MINISTERUL EDUCAȚIEI ȘI CERCETĂRII
UNIVERSITATEA NAȚIONALĂ DE ȘTIINȚĂ ȘI TEHNOLOGIE
POLITEHNICA BUCUREȘTI
Școala Doctorală de Transporturi

Rezumatul Tezei de Abilitare

CERCETĂRI PRIVIND ADAPTAREA MENTENANȚEI MIJLOACELOR DE TRANSPORT LA EXIGENȚELE MOBILITĂȚII/TRANSPORTULUI SUSTENABIL

RESEARCH ON ADAPTATION OF TRANSPORT VEHICLE MAINTENANCE TO THE REQUIREMENTS OF SUSTAINABLE MOBILITY/TRANSPORT

Domeniul: Ingineria Transporturilor

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București 2025

Abstract

At the national level, in the Transport sector, according to the "Component C4. Sustainable Transport" of the NRRP, investment needs for transport infrastructure exceed €70 billion, based on the latest estimates presented in the Investment Plan for Transport Infrastructure Development for the period 2020-2030. The financial resources allocated through the NRRP amount to approximately €7.62 billion. The objective of this component is to enhance the sustainability of Romania's transport sector by supporting the transition to a non-polluting and digitalised transport sector, as well as developing sustainable transport infrastructure.

Sustainable development in transport and mobility must consider multiple factors, including the integration of measures for reducing carbon emissions and environmental protection, as noted in references [116], [121].

Personal cars remain the primary mode of transport in major regions worldwide. The study presented in reports on transport modes across 794 cities in 61 countries, covering a total population of 850 million.

Among these 794 cities, as of 2022, active mobility (which involves physical effort by the individual) accounted for 22.4% of trips in less than a quarter of the cities. Public transport was used in 26.2% of cases, while cars were involved in 51.4% of journeys. The proportion of transport modes varies significantly across the regions studied.

"**The research titled "Studies on adapting the maintenance of transport means to the requirements of sustainable mobility/transport"** is organised in accordance with the current national regulations and the Regulation on the authorisation and awarding of doctoral supervisor status within the IOSUD of the National University of Science and Technology Politehnica Bucharest, 2022. The work is structured in two parts. The first part presents the significant results achieved in the research and development activities carried out by the candidate following the award of their doctoral degree. The second part then focuses on highlighting the progression in their academic and scientific research career, as well as the development of skills in leading research teams.

The topic of the habilitation thesis reflects the main professional and scientific interests since obtaining the doctoral degree. The research focus on "air filtration" for internal combustion engines used in transport vehicles is significant, at least for the following reasons:

- It ensures high reliability of internal combustion engines, thereby guaranteeing the high availability of the vehicles equipped with them.
- The solutions developed contribute to safe travel and additionally promote sustainability through economic benefits and, notably, positive environmental impacts, as will be demonstrated later in the thesis.

The focus on this research area, as well as its ongoing development and expansion, is due to the numerous fluctuations in political stability (including geopolitical factors) and economic developments both in Romania and globally.

Socio-economic uncertainties continue to hinder the establishment of a purchasing behaviour favouring exclusively electric modes of transport, or even new conventional engine vehicles, among individual users and companies alike.

The global market for filtration equipment was valued at $38 billion in 2007 and reached approximately $50.5 billion in 2023. Filters used in the transportation sector account for 15.9% of the market [51], [98].

In Romania, by the end of 2024, there were 10,785,260 registered vehicles according to [104] of which 8,106,570 were passenger cars. Among these, only 39,271 are equipped with a purely electric propulsion system [105],[106], representing just 0.5%.

Globally, according to [108] there are 1.475 billion passenger cars registered, of which it is estimated that only 64 million are electric [107], amounting to only 4.34%.

From this data, we can conclude that the internal combustion engine will continue to be used alongside new technologies for a considerable time to come, and regardless of the type of energy it uses, it will consume air, which must be filtered.

The habilitation thesis succinctly and thoroughly presents the main scientific achievements obtained following the award of the doctoral degree, across multiple areas:

- within research projects;
- through coordinating undergraduate and master's students in preparing papers for student scientific sessions;
- by supervising doctoral candidates as a member of supervisory and academic integrity committees.

