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Next generation connectivity for enhanced, safe & efficient transport & logistics

D8.6: MOOC

Autonomous Vehicles in Logistics

Work package	WP 8
Task	Task 8.1 Dissemination and communication
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Deliverable lead	HZ University of Applied Sciences (HZ)
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Abstract

The objective of deliverable 8.6 is to present an educational program that aims to become directly available on a European scale by means of a Massive Open Online Course (MOOC). The intended audience for the MOOC is broad and ranges from students to professionals, and anybody interested in the logistics sector, willing to deepen their knowledge about the application of autonomous vehicles (AVs) in logistics. The course provides a comprehensive outlook on the relevant features, technological aspects, and characteristics of autonomous vehicles and their potential applications in logistics and will purvey tools helping to tackle the challenges that the application of AVs will bring. The chosen format consists of online lectures and tests made available via an online learning environment. The MOOC spans eight weeks, and can be followed by participants at their own pace. Deliverable 8.6 presents an overview of the objectives, principles, structure and content of the MOOC.

Keywords:

Teleoperated driving, platooning, autonomous vehicles, applications in logistics, online course, education, MOOC

Document Revision History

Version	Date	Description of change	List of contributor(s)
V0.1	03-11-2023	First draft of the document	Evelot Westerink-Duijzer (HZ)
V0.2	27-11-2023	Internal review	Wolfert Otte (HZ)
V0.3	01-12-2023	External review	Rakshith Kusumakar (V-tron on behalf of HAN), Vasilis Maglogiannis (imec), Dries Naudts (imec), Johann Marquez-Barja (imec)
V1.0	12-12-2023	Final editing	Evelot Westerink-Duijzer (HZ)

Disclaimer

Project co-funded by the European Commission under H2020-ICT-2018-20		
Nature of the deliverable:	R	
Dissemination Level		
PU	**Public, fully open, e.g. web**	√
CI	Classified, information as referred to in Commission Decision 2001/844/EC	
CO	Confidential to 5G-Blueprint project and Commission Services	

* R: Document, report (excluding the periodic and final reports)

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

OTHER: Software, technical diagram, etc

EXECUTIVE SUMMARY

The objective of deliverable 8.6 is to present an educational program that aims to become directly available on a European scale by means of a Massive Open Online Course (MOOC). The course provides a comprehensive outlook on the relevant features, technological aspects, and characteristics of autonomous vehicles (AVs) and their potential applications in logistics and will purvey tools helping to tackle the challenges that the application of AVs will bring.

The MOOC focuses on a broad range of participants, that may fall under one of the following profiles:

- **Students** who are interested in mobility, logistics, supply chain management, etc.
- **Knowledge and research institutes** that are active in the area of logistics
- **Road authority and infrastructure planners** who will be responsible for managing the integration of autonomous vehicles into the current system
- **Logistics and terminal operators** who will have to adapt their operations to the arrival of the AVs
- **Automotive industry managers and OEMs** who will integrate autonomous technology into their vehicles
- **Any non-professionals** who are interested in the application of autonomous vehicles in logistics

The course consists of video lectures with accompanying slide sets, as well as assignments. There is also an online discussion forum to get in touch with other students that can largely facilitate the interaction among involved attendees. Participants can also receive online support from lecturers and their peers via the online discussion forum.

The course is comprised of three modules: Introduction to autonomous systems, Technology, and Teleoperation. Each of these modules contains several sub-modules on topics like the intermediate steps toward full automation; teleoperation on the road and on waterways; 5G technology in teleoperation. Several project partners contributed to the MOOC by giving an online guest-lecture.

After completing each module, participants can test themselves with formative knowledge tests (multiple choice), aimed at understanding and being able to apply the knowledge.

The MOOC is made available via the online learning environment of HZ University of Applied Sciences: HZ Learn. Interested participants can register themselves and will receive a username and password to access this online learning environment. Participants have access to the course material until the end of the project, December 31, 2023. In the first quarter of 2024 the course material will be transferred to another platform, where the material remains openly available.

Attendees can get a participation certificate upon the completion of the course credited by the 5G-Blueprint project, provided that they complete all units and obtain a sufficient score for each test by the intended deadline.

In total 28 people registered for the course of which 9 completed all modules and earned the certificate.

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ABBREVIATIONS

AVs	Autonomous Vehicles
CAD	Connected and Automated Driving
CAM	Connected and Automated Mobility
CAPEX	Capital Expenditure
ECTS	European Credit Transfer and Accumulation System
MOOC	Massive Open Online Course
OEMs	Original Equipment Manufacturer
OPEX	Operational Expenditure
SPOC	Specific Private Online Course

1. INTRODUCTION

1.1 Connected and Automated Driving

Connected and Automated Driving (CAD) is expected to revolutionize transportation and logistics by providing benefits such as safety, traffic efficiency, comfort, and reducing emissions (Elliott et al., 2019). Recent advancements in vehicle and communication technologies have enabled connected and automated driving in certain controlled environments (e.g., driving in motorways under normal weather conditions). However, some technological challenges for enabling connected and automated driving in all driving domains and under all conditions remain unresolved.

According to SAE International (2021), there are five levels of vehicle automation. Driving automation systems at level-1 and level-2 provide the driver with longitudinal and lateral control (i.e., adaptive cruise control and lane keeping). Such technologies are available on some vehicles currently sold on the market. At level-3, automated driving systems monitor the environment and execute driving tasks on certain operating design domains (e.g., driving in motorways), allowing the drivers to avert their attention from driving tasks while being ready to take back control in case of a failure in the automated driving system. Level-4 automated driving systems are expected to handle the fail-safe situation autonomously; however, within a limited operating design domain. Therefore, level-3 and level-4 vehicles cannot activate their automated driving systems in all driving domains. Finally, level-5 refers to fully autonomous vehicles with unlimited operating design domains.

1.2 Impact of Connected & Automated Driving

For passenger cars, it is likely that the level of autonomy will increase step by step when the technology makes it possible to drive the car autonomously in more driving domains. In logistics and other commercial applications, there is only a positive business case for autonomous driving if a driver is no longer needed in the vehicle. The development of autonomous transport in commercial operation may become financially feasible when vehicles are teleoperated, whereby a driver controls the vehicle remotely. It will then be possible to gradually increase the level of autonomy and to have the operators monitor and support multiple vehicles instead of a single vehicle, like a driver.

Teleoperated driving is expected to have major implications for logistics or fleet operations. Goodall (2020) analyses the operational performance of fleets of teleoperated vehicles. The author assumed that a team of teleoperators would be responsible for monitoring a large fleet of automated vehicles and would take control of the vehicle upon request by the vehicles' automated driving system. Such concepts are relevant when the teleoperated vehicles are level-4 automated vehicles. Teleoperation can also enable passenger car and truck platooning (Bhoopalam et al., 2018; Boban et al., 2018), which can significantly reduce logistics or fleet operations costs and environmental impacts.

1.3 Goal of 5G-Blueprint

The overall objective of the 5G-Blueprint project is to design and validate a technical architecture, business and governance models for uninterrupted cross-border teleoperated transport based on 5G connectivity. The project's outcome should be usable as the blueprint for subsequent operational pan-European deployment of teleoperated transport solutions in the logistics sector and beyond.

