle, powerful in rough terrain	The Boxer is quieter and faster; the CV90 performs better in difficult terrain but is slower.
Crew	9 personnel (3 crew + 6 infantry)	10 personnel (3 crew + 7 infantry)	The internal layout and configuration differ significantly; the Boxer offers more space for tools and equipment.

Table 10, Boxer VS CV90

B. Boxer Storage

Insight:

Storage locations 2, 3, 5, and 6 are not accessible to infantry while seated. This is because the seat must be folded forward to reach them. This insight is relevant, as certain items may need to be accessible from a seated position.

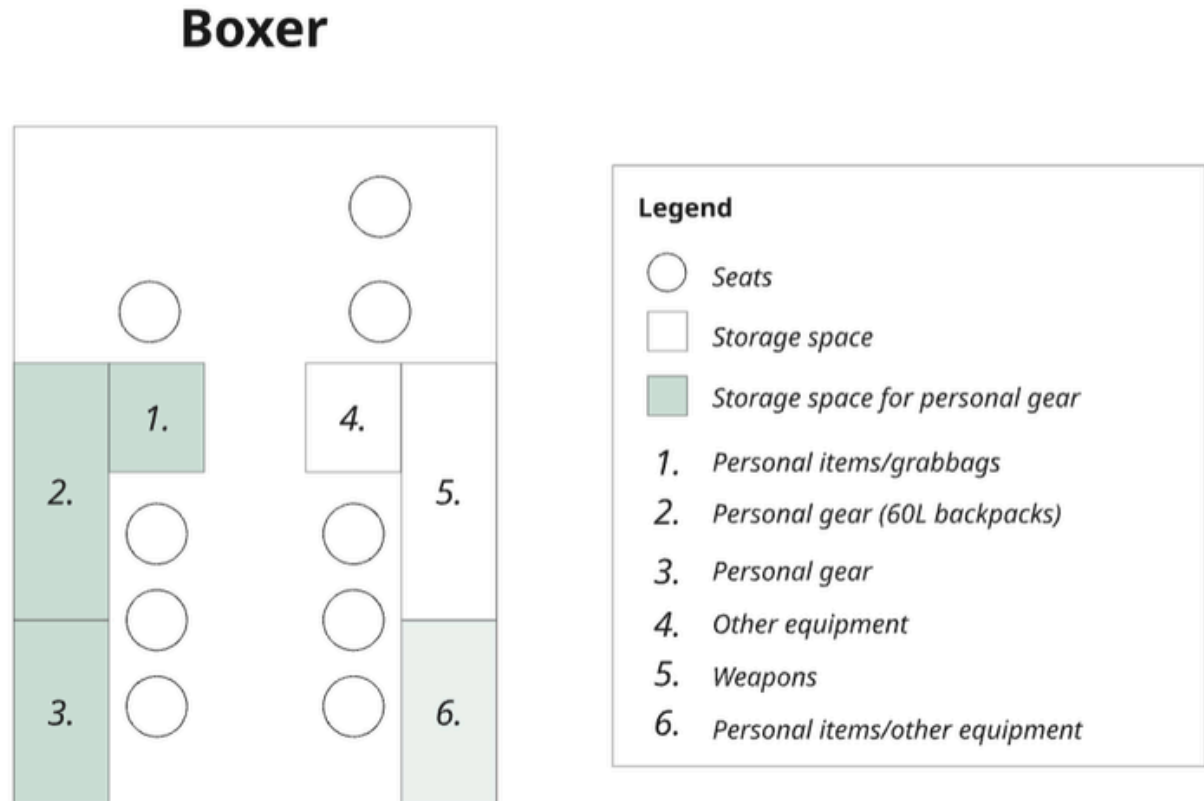


Figure 65, Schematic Representation Boxer Storage Top View

C. Persona

MILAN VAN DIJK

FINISHED EDUCATION: High school

RANK: Private Second Class

AGE: 29

GENDER: Male

LOCATION: Johannes Postkazerne, Havelte

"IT'S NOT ABOUT THINKING BUT DOING"

ABOUT

My name is Milan van Dijk, a disciplined infantryman in the 43 Mechanised Brigade. After high school, I chose a challenging career in the Royal Netherlands Army to prove myself to my family.

PERSONALITY

Loyal ●●●●●

Disciplined ●●●●●

Decisive ●●●●●

Delicate ●●●●●

SKILLS

Physical fitness

Teammplayer

Cognitive capacity

GOALS

- Going on deployment
- Moving up in rank
- Improving leadership skills
- Pushing my physical and mental limits.

IDENTIFYING LOGO'S

Figure 66, Persona of User

H. Creative Group Brainstorm

Participants:

- Gerben – Engineering department, background in Integrated Product Design (IPO)
- Albert – Engineering department, background in Integrated Product Design (IPO)
- Mark – Engineering department, background in Integrated Product Design (IPO)
- Lean – Intern, background in Mechanical Engineering
- Isabel – Participated actively to encourage equal contribution, foster engagement, and support team-driven idea generation.

Location: K8, COMMIT, 2nd Floor, Meeting Room

Date: 05-03-2025

Objective

To generate, combine, and discuss ideas with participants who are already somewhat familiar with the project, in order to gain new inspiration and valuable input.