The habilitation thesis presents the results of research activities conducted within the projects POSDRU/159/1.5/S/134398 – "Studies on the Influence of the Technical Condition of Air Filters on the Ecological, Energy, and Economic Performance of Internal Combustion Engines", "GEX2017, Ctr. No. TR 27-17-06 /2017 – Research on Air Filters," and "GnacArut 2023 – Research on the Air Filtration System in Thermal Engines for Hybrid Propulsion Vehicles".

The air supply system of internal combustion engines is the primary pathway through which harmful impurities in the air reach the engine's kinematic components.

In many previous studies, the air filter is often considered mainly as a source of pressure drop (a restriction) affecting the airflow admitted into the engine. This approach overlooks how the pressure restriction caused by the filter evolves over its service life and does not account for the impact that specific air filter maintenance activities have on the wear of the thermal engine, along with all the resulting consequences.

The research presented in this thesis is based on experiments conducted both in modern laboratories and in the field, aligning with the relevant specialised literature.

It is well understood that maintenance activities begin at the system design stage. The methods of recycling and the volumes recycled are particularly important factors considered during design. Reducing the volume of waste is primarily achieved by decreasing the need for maintenance (less frequent replacement of parts and materials), which, in turn, contributes to improved sustainability.

The final decision regarding maintenance activities rests with the owner, along with all the consequences that follow. There are cases where a component performs its specific functions better as it is used, rather than when it is new (for example, air filters designed for internal combustion engines – the filtering efficiency of new filters is lower compared to that of filters already in use). These facts are little known by users, as highlighted in the study [59]. Using these components correctly helps to reduce the need for maintenance, lower costs, and minimise waste volume. It is well known that the air filter is part of a system for capturing, directing, and filtering air intended for processes within the combustion chamber.

The air filters studied were fitted to car engines, featuring different design and functional characteristics. The analysis of various air filters revealed that the vast majority were replaced prematurely (91.4% of the 132 filters tested), a small number were replaced late (3.4%), and only a few (5%) were changed at the appropriate time.

Premature replacement of air filters impacts sustainability by causing:

- unnecessary additional costs for purchasing new components;
- recycling of the replaced filters, which has environmental pollution implications;
- reduced filtering efficiency, as filters become more effective the longer they are used, thereby increasing engine protection against abrasive wear.

This final aspect is important because it is estimated that in 80% of cases, the lifespan of internal combustion engines (the engine mechanism) is limited by the effects of wear [73]. Delayed replacement of filters leads, on one hand, to a significant increase in aerodynamic resistance within the engine's air intake system. Depending on the engine, an increase in restriction beyond the limits recommended in specialist literature results in reduced dynamic performance of the vehicle. On the other hand, as aerodynamic resistances increase, there is a risk of damage to the filter material and sealing gasket, considerably diminishing filtration efficiency.

All of these factors impact transport efficiency by reducing vehicle availability and increasing the need for additional investment.

Replacing air filters based solely on distance travelled or usage duration does not guarantee timely (appropriate) replacement, leading to higher maintenance and recycling costs and, most critically, diminishing protection against abrasive engine wear. Replacement should be guided by the increase in restriction, which ought to be measured using a specialised sensor installed at the engine’s air supply system. Unfortunately, some maintenance units, where such sensors exist, tend to disregard their readings. This approach stems from the mistaken empirical belief that a new air filter is inherently “better” than one already in use.

Research activities were subsequently focused on comparing the restriction caused by air filters with that caused by the air intake ducting and filter housing. Several filtration systems were analysed for this purpose, and the results showed that, of the total restriction in the air intake system, the majority is due to the air intake ducting and housings, with the air filter itself contributing less. It was also found that as the service intervals of air filters increase, the optimal solution is to replace current air intake systems with new ones that, under normal operating conditions, require no maintenance. In other words, "lifetime air filters" should be used, designed to minimise restriction and improve the filling of cylinders with fresh charge. The term "lifetime air filters" refers to a maintenance-free air filtration system that, under normal use, lasts for example 10 years or 200,000 km (or an equivalent number of operating hours). Such a system also requires the installation of a sensor to indicate a dangerous level of filter clogging. Accordingly, maintenance is performed based on three criteria, in order: primarily according to the sensor’s indication, then based on distance travelled, and finally on duration of use.