To achieve this, the 5G-Blueprint will explore and define:

- The economics of 5G tools in cross border transport & logistics as well as passenger transport: bringing CAPEX (capital expenditure) and OPEX (operational expenditure) into view, both on the supply (telecom) side and the demand (transport & logistics) side for the transformation of current business practices as well as new value propositions
- The Governance issues and solutions pertaining to responsibilities and accountability within the value chain dependent on cross border connectivity and seamless services relating to the Dutch & Belgian regulatory framework (telecommunications, traffic and CAM (Connected and Automated Mobility) experimentation laws, contracts, value chain management)
- Tactical and operational (pre-) conditions that need to be in place to get the full value of 5G tooled transport & logistics. This includes implementing use cases that increase cooperative awareness to guarantee safe and responsible teleoperated transport. Tele-operation will be enabled by the following 5G qualities, such as low latency, reliable connectivity and high bandwidth that current 4G LTE cannot deliver sufficiently.

1.4 Objective of Deliverable 8.6

The task of Work Package 8 of the 5G Blueprint-project is to define and implement a comprehensive and effective set of dissemination and communication activities, creating awareness about project results and stimulating involvement of private and public stakeholders.

Task 8.6 in the 5G-BP project is to develop an educational program that aims to become directly available on a European scale by means of a Massive Open Online Course (MOOC). The MOOC will be freely available until the end of the project for students, professionals, and anybody interested in the logistics sector and willing to deepen his/her knowledge about the application of autonomous vehicles in logistics. After the closure of the project, participants can no longer receive support, but the course material will remain openly available.

The course will provide a comprehensive outlook on the relevant features, technological aspects, and characteristics of autonomous vehicles and their potential applications in logistics and will purvey tools helping to tackle the challenges that the application of AVs will bring.

Deliverable 8.6 (the MOOC) is developed in close relation to Deliverable 8.5 (the minor). There is some overlap between the two reports, to ensure that both documents can be read independently.

1.5 Outline of the deliverable

Deliverable 8.6 consists of six chapters. Chapter 2 introduces the MOOC and explains the relation to the minor (Deliverable 8.5). In Chapter 3, we describe the objectives and learning objectives of the MOOC. Chapter 4 contains the setup and structure of the MOOC. Chapter 5 deals with the content (structure and content of the lessons and assignments and the partners involved) of each module. In Chapter 6, we evaluate the MOOC and present statistics on the participants.

2. DEVELOPMENT

2.1 Introduction and purpose

Deliverable 8.5 on the 'Minor-course Automated Vehicles in Logistics' explains the development of an online course in the form of a Massive Open Online Course (MOOC) or a Specific Private Online Course (SPOC). In this section we briefly explain those two formats, and mention which one was chosen.

A MOOC is an online course aimed at unlimited participation and open access via the internet. In addition to traditional course materials, such as filmed lectures, readings, and problem sets, many MOOCs provide interactive courses with user forums or social media discussions to support community interactions among students, professors, and teaching assistants, as well as immediate feedback to quick quizzes and assignments.

Alternative to a MOOC, a Specific Private Online Course (SPOC) supports blended learning and flipped classroom learning, which variously combine online resources and technology with personal engagement between faculty and students. Early research results point to improved learning and student outcomes using such approaches. When a SPOC is implemented at an institution, faculty determines which features and course content to utilize. This can include video lectures, assessments (with immediate feedback), interactive labs (with immediate feedback) and discussion forums used in MOOCs. Using MOOC technology allows the faculty to organize their time with students in different ways, such as allowing more time in class for project-based work instead of grading assignments or preparing lectures. SPOCs have been analogized to "next-generation textbooks," by allowing faculty to decide how to use some or all parts of the SPOC. In a SPOC as well as in a MOOC, students typically access interactive content at their own pace. Unlike MOOCs, SPOCs have limited enrolment and are often used as part of a course for credit.

The online course developed for Deliverable 8.6 bears the most similarity to a MOOC. The advantage of the MOOC-setting is that the course material is widely available for anyone interested. The disadvantage of this setup is that it is difficult to offer real-life projects for students to work on. Such real-life projects are therefore not included in the MOOC.

2.2 MOOC design

The MOOC is structured alongside three modules, together covering the characteristics of autonomous vehicles and their potential applications in logistics. In each module, knowledge is offered in the form of reading material, lectures and videos. Students can test themselves with formative knowledge tests (multiple choice), aimed at understanding and being able to apply the knowledge. These tests give the students insight into their knowledge level and they can verify whether their knowledge is already up to standard. Students can receive online support from lecturers and their peers via the online discussion forum. Figure 1 presents the designed structure of the MOOC.

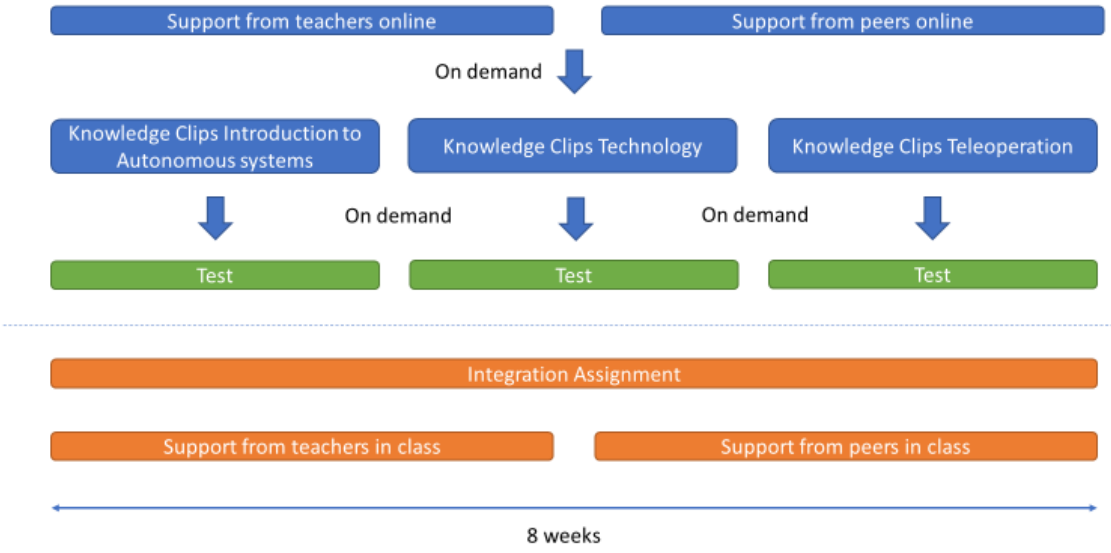

Figure 1: Design of the MOOC

Lecturers can integrate the course material of the MOOC into their own teaching program by offering building blocks (lectures, video's and assignments) to students for self-study. By using the course material from the MOOC in a SPOC-like fashion, lecturers can offer discussions and feedback sessions to have direct contact with their students to guide and support them. It also allows schools to add their own integration assignment in which knowledge from all three modules is combined. This assignment then must be assessed by the home university. The option to use the course material of the MOOC within own education programs is represented by the orange blocks in Figure 1.

2.3 Relation to minor

The MOOC is related to the minor program 'Automated Vehicles in Logistics', delivered as Deliverable 8.5 of the 5G-Blueprint project. The minor is an educational program for bachelor students in which students can explore, understand and apply the technical aspects and characteristics of autonomous systems and explore potential applications and their impact on mobility and society in general. The minor is offered as a physical educational program at HZ University of Applied Sciences. To expand the exposure of the educational material developed, the minor is converted into a MOOC. The MOOC aims at a more general audience and allows participants to follow the program independently via the Internet. More information on the minor is provided in the report of Deliverable 8.5.

If we compare the content of the minor and the MOOC, there are substantial similarities. The minor consists of four themes: Technology, Applications, Innovation Eco-system and Societal impacts. The content of these four themes is covered in the three modules of the MOOC. Figure 2 illustrates the overlap in content between the minor and the MOOC.