Ground Rules

- The crazier, the better
- Respect each other
- No idea is wrong, anything shared can lead to new insights

Materials

- Post-its
- Markers
- Cookies and coffee
- Paper
- Colored pens and markers
- Photos taken during the session
- Audio recording of the discussion
- Activities

Assignment 1: HKJ's (1 minute per round)

Questions to spark creativity:

- How can you attach something?
- How can you store something?
- How can you carry something?
- How can you make something smaller?
- How can you use space more efficiently?

Assignment 2: Combine (5 minutes)

Select 3 to 4 elements and sketch a concept idea by merging them.

Assignment 3: Pitch Your Idea

Present your idea as convincingly as possible – the goal is to persuade others of its value and potential.

Assignment 4: SCAMPER Method (1-2 minutes per round)

Rotate through each idea using the SCAMPER technique (Figure X). After each round, briefly explain your changes.

- Substitute

What parts or materials can be replaced? Can a function be fulfilled differently?

- Combine

Can you merge elements to create something new?

- Adapt

What can you adapt to improve it?

- Modify

What happens if you enlarge or reduce something?

- Put to Another Use:

Can it be used for a different purpose?

- Eliminate

What can be removed to simplify or improve effectiveness?

- Reverse/Rearrange

Can you change the order or reorganise the components?

Assignment 5: Open Discussion & Wrap-Up

Free discussion to reflect on ideas and share final thoughts.

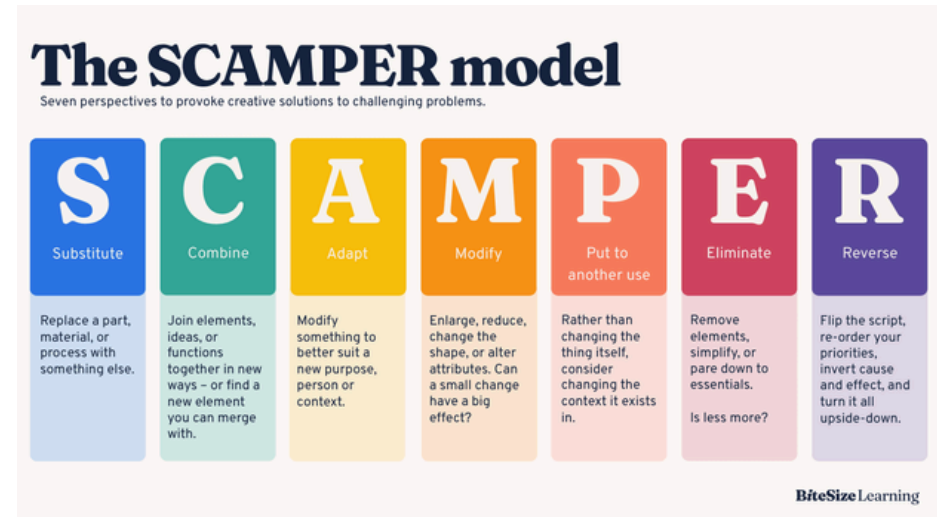


Figure 67, SCAMPER Method Image

F. Process Overview

1. Location

Defining location



2. Sketching

Concept sketching



3. Mockup

Prototyping mockup



4. Volume check

Placing gear



5. Integration

Fit check Combat Vest



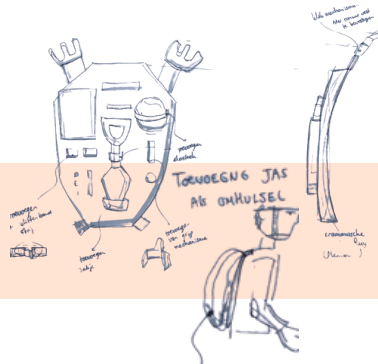
1. Location

Defining location



2. Sketching

Concept sketching



3. Mockup

Prototyping mockup



4. Volume check

Placing gear



5. Integration

Fit check Combat Vest



G. HKJ Method

Space Optimization Strategies



vacuum



squeezing



folding/flattening



shrinking



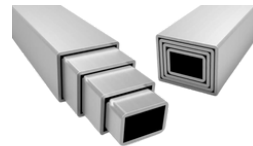
roll



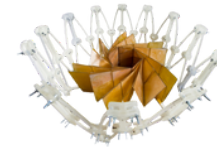
Stacking



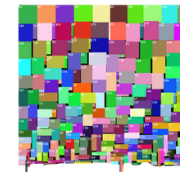
in-&deflating



telescoping



Origami Engineering



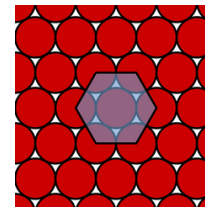
Rectangular Packing



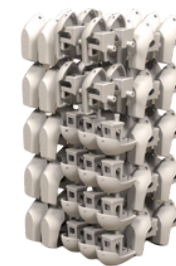
Interlocking



Nested Stacking



Hexagonal Packing



3D
Nesting

Figure 70, HKJ Method Space Optimization Strategies



HKJ FASTEN SOMETHING

Figure 71, HKJ Method Fasten Something

H. Water-Fill Experiment

To test the capacity, a garbage bag was placed inside the adjusted backpack and filled with water using a measuring cup. The backpack held 16 liters up to the top.



Figure 72, Water-Fill Experiment