Starting from the limits specified in the specialised literature regarding the appropriate time for filter replacement, the research conducted also focused on their behaviour under controlled dust loading. This highlighted the dust storage capacity until replacement conditions are met, namely when the restriction caused by the used filter increases by 2.5 kPa compared to that of a new filter [11], [13], [14], [16], [21], [20], [39], [54], where 2.5 kPa is equivalent to 10 in H2O.

The research findings showed that the rate at which the restriction increases remains low until the increase in pressure drop across the loaded filter compared to the new filter reaches 1 kPa. Beyond this, with additional dust accumulation, the restriction rate accelerates. The point at which a sharp rise begins corresponds to the stage where the filter becomes too clogged to be used.

Research has also shown that:

- For the same filter-induced restriction, the amount of dust retained under laboratory conditions is greater than that retained under actual usage conditions [4].
- The impurity retention capacity increases by 1.5 to 3 times when the fibres of the filtering material are moistened with oil [40].
- Controlled dust loading of filters on a test rig demonstrates the high dust retention capacity of air filters.
- Maintenance intervals can be extended or filter sizes reduced for a particular engine, at the expense of more frequent replacements [41].

Another research direction developed was the analysis of the influence of the technical condition of filters on the energy and environmental performance of vehicles.

Experimental studies were carried out over different time periods and on vehicles from different generations, one domestically produced and the other of foreign origin. New and used air filters of the same type were used.

In tests conducted with a new-generation spark ignition car (2021) running the WLTC cycle, an increase in resistance of 0.809 kPa (from the loaded filter compared to the new one) was found to raise fuel consumption without affecting the vehicle's stable, normal operation. The fuel consumption increased by 15.65% when using a severely clogged air filter.

Although the air filter has a relatively low impact on the power and torque of the combustion engine, replacing the air filter should not be neglected. The air filter’s role is not to increase engine power, but to capture impurities that can significantly reduce engine lifespan and provide protection.

From the perspective of the design engineer simulating internal combustion engine processes, the air filtration system is characterised by a pressure drop, which is used as an input parameter in the simulation. The selected value for this pressure drop must be based on solid reasoning to ensure stable engine operation, with only a minimal sacrifice in energetic performance but with the significant benefit of reducing wear intensity on the engine’s kinematic joints, especially the piston-ring-cylinder assembly.

To study the impact of gas-dynamic losses in the intake path (pressure drop) resulting from the clogging of the air filter, I employed the AMESim software and a Mean Value Engine Model (MVEM), calibrated to simulate the behaviour of a supercharged spark-ignition engine. The MVEM model offers an average-value estimate of engine behaviour on a cycle-by-cycle basis.

The simulated engine has a displacement of 1000 cm^3 and is used in vehicles produced by the domestic manufacturer.

Two reference points were used to analyse the results: a 2.5 kPa restriction, recommended in specialist literature as the limit for filter replacement, and a 6 kPa restriction, a very high value beyond which the air filter's integrity is considered at risk.

The simulation showed a maximum decrease of approximately 0.62% in energetic performance for a pressure drop of around 6 kPa downstream of the air filter, and a 0.27% decrease for the 2.5 kPa restriction. The performance reduction is explained by a slightly reduced air intake flow rate (an insignificant impact) of 0.67%, and a minor decrease in manifold pressure (also an insignificant impact) of 0.07%. There was a slight increase in cylinder filling efficiency (volumetric efficiency) of approximately 0.0026%.

The slight increase in the turbocharger shaft's rotational speed is explained by the fact that, although approximately the same energy from the exhaust gases is available at the outlet, a slightly lower mass flow rate of air is available for compression at the intake. This results in a reduced mechanical resistance power encountered by the compressor. Consequently, the turbocharger shaft speed experiences a slight rise.

The small decrease in the engine's air mass flow rate leads to a minor deterioration in combustion, which negatively affects fuel consumption. The specific fuel consumption increases by approximately 0.52% for a pressure drop of around -6 kPa downstream of the air filter.