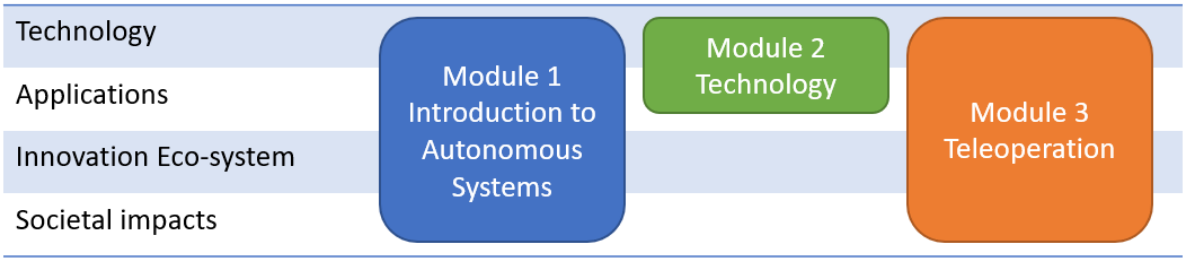

Figure 2: Content relation between minor themes and MOOC modules

3. LEARNING OBJECTIVES

3.1 Human capital challenges

The development of CAD not only impacts the functioning (flow, safety and costs) of the traffic and transport system, it also offers opportunities for new applications, services and business models. For example, autonomous or teleoperated taxis can lower the barrier to flexible and on-demand solutions through technology and lower costs and provide mobility services in times and places where services are currently not financially feasible or affordable, such as overnight or rural transportation services.

CAD will also lead to the adaptation of logistics processes and structures. CAD makes it possible to handle more logistics flows at night by setting up hubs that can load, unload or connect and disconnect trailers at night so that the logistics traffic will burden the road network in a different way. 24-hour operations also mean that lead time in logistics networks can be shortened and that the distance between warehouse and customer can be increased. Logistics service providers and shippers can therefore manage with fewer, but larger warehouses. As a result, locations and requirements for warehouses (in volume) may change in the future.

The development and implementation of these new applications, services and business models generates new application-related issues for companies and governments. The challenge is not only to develop knowledge about the technology for this development, but also knowledge and skills about the application of CAD to ensure the successful introduction and adoption of these systems.

In this phase of the development of autonomous transport, there is a particular demand for technically trained professionals in the fields of Sensoring, Data Science and Artificial Intelligence. As technology continues to develop and autonomous vehicles can be used in more situations, it will become interesting for companies, governments and social organizations to develop and implement concrete applications of autonomous vehicles. This requires professionals who can properly design, organize and manage solutions in which autonomous systems play a role. These professionals have a good understanding of the technical possibilities and impossibilities and have in-depth knowledge of the application domain to seamlessly integrate solutions with autonomous vehicles.

3.2 Objective of the MOOC

The objective of the MOOC Autonomous Vehicles in Logistics is to provide a comprehensive outlook on the relevant features, technological aspects, and characteristics of autonomous vehicles and their potential applications in logistics. The MOOC will also present tools helping to tackle the challenges that the application of AVs will bring. The MOOC is intended for a broad audience of students, professionals, and anybody interested in the logistics sector, and willing to deepen their knowledge about the application of autonomous vehicles in logistics.

3.3 Learning objectives of the MOOC

After completing the MOOC, participants:

1) Know the characteristics of autonomous transport systems
2) Understand what the impact of autonomous systems and teleoperation can be on transport systems and society

3) Are aware of technologies like teleoperation and platooning as intermediate steps toward full automation
4) Understand the most important technical, organizational, economic and social issues in the introduction and application of autonomous systems
5) Know various applications of teleoperation on roads and waterways
6) Can explain which stakeholders play a role in the development and application of autonomous vehicles
7) Understand the impact of 5G technology on teleoperation
8) Understand the business and governance aspects of teleoperation

These learning objectives will be measured with formative knowledge tests consisting of multiple choice questions. In Section 6.2 we evaluate these learning objectives.

3.4 Target groups

The MOOC focuses on a broad range of participants, that may fall under one of the following profiles:

- **Students** who are interested in mobility, logistics, supply chain management, etc.
- **Knowledge and research institutes** that are active in the area of logistics
- **Road authority and infrastructure planners** who will be responsible for managing the integration of autonomous vehicles into the current system, including the authorities that are responsible for approving the vehicles on the road
- **Logistics and terminal operators** who will have to adapt their operations to the arrival of the AVs
- **Automotive industry managers and OEMs** who will integrate autonomous technology into their vehicles
- **Any non-professionals** who are interested in the application of autonomous vehicles in logistics

Note: Participants are not required to have specific previous education in the AV field.

4. ORGANISATION

4.1 Structure

The course consists of video lectures with accompanying slide sets, as well as complimentary optional reading material, and assignments. There will also be a discussion forum to get in touch with other students that can largely facilitate the interaction among involved attendees.

The course is comprised of three modules: Introduction to autonomous systems, Technology, and Teleoperation. Each of these modules contains several sub-modules as follows:

1. **Introduction to autonomous systems**
   - 1.1. Features of AVs and State of the art (Andres Caballero Rosas)
     Main characteristics of AVs such as self-driving, self-awareness, and safety features and the state of the art on application of AVS
   - 1.2. Advantages & disadvantages (Evelot Westerink-Duijzer)
     Pros and Cons of applying AVs
   - 1.3. Use cases description (Maarten van Oeveren)
     Different use cases for the application of AVs
   - 1.4. Intermediate steps toward full automation (Nadia Pourmohammadzia)
     Teleoperation and platooning as short-term solutions for autonomy

2. **Technology**
   - 2.1. Localization (Maarten van Oeveren)
     Localization of AVs, its importance, and methods
   - 2.2. Perception (Maarten van Oeveren)
     Perception of AVs, its importance, and requirements
   - 2.3. Prediction and routing (Maarten van Oeveren)
     The way prediction and routing work for AVs
   - 2.4. Motion planning (Maarten van Oeveren)
     The way motion planning works for AVs

3. **Teleoperation**
   - 3.1. Teleoperation on the road (Bas Hetjes and Gijs van Stekelenburg)
     The application of teleoperation in roadways
   - 3.2. Teleoperation of barges (Ghazaleh Kia)
     The application of teleoperation on waterways
   - 3.3. 5G technology in teleoperation (Johann Marquez-Barja)
     The impact of 5G technology on teleoperation
   - 3.4. Business and Governance (Asma Chiha eb Harbi)
     Business and governance aspects of teleoperation

As can be seen in the structure above, several project partners contributed as guest-lecturers to the MOOC. A more extensive overview of the contributors can be found in Section 4.6.

4.2 Platform

The online course Autonomous Vehicles in Logistics is made available online via the online learning environment of HZ University of Applied Sciences, HZ Learn. The MOOC is advertised with a flyer (see Appendix A), which includes a link to a form where people can register (see Appendix B).

After registration people receive a username and password with which they can access the course material on HZ Learn. The following figures show some screenshots of the online learning environment.

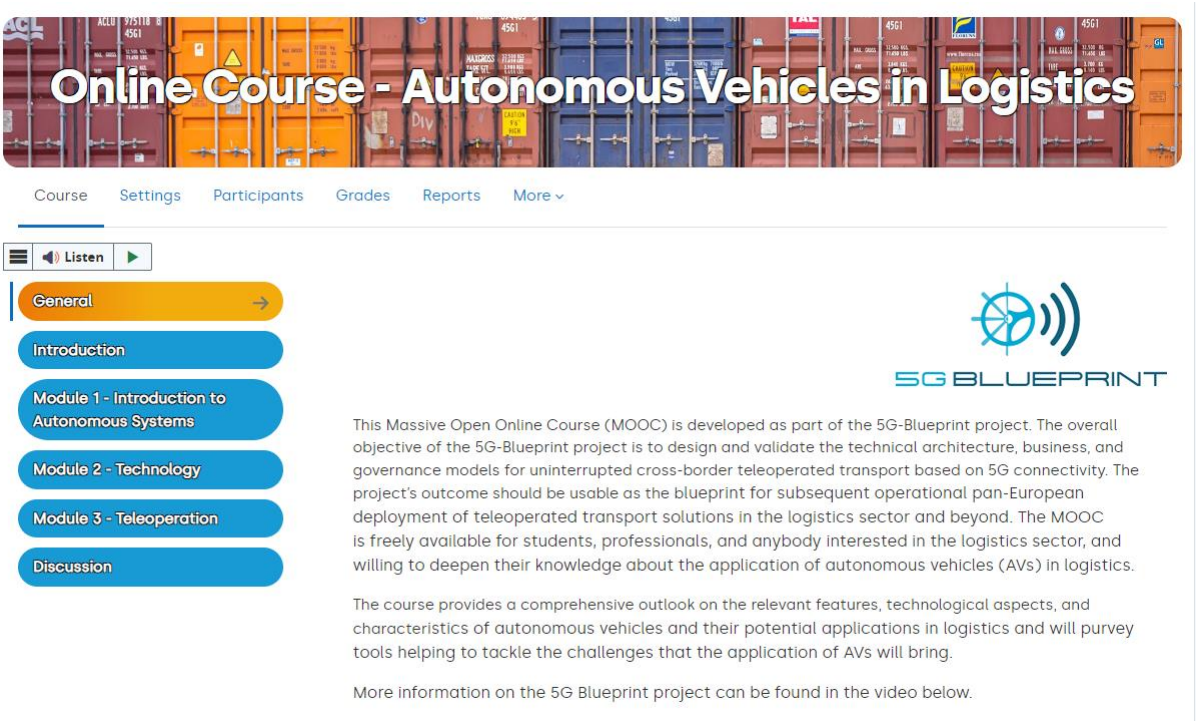

Figure 3: Screenshot of online learning environment (opening page)

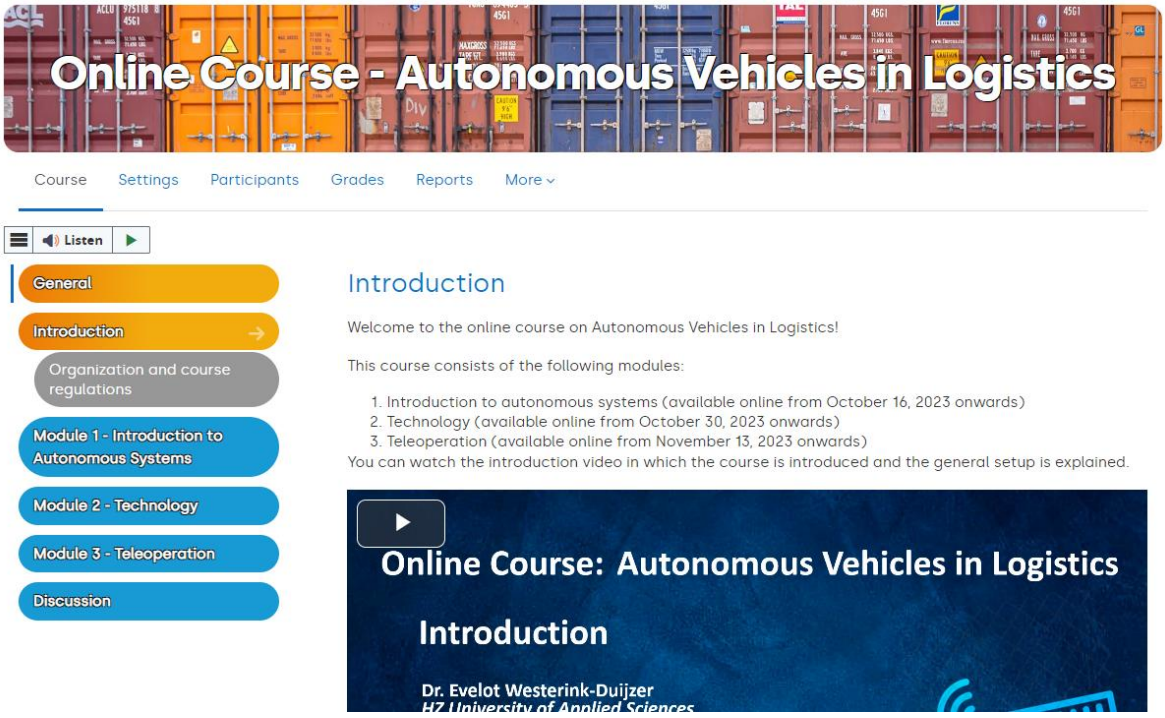

Figure 4: Screenshot of online learning environment (introduction page)

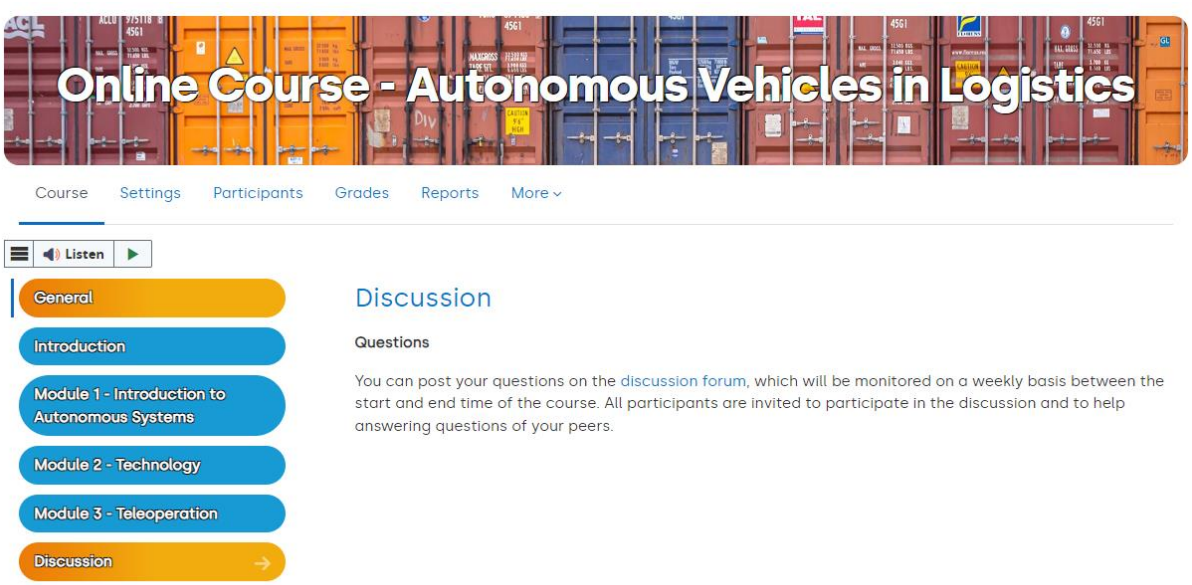

Figure 5: Screenshot of online learning environment (discussion forum)

4.3 Timing

The kick-off of the course took place on October 9, 2023. Course material was available online from that date onwards, and the modules are released over time according to the following schedule.

		Oct 9-13	Oct 16-20	Oct 23-27	Oct 30 - Nov 3	Nov 6-10	Nov 13-17	Nov 20-24	Nov 27 - Dec 1
	Kick-off								
Module 1	1.1								
	1.2								
	1.3								
	1.4								
	Test								
Module 2	2.1								
	2.2								
	2.3								
	2.4								
	Test								
Module 3	3.1								
	3.2								
	3.3								
	3,4								
	Test								

Figure 6: Schedule of the MOOC

After registering for the course, participants can follow the course at their own pace. They do not have to follow the above course schedule. This schedule is provided as a guideline for participants: if they follow this schedule, all material will be available on time and participants can complete the MOOC before the final deadline.