The results obtained through simulation provide an indicative overview for analysing the trends of the parameters presented above. The simulation outcomes confirm the experimentally derived trends: as the restriction significantly increases, fuel consumption rises and energy performance declines. The numerical values are highly dependent on the specific design and functional characteristics of the tested vehicle engines.

For a high level of model accuracy, calibration is required by varying the main engine control parameters across as many operating regimes as possible, as encountered in the "ISO regime."

The next phase of research focused on determining the filtration efficiency. This stage aimed to evaluate the filtration efficiency of the tested filters on the laboratory stand and to analyse the granulometric structure of impurities passing through the filters by examining images obtained with an electron microscope. Both new and used air filters were analysed.

Used filters, of both types, showed higher efficiency than new filters because the dust initially loaded onto them reduces the cross-section of the flow channels and even forms a dust layer on the surface of the filter material, thereby improving efficiency.

Based on the research and considering the efficiency values of the used filters, it was concluded that these filters could still be utilised, with their efficiency further enhanced. Consequently, these filters had been replaced prematurely, increasing transport operating costs through the purchase of new components and recycling of the replaced parts, with associated environmental pollution implications.

For each air filter whose effectiveness was assessed, an absolute filter was used to capture the particles that passed through the tested air filter. Samples of the filtering material were taken from the central area of each absolute filter. By obtaining and analysing images of the filtering material from the absolute filters under an electron microscope, the aim is to identify the size of the particles that passed through the air filter, as well as their proportion relative to the total particles present in the studied sample. For analysis, images at a 100 µm scale were selected. The most numerous particles in the samples are those sized between 0 and 2 µm, which have a lower impact on wear, unlike particles sized 2–5 µm and 5–10 µm, which are less common but have a significantly greater potential for causing wear [12], [46].

Research concludes that air filters should be used to their full potential. This approach not only reduces maintenance costs but also provides enhanced protection for the engine's kinematic couplings. Using filters to their maximum capacity ensures higher vehicle availability, which is a crucial part of intelligent transport systems.

Considering that the cost of new air filters, even high-quality ones, is not high, owners often replace filters frequently out of a desire to do well, following the principle that "a new product is better than a used one." However, this principle proves incorrect when it comes to air filters. They actually provide better engine protection the longer they are used.

To evaluate filters with a high level of confidence, several samples from the same specific filter must be analysed under an electron microscope.

Air filters for internal combustion engines are relatively inexpensive components and are often replaced before reaching their full service life. These statements apply to vehicles used under normal conditions. When vehicles operate in special conditions with high dust levels—such as on unpaved roads, in construction areas, or in agriculture—filter contamination occurs very rapidly and severely. Under these circumstances, depending on the vehicle type and the number of filtration stages, manufacturers recommend reducing maintenance intervals or periodically cleaning the air filters by blowing them with compressed air [9].

For passenger cars, air filters have a service life ranging from 20,000 km to 120,000 km or 2 to 6 years of use (Annex 1). Cleaning and reusing them is not recommended for cars. However, some users opt to clean the filters to reduce maintenance costs.

In the case of special vehicles, such as agricultural machines and land management equipment, which have two or three filtration stages and operate in very dusty environments, filter cleaning is advised.

The examination of the filter material under an electron microscope aimed to determine whether compressed air blowing during cleaning damages the filter fibres. The results showed that the filter material began to degrade after cleaning with compressed air, which is why cleaning the filters is not recommended.

Following the investigation into the controlled and repeated loading of air filters with dust, and after cleaning them by blowing with compressed air, the following conclusions are drawn:

- The increase in restriction after injecting dust into new filters is significantly lower than the increase recommended in specialised literature for filter replacement. This behaviour once again demonstrates the high dust-holding capacity of the filters.
- Cleaning the filters by blowing compressed air does not allow complete removal of particles from the filters.
- After each cleaning, the filters do not return to their initial restriction level. The restriction of cleaned filters is higher than the initial value before dust injection.