4.4 Assessment and certificates

Each of the three course modules can be completed with a test consisting of 16 multiple-choice questions. These tests are intended for the participants to check their own progress and understanding of the course material. The number of times a participant can take a test is unlimited and the tests will be checked and graded automatically.

Table 1 shows the relation between the learning objectives and the test questions. Many questions cover multiple learning objectives, but we assigned them here to the objective that fits the most.

Learning objectives	**Test Module 1**	**Test Module 2**	**Test Module 3**
1) Know the characteristics of autonomous transport systems	Question 1-4		
2) Understand what the impact of autonomous systems and teleoperation can be on transport systems and society	Question 5-8		
3) Are aware of technologies like teleoperation and platooning as intermediate steps toward full automation	Question 13-16		
4) Understand the most important technical, organizational, economic and social issues in the introduction and application of autonomous systems		Question 1-16	
5) Know various applications of teleoperation on roads and waterways	Question 9-12		Question 1-6
6) Can explain which stakeholders play a role in the development and application of autonomous vehicles	Covered in various questions and in the course introduction.		
7) Understand the impact of 5G technology on teleoperation			Question 7-12
8) Understand the business and governance aspects of teleoperation			Question 13-16

Table 1: Relation between the learning objectives and the tests.

Attendees can get a certificate upon the completion of the course credited by the 5G-Blueprint project, provided that they complete all units and obtain a sufficient score for each test by the intended deadline (sufficient is a score of 10 correct out of the 16 questions). The certificate is a proof of participation, but no ECTS points are awarded for completing the MOOC.

In consultation with Maria Chiara Campodonico from Martel, it was concluded that Martel would provide a format for the certificates. HZ University of Applied Sciences would then monitor the progress of participants in the MOOC and would use the provided format to hand out certificates to participants who fulfilled all the requirements. The format for the certificate can be found in Appendix C.

After the ending date of the MOOC (December 1, 2023), the course will be archived, which means you can review the course content but can no longer participate in graded assignments or work towards earning a certificate. Access to the learning environment lasts until December 31, 2023, after which the material can no longer be accessed and support will no longer be available. We refer to Section 6.3**Error! Reference source not found.** for a discussion on f urther development and longer availability of the course material.

4.5 Promotion

The course is promoted through a campaign advertised by HZ University of Applied Science's channels, social media, and personal networks, together with Martel-Innovate's efforts. A flyer is developed (see Appendix A) to facilitate this promotion.

The MOOC was mentioned in the 5GBlueprint Newsletter of October 2023: https://mailchi.mp/d1ad19571517/5g-blueprint-newsletter-13918414

We also refer to the website of the 5GBlueprint project for an announcement on the MOOC: https://www.5gblueprint.eu/the-hz-university-massive-open-online-course-mooc/

When the last module of the MOOC was released on October 13, a LinkedIn message was posted on HZ University of Applied Science's social media channel to promote the course one more time. This message is displayed below and can be found online via the following link.

> The Supply Chain Innovation research group of HZ University of Applied sciences has developed a Massive Open Online Course (MOOC) on **#autonomoustransport**, **#transportation** and **#logistics**. The group created it as part of the 5G Blueprint project. In this project, the partners are investigating how teleoperation (operating a machine remotely) can make transportation and logistics more efficient, including across borders. Read more here: **https://lnkd.in/ejWAZsGv** **#h2020** **#5G**

Together with this LinkedIn message, also a news message on the website of HZ University of Applied Sciences was posted: https://hz.nl/en/applied-research/news/massive-open-online-course-on-autonomous-transport

4.6 Contributors

The following people have contributed to the MOOC:

1. **Wim Vandenberghe (senior ITS advisor, Dutch Ministry of Infrastructure and Water Management)**

Wim has a background in computer science, with an emphasis on wireless networks. He has been working on C-ITS / CCAM topics since 2007, first in an academic setting, then in industry, and now in the public sector. He currently works at the Dutch Ministry of Infrastructure and Water Management where he is the coordinator of the 5G-Blueprint project.

2. **Andres Caballero Rosas (Researcher, HZ University of Applied Sciences)**

Andres is a lecturer and researcher in the Supply Chain Innovation lectorate at HZ. He obtained his MSc in Innovation Management from the Eindhoven University of Technology. He has a 15-year experience in multiple tactical and operational roles in the supply chain field in the automotive and chemical industries. His current interest is in autonomous shipping technologies and digitalization in smart logistics assets.

3. **Evelot Westerink-Duijzer (Researcher, HZ University of Applied Sciences)**

Evelot is a researcher in Supply Chain Innovation at HZ University of Applied Sciences, joining the group in 2022. After a completing a masters in Econometrics and Operational Research, she did her PhD in Operational Research focusing on healthcare logistics. Within the research group Supply Chain Innovation at HZ University of Applied Sciences, Evelot is researcher and

project leader for several projects on ‘Logistical flows and connections’ and ‘Autonomous Transport’.

4. **Maarten van Oeveren (CEO, NTxDuurzaam)**

Maarten has his own consultancy company with which he advises companies and governments to reduce energy consumption and CO2. He also develops a flag mill and is chairman and founder of energy cooperative TholenSolar. Until mid-2023 Maarten worked for HZ University of Applied Sciences, where he was involved in developing the minor Automated Vehicles in Logistics. He is also working on the design of a project for the realization of self-propelled ferries.

5. **Nadia Pourmohammadzia (Assistant Professor, TU Delft)**

Nadia is an assistant professor within the "Ports and Waterways" group, CEG, TU Delft. With a profound passion for advancing the field of data science, Nadia's research primarily revolves around the application of data-driven methodologies to address challenges in Ports and Waterways.

6. **Bas Hetjes (R&D engineer, V-tron)**

Bas is working at V-tron B.V. as an R&D engineer in the field of Automotive, specialized in the Smart Mobility and Safety domains

7. **Gijs van Stekelenburg (R&D engineer, V-tron)**

Gijs is working at V-tron B.V. as an R&D engineer in the field of Automotive, specialized in the Smart Mobility and Safety domains

8. **Ghazaleh Kia (R&D project manager, Seafar)**

Ghazaleh Kia is an R&D project manager at Seafar, overseeing several EU Horizon and government-funded projects. With a background in Electrical Engineering, her expertise lies in wireless sensors and communications. Her PhD candidacy is focused on the field of Computer Science, with a specialization in machine learning for navigation and localization using radio frequency signals.

9. **Johann Marquez-Barja (Professor, University of Antwerp/imec)**

Johann is a Professor at the University of Antwerp, as well as a Professor in imec, Belgium. He is leading the Wireless Cluster at IDLab/imec Antwerp. He was and is involved in several European research projects. His main research interests are: 5G advanced architectures including edge computing; flexible and programmable future end-to-end networks; IoT communications and applications.

10. **Asma Chiha Ep Harbi (Postdoctoral researcher, IDlab/imec)**

Asma is a postdoctoral researcher at IMEC, specializing in the techno-economic analysis of cutting-edge ICT solutions, including 5G networks, satellite communications, CCAM, and other emerging technologies.