- Analysing the increase in restriction after cleaning, compared to the restriction caused by new filters, it is observed that the filters can be successfully cleaned in terms of restriction.
- Granulometric diagrams show that numerous particles of various sizes have passed through the air filters. The majority are particles up to 5 µm in size.
- OEM and PMF filters retain the most harmful particles for the engine's kinematic couplings more effectively than the LCF filter, which has lower efficiency.
- After cleaning, OEM_U filters provide better protection compared to new filters.
- During filter cleaning, there is a risk of contaminating the filter media on the air outlet surface.
- Compressed air cleaning causes local damage to the fibres of the filter media. The extent of damage within the internal layer could not be determined.

Another research avenue explored was the assessment of drivers' perceptions regarding the maintenance of air filters used in internal combustion engines for vehicles, as they are the decision-makers determining the timing of maintenance interventions.

The research objectives were:

- To analyse the level of knowledge regarding the types of filters used in automobiles;
- To determine the criteria for selecting air filters;
- To investigate the frequency of maintenance performed on air filters;
- To establish the level of awareness of the consequences of carrying out maintenance actions.

The data collection tool used in this study was a questionnaire. The first section of the questionnaire included a series of questions investigating the respondents' experience as drivers: the type of driving licence held, the duration of licence ownership, the annual distance driven, and the type of vehicle most frequently driven. The second section aimed to assess the level of knowledge regarding filter performance indicators, the criteria for selecting air filters, and the consequences of maintenance actions performed. Finally, questions concerning the respondents' identifying information were included.

The sample consisted of 312 vehicle drivers. Analysis of the results revealed that the vast majority of respondents were familiar with the main filters used in automobiles. Responses about the importance of performance indicators in choosing air filters demonstrated an understanding of the terms used and a good level of technical knowledge [50].

Concerning the filtration mechanisms, although the majority of respondents have a high level of expertise and consider themselves knowledgeable in the field of transport and road vehicles, their answers were incorrect. This indicates a lack of understanding of the filtration mechanism of air filters designed for internal combustion engines. Typically, a new product is better than a used one. Using this analogy, most respondents were mistaken.

Regarding the criteria applied for replacing filters, the primary factor considered, in terms of importance, is the recommendation found in the vehicle's maintenance and repair manual. This is a sound and objective criterion. The "service advisor's recommendation" scored low, ranking fourth, which shows that respondents have little trust in service advisors. Maintenance and repair units are numerous, and the qualification level of service advisors varies greatly. They should recommend maintenance actions according to the manufacturer's plan, but ultimately the client makes the final decision and often seeks the service advisor's personal, subjective opinion.

When assessing the condition of air filters, respondents often rely on its appearance. The air filter darkens shortly after being put into use, but this does not reduce its technical performance—in fact, quite the opposite. Consequently, a service advisor guided solely by appearance may make incorrect recommendations. Positively, subjective factors such as auto forum advice, friends' recommendations, and design-related aspects are less frequently considered by clients when replacing filters.

Following research activities on air filters for internal combustion engines, the main conclusion is the need to change the maintenance strategy applied to them. It has been shown that replacing filters based on distance travelled or time in use are inefficient criteria. Additionally, since most indicators are of the "pass/fail" type, filter replacements are again decided incorrectly.

Following the research conducted, we have proposed a system to monitor the technical condition of the filter, which will generate multiple confirmation messages indicating the filter's proper functioning. There are at least two options for this:

- The first involves installing a measurement system in the engine compartment, comprising a pressure sensor and a development board, such as an Arduino.
- The second option is to identify, capture, and interpret signals from a pressure sensor located in the intake manifold, downstream of the air filter, as equipped in vehicles.

The theoretical and experimental development of the proposed topic provides a range of original contributions to the maintenance of air filters for internal combustion engines.

These will be presented as follows:

- Conducting a comprehensive study on the behaviour (evolution of parameters defining the technical condition) of air filters during their usage;
- Analysing the performance indicators of the filters (restriction, dust holding capacity, filtration efficiency);
- Presenting solutions to enhance the availability (service life) of transport vehicles;
- Obtaining dust used for loading air filters (a mixture of powders with different granulations for filter loading on the test rig);
- Designing and constructing an original test rig and the testing methodology for air filters with the relevant components;
- Determining the influence of the air filter's technical condition, assessed by restriction, on the energy and environmental performance of two internal combustion engines;
- Developing a simulation model for a supercharged spark ignition engine to study the impact of gas dynamic losses, evaluated by restriction, in the intake system;
- Investigating, using an electron microscope, the mechanisms of dust particle filtration and the loading state of cellulose fibre paper air filters;
- Designing and implementing a continuous monitoring system for the technical condition of the air filter;
- Providing specialists with a comprehensive experimental data set regarding the performance indicators of air filters.

In the second part of the thesis, the progression of the teaching/research career and the development of skills in leading a research team are presented.

The teaching and scientific activity began in 2002 at the National University of Science and Technology POLITEHNICA Bucharest, Faculty of Transport, immediately after graduating from the long-term (five-year) undergraduate programme. All teaching activities have taken place within the Faculty of Transport.

I held the position of assistant from 2002 to 2014, served as senior lecturer from 2014 to 2021, and since 2021 I have been a lecturer in the Department of Road Vehicles. I was awarded a doctoral degree in 2014 in the field of Transports.

The experience gained, along with collaboration with academic staff, research centres, industry partners, and students, forms the foundation of my academic career development and helps me provide solid training for future transport specialists. This training is aligned in content and teaching methods with other subjects in the curriculum.

Over the course of more than 22 years, I have taught laboratory work, seminars, and project courses in subjects including Road Traffic, Vehicle Manufacturing and Repair, Vehicle Reliability, Utility Software, Reduction of Vehicle-Generated Environmental Pollution, Vehicle Software Development, Vehicle Diagnostics, Vehicle Maintenance, Tractors, Maintenance of Vehicle Propulsion Systems, and Diagnostics of Propulsion Systems.

Currently, I teach Maintenance of Vehicle Propulsion Systems; Vehicle Diagnostics; Tractors; Diagnostics of Propulsion Systems; and Advanced Vehicle Maintenance Methods.

Intelligent transport systems are continually evolving, with vehicles being an integral part of these systems. All vehicle subsystems are subject to research. The main changes occur in propulsion systems, where there is a trend towards hybrid drive systems (combining internal combustion engines with one or more electric motors) or replacing internal combustion propulsion with electric motor-based systems.

In the short to medium term (2025-2035), hybrid vehicles will constitute a particularly important category, acting as a bridge from conventional propulsion vehicles to electric vehicles. They are currently preferred due to their favourable cost-efficiency ratio and compatibility with the existing refuelling infrastructure, according to sources [109],[110],[111].

The future of vehicles equipped with internal combustion engines lies in reducing fuel consumption and pollutant emissions, even though their market share is expected to continue declining as electric refuelling infrastructure advances, as noted in [112].

The aforementioned road transport modes are likely to coexist in the medium term and possibly in the long term as well, considering today’s political instabilities.

Electric traction motors in vehicles require less maintenance compared to internal combustion engines. Regardless of the type of propulsion, road vehicles will still have running systems, steering systems, braking systems, climate control systems, and safety systems, all of which require specific maintenance actions.

In the course "Maintenance of Vehicle Propulsion Systems," we have developed students' skills in organising both preventive and corrective maintenance activities on vehicles with conventional, hybrid, and electric propulsion systems.

For heavy-capacity road transport vehicles (lorries and buses), the trend in maintenance is to send information regarding the technical status of the systems from sensors fitted to the vehicles to a specialised control centre. This centre then identifies the nearest service unit capable of resolving any technical issues. Research focuses on the causes of changes in technical condition, the impact of vehicle operating modes on maintenance activities, as well as documenting inspections, adjustments, and maintenance carried out on vehicles with conventional, hybrid, and electric propulsion systems.

Throughout the use of road transport vehicles, the technical condition continuously changes due to various phenomena developing within their systems. The consequences of these changes are multiple, leading to a deterioration in dynamic, economic, environmental, ergonomic, comfort, and even safety performance. For these reasons, it is essential to monitor the technical condition of vehicles throughout their operational life through diagnostic procedures.