5. COURSE CONTENT

5.1 Course introduction

	Course introduction
Learning objective	After completing this module, participants have an understanding of the 5G Blueprint project, they understand the organization of the MOOC and they have a general understanding of HZ University of Applied Sciences and the Supply Chain Innovation Research group.
Topics	- Introduction 5G Blueprint project and its objectives - Explanation of teleoperation - Explanation of use cases in the 5G Blueprint project - Introduction of 5G Blueprint project partners - Introduction MOOC content - Introduction MOOC organization - Introduction MOOC lecturers - Introduction HZ University of Applied Sciences and the research group of Supply Chain Innovation
Structure module	**Introduction 5G Blueprint project** Online video (12 min) **Introduction MOOC** Online video (6 min) **Introduction HZ University of Applied Sciences** Online video (2 min) **Discussion forum (available throughout the course)** Online discussion forum where participants can post their questions on the organization and content of the MOOC.
Lecturers	Introduction MOOC: Evelot Westerink-Duijzer (HZ University of Applied Sciences) Introduction 5G Blueprint project: Wim Vandenberghe (Dutch Ministry of Infrastructure and Water Management) Introduction HZ University of Applied Sciences: Evelot Westerink-Duijzer
Sources	Slides of the introduction to the MOOC are available in the online learning environment.

5.2 Module 1

Module 1	Introduction to Autonomous Systems
Learning objective	After completing this module, participants know the most important technical, organizational, economic and social issues in the introduction and application of autonomous systems. They also know the characteristics of transport systems using teleoperation or platooning.
Topics	- Features of autonomous vehicles - Technology readiness level - State of the art of AV technology - Advantages of AVs - Disadvantages of AVs - Criteria for use case selection - V-model - Critical to quality evaluation - Teleoperation and platooning as intermediate steps towards full automation

	- Benefits and challenges of teleoperation - Benefits and challenges of platooning
Structure module	**Module 1.1 Features of AVs and State of the art** Online lecture (25 min) **Module 1.2 Advantages and disadvantages** Online lecture (15 min) **Module 1.3 Use cases description** Online lecture (35 min) **Module 1.4 Intermediate steps toward full automation** Online lecture (15 min) **Assignment** Multiple choice test with 16 questions
Lecturers	Module 1.1: Andres Caballero Rosas (HZ University of Applied Sciences) Module 1.2: Evelot Westerink-Duijzer (HZ University of Applied Sciences) Module 1.3: Maarten van Oeveren (HZ University of Applied Sciences) Module 1.4: Nadia Pourmohammadzia (TU Delft)
Sources	Slides of all recordings are available in the online learning environment.

5.3 Module 2

Module 2	Technology
Learning objective	After competing this module, participants have an understanding of the technology required to drive or sail autonomously or via teleoperation. Participants understand the relevance of the required technologies and have a general understanding of their requirements.
Topics	- Localization: the importance, requirements and methods/technologies - Perception: definition, relevance and requirements - Prediction, routing and navigation: relevance and requirements - Illustration of these technologies in use cases - Functional requirements and technical requirements - Mechanical design, electrical design and software design
Structure module	**Module 2.1 Localization** Online lecture (35 min) **Module 2.2 Perception** Online lecture (46 min) **Module 2.3 Prediction and routing** Online lecture (35 min) **Module 2.4 Motion planning** Part 1 – Online lecture (25 min) Part 2 – Online lecture (25 min) **Assignment** Multiple choice test with 16 questions
Lecturers	Module 2.1 -2.4: Maarten van Oeveren (HZ University of Applied Sciences)
Sources	Slides of all recordings are available in the online learning environment.

5.4 Module 3

Module 3	Teleoperation
Learning objective	After competing this module participants have a good understanding of what teleoperation is and which requirements are needed to perform teleoperation. Participants have an overview of applications of teleoperation on the road and on waterways. Participants understand 5G concepts and how 5G can enable teleoperation. Participants know the basics of techno-economic analysis and understand how it can be applied to compare multiple scenarios of 5G enabled teleoperation.
Topics	- Definition of teleoperation - Requirements for teleoperation and configuration of the system - Examples of teleoperation on the road and on waterways - Relation between teleoperation and autonomous transport - Teleoperation and its connectivity requirements - 5G concepts and how 5G enables teleoperation - Techno-economic analysis - Application of techno-economic analysis to 5G enabled teleoperation
Structure module	**Module 3.1 Teleoperation on the road** Online lecture (34 min) **Module 3.2 Teleoperation of barges** Online lecture (12 min) **Module 3.3 5G technology in teleoperation** Online lecture (47 min) **Module 3.4 Business and governance** Online lecture (24 min) **Assignment** Multiple choice test with 16 questions
Lecturers	Module 3.1: Bas Hetjes and Gijs van Stekelenburg (both V-tron) Module 3.2: Ghazaleh Kia (Seafar) Module 3.3: Johann Marquez-Barja (imec) Module 3.4: Asma Chiha Ep Harbi (imec)
Sources	Slides of all recordings are available in the online learning environment.

6. EVALUATION

6.1 Participants

In total 28 people registered for the MOOC. The figure below gives an overview of the enrolments over time, including the enrolment of 5 lecturers at the start of the course.

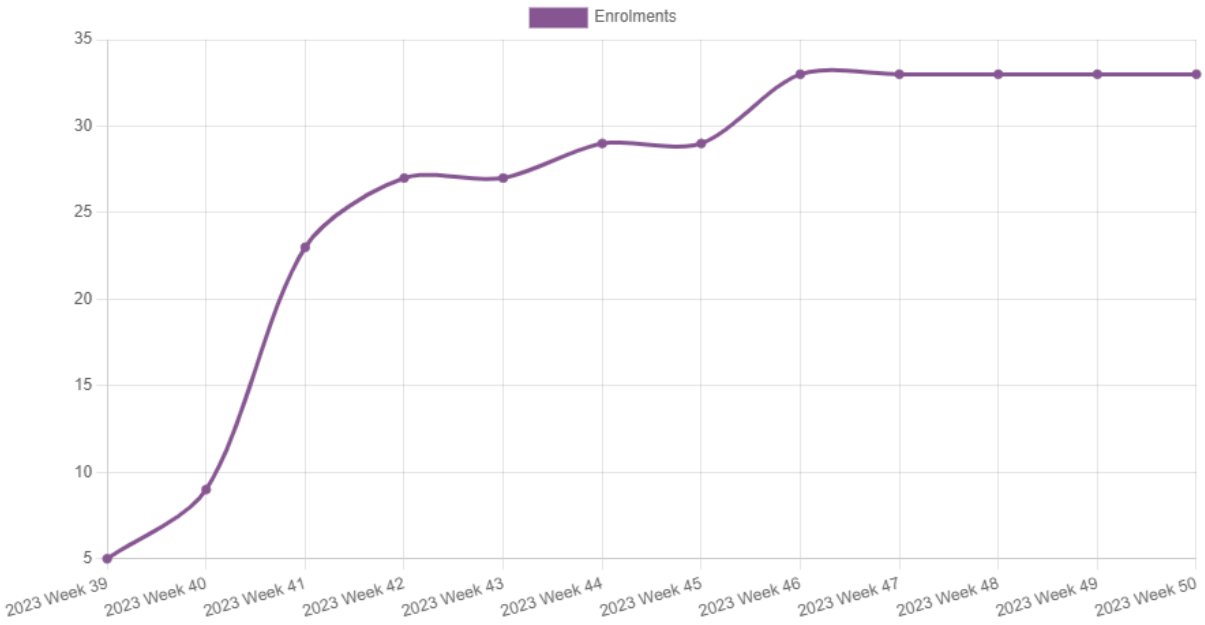

Figure 7: Enrolments of participants of the MOOC over time

The kick-off of the course was in week 41 which explains the high increase at that time. Also during the course, some more people joined until around mid-November (Week 46) when enrolments stabilized. The background of the participants is presented in the figures below.