From the perspective of student training, it is essential to consider global trends alongside the realities of our country, as the vast majority of engineers trained at the Faculty of Transport secure employment domestically. The propulsion group of vehicles, traditionally equipped with internal combustion engines, will continue to be introduced to students, with emphasis on both innovative design solutions and those currently in use.

Collaborations with major automotive manufacturers in our country enable the faculty's teaching staff to maintain their knowledge and skills at the highest advanced levels, ensuring that students at all stages are exposed to the latest innovations in the field. Notable examples include partnerships with Mercedes-Benz Romania, MHS Romania, and Porsche Romania, which provide access every semester to vehicles (such as VW or Mercedes models with electric or hybrid propulsion systems) and the latest generation trucks (MAN and Mercedes).

Since the 2024–2025 academic year, the Integrated Human-Vehicle-Environment Master's programme has introduced a new course, "Advanced Methods for Vehicle Maintenance." There is a continual focus on keeping the course content highly current across all subjects taught, with the aim of enhancing the quality of education and securing reliable employment opportunities for graduates within the transport sector.

The use of modern teaching methods (Moodle platform, Microsoft Teams platform) combined with student-centred assisted teaching activities contributes to improving the efficiency of the learning process and strengthening the connection between students and teaching staff.

Research activity- I participated in research teams for multiple contracts within national and international programmes, as well as projects conducted with third parties, both within the "Research, Design, Service, and Consulting Centre for Road Transport – CPSCTA" and independently within various transport companies. I served as director for two research contracts, and the most recent and significant results are presented in Part I of the habilitation thesis.

I have published:

- 5 books and book chapters in specialised publications with recognized publishers, including Politehnica Press, AGIR Publishing House, and the Romanian Scientists' Publishing House;
- 2 teaching textbooks and 2 laboratory guides published by Politehnica Press and BREN Publishing House;

- 22 articles in peer-reviewed journals and conference proceedings indexed by ISI Thomson Reuters;
- 15 articles in journals and volumes of scientific events indexed in other international databases acknowledged by the CNATDCU commission;
- 5 articles published in national journals and proceedings of national and international scientific events that are not indexed.

The results from the Google Scholar platform show an h-index of 7 and an i-10 index of 6, with a total of 193 citations.

According to the research activity data from the UNSTPB CRESCDI portal, there are more than 200 citations, including 82 from WOS, 211 unique citations, and a citation score of 2930. The cumulative impact factor presented by the portal is 7.4.

Research and Development Projects as Director:

- GEEX Grant 2017, contract no. 67/25.09.2017, code TR 27-17-06, Research on air filters. Research grant awarded through competitive selection. Contract value: 22,000 lei.
- GNAC ARUT Grant 2023, no. 118/04.12.2023, Research on the air filtration system in thermal engines for hybrid propulsion vehicles. Research grant awarded through competitive selection. Contract value: approximately 10,000 EUR.

From my first year working as a trainee in the Road Vehicles Department, I have been involved in research teams: prior to earning my doctorate, I contributed as a researcher on seven research contracts. Since obtaining my doctorate, I have participated as a researcher in six research contracts.

Skills for Leading a Research Team - Effectively managing a research team in an academic environment requires a blend of technical expertise, managerial skills, and interpersonal abilities (harmonious and efficient interaction with others). These skills are crucial for ensuring efficiency, innovation, and the success of research projects. When supervising doctoral candidates, it is important to develop existing skills and deepen expertise in specific areas of Transport Engineering research. This will enable the effective identification and guidance of valuable research topics.

Strengthening ties with industry partners ensures that research remains practical and applicable, while also providing additional funding opportunities through strategic partnerships.

In interactions with students, I consistently emphasise the importance of independent study as a means to deepen understanding. Active participation in scientific communication sessions is encouraged, alongside support for publishing articles to disseminate research findings.

These efforts have yielded remarkable results among supervised students at student research group sessions, with 17 papers published in the last six years out of over 45 supervised works, and students guided through more than 120 undergraduate and dissertation projects throughout my academic career. Close collaborations are also maintained with former students who are now practising engineers or researchers, facilitating mutual support in the exchange of information and logistics, particularly benefiting current students.

In my role as Deputy Dean, I am responsible for coordinating and overseeing