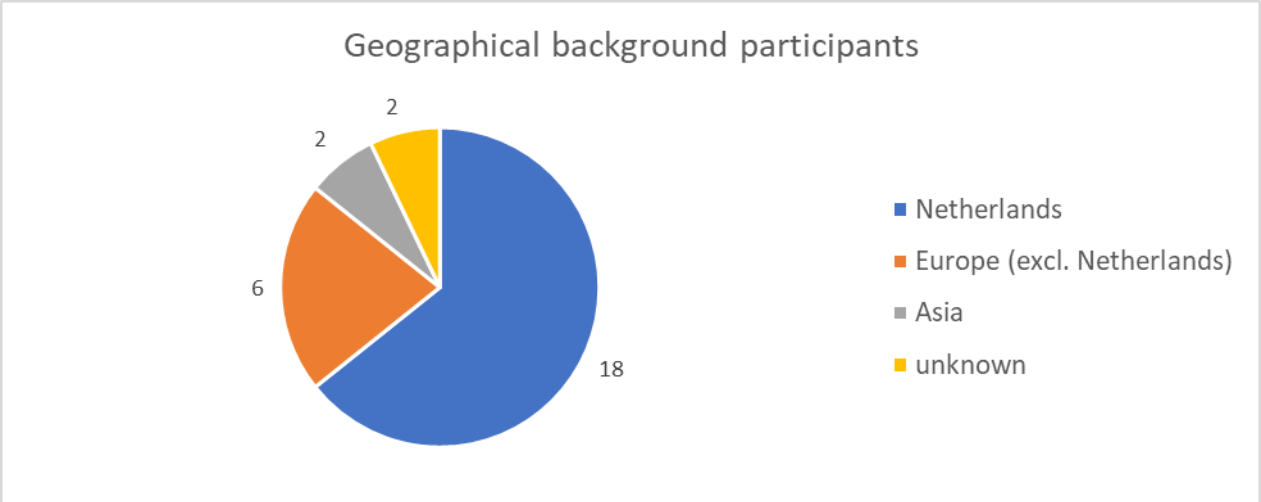

Figure 8: Geographical background of the participants

We notice that most participants come from the Netherlands. This is probably due to the promotion of HZ University of Applied Sciences which resulted in quite a number of students from this Dutch institution participating in the MOOC. Apart from participants from the Netherlands, the course is followed by other European participants from Spain, Lisbon and Cyprus amongst others. Also a few Asian participants registered for the course.

The MOOC was intended for a broad audience, and Figure 9 shows that the course indeed managed to attract people from various backgrounds.

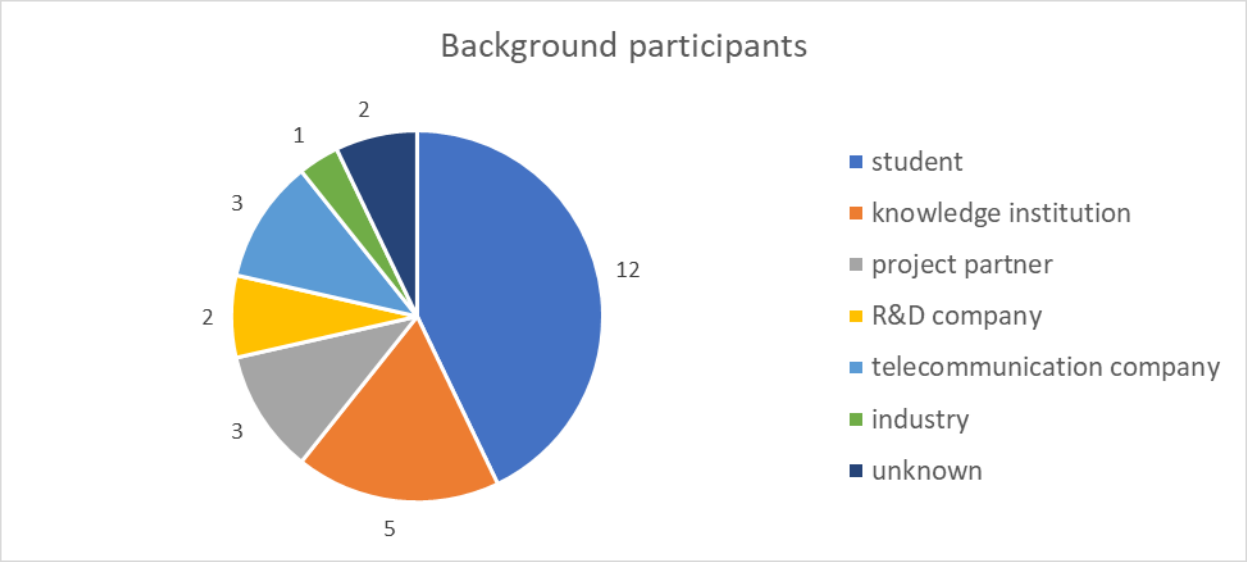

Figure 9: Background of the participants

Out of the 28 people who registered for the course, only 9 completed all modules and tests (see Figure 10). These participants were awarded the certificate. All of them were students from HZ University of Applied Sciences. We do not perceive it as negative that only one third of participants completed the full course. Since the course is aimed at anyone willing to deepen their knowledge about the application of autonomous vehicles in logistics, it might very well be that participants are already partly familiar with the topic and therefore choose to study only those parts of the course that interest them.

We do pity the fact that slightly less than half of the people who registered for the course did not even access the course material. This is despite the reminder emails we sent when the consecutive course modules were released.

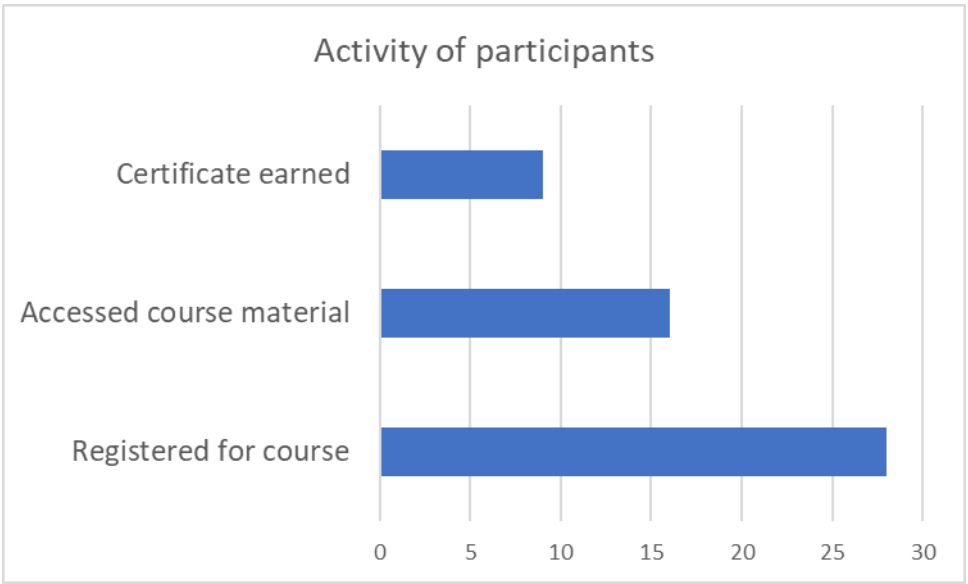

Figure 10: Activity of the participants

6.2 Evaluation learning objectives

In this section we evaluate the test results of the 9 participants who completed all course modules and tests. We would like to see how they scored on the learning objectives. In Section 4.4 we showed the relation between the learning objectives and the questions in the tests. In this section, we determine an average score for each of the learning objectives, combining all questions that contribute to that objective. Table 2 presents these average scores on a scale of 0-100.

Learning objectives	Number of questions	Average score
1) Know the characteristics of autonomous transport systems	4	78
2) Understand what the impact of autonomous systems and teleoperation can be on transport systems and society	4	94
3) Are aware of technologies like teleoperation and platooning as intermediate steps toward full automation	4	94
4) Understand the most important technical, organizational, economic and social issues in the introduction and application of autonomous systems	16	77
5) Know various applications of teleoperation on roads and waterways	10	90
6) Can explain which stakeholders play a role in the development and application of autonomous vehicles	0	NA
7) Understand the impact of 5G technology on teleoperation	6	74
8) Understand the business and governance aspects of teleoperation	4	75

Table 2 - Average score on the learning objectives (n=9).

We must be careful in our conclusions because of the small sample size (n=9), but the results seem to indicate that the course material of the MOOC successfully helps participants in achieving the learning objectives. The higher scores on objectives 2, 3 and 5 show that participants particularly have a good understanding of the various applications of automation in logistics. Objective 6 is not covered in the test questions, but both the introduction of the course as well as various online lectures discuss important stakeholders. Also the different lecturers of the course represent the perspectives of different stakeholders. We may therefore safely assume that participants who completed the entire MOOC are also aware of the different stakeholders that play a role in the development of autonomous vehicles.

6.3 Organizational lessons learned

The online course Autonomous Vehicles in Logistics was hosted via the online learning environment of HZ University of Applied Sciences: HZ Learn. This online environment is designed for teaching activities and was therefore very suitable for sharing course material and creating online self-graded tests. As a result, designing the MOOC environment and adding the relevant material went very smoothly. Despite these advantages, the online learning environment has one drawback. Granting access to this online learning environment had to be done manually. With the limited number of participants this was no problem and all participants had access within one working day after their registration. However, when a larger number of participants is foreseen, a platform where participants can get access automatically after registration would be preferred.

When we reflect on the format of the MOOC, we see that participants mostly watched the online lectures or read the online documents. Only a few of them participated in the formative tests. The MOOC also contained an online discussion forum to facilitate interaction among involved attendees and to provide a way to ask questions. We noticed that this forum was hardly used by the participants, although the reasons for this are unclear. Figure 11 shows the only post on the discussion forum, asking an organizational question. If interaction is desired, and particularly interaction related to the content of the course, developers of a MOOC could consider boosting the discussion by actively posting questions or statements on the forum and asking for replies.

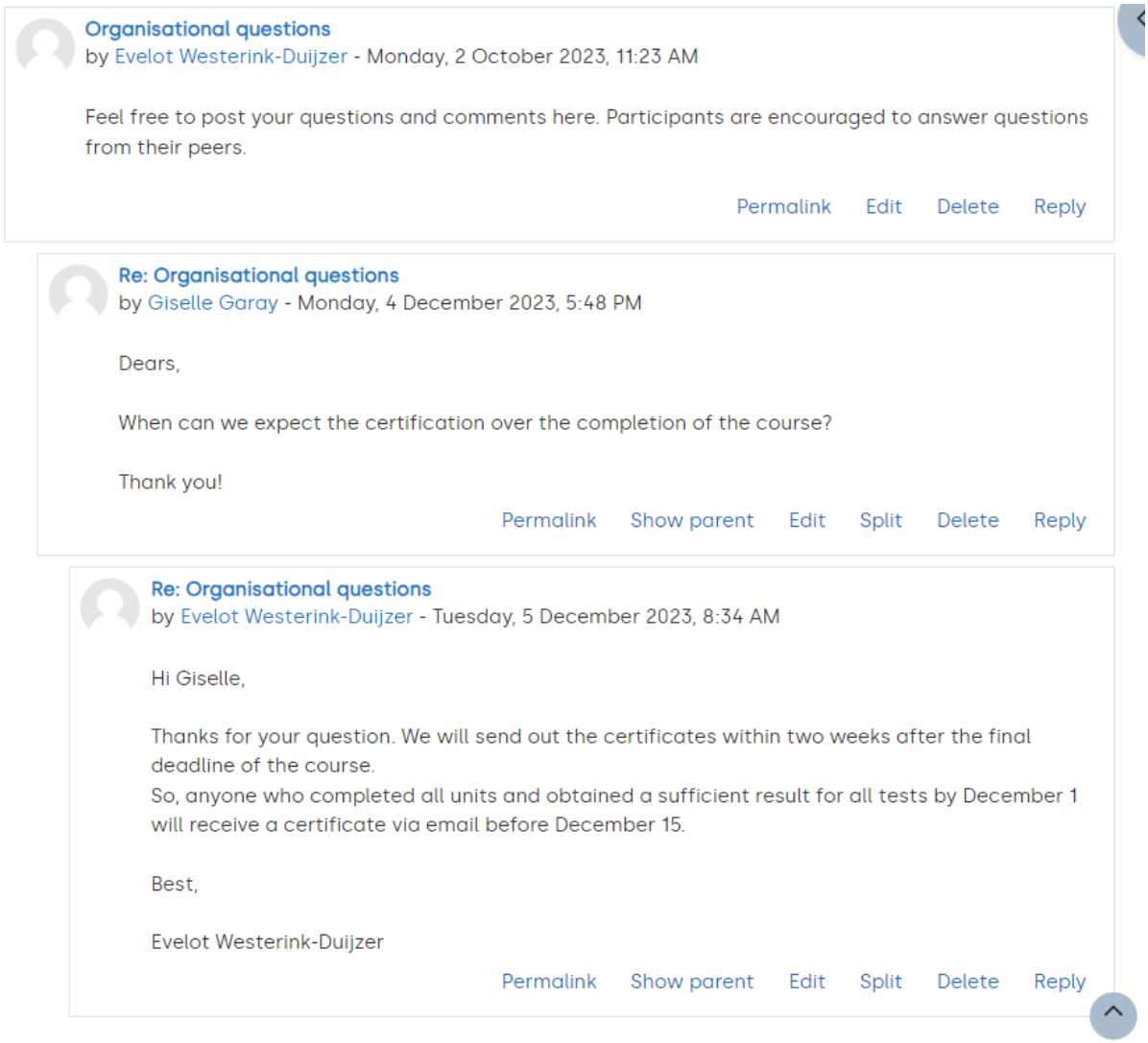

Figure 11: Screenshot of online learning environment (discussion forum)

6.4 Future development

HZ University of Applied Sciences is currently developing an online learning environment where external participants can register themselves to follow online courses. This environment is expected to be ready in the first quarter of 2024. The online course Autonomous Vehicles in Logistics will then be transferred to this environment, such that the material can be accessed by interested participants without the need of additional support. The developed course material will thus remain available after the closure of the 5G Blueprint project.

LITERATURE

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APPENDIX A – FLYER MOOC

APPENDIX B – ONLINE REGISTRATION FORM

Online course : Autonomous Vehicles in Logistics

With this form you can register for the online course Autonomous Vehicles in Logistics. Course material will be available online from October 9, 2023 until December 1, 2023 via https://learn.hz.nl/course/view.php?id=29529#section-0.
You can follow the course at your own pace.

1. Last name *

Enter your answer

2. First name *

Enter your answer

3. Initial(s) *

Enter your answer

4. Email address *

Enter your answer

5. Comments or questions

Enter your answer

APPENDIX C – FORMAT CERTIFICATE

UNIVERSITY OF APPLIED SCIENCES

5G BLUEPRINT

PARTICIPATION CERTIFICATE

This is to certify that

_____

Attended the

"Online Course Autonomous Vehicles in Logistics"

Co-organised by HZ University of Applied Sciences and 5G-Blueprint Project

11 December 2023

Vlissingen, Zeeland, The Netherlands

THIS PROJECT IS PART OF THE 5G PUBLIC AND PRIVATE PARTNERSHIP

5G PPP WWW.5G-PPP.EU

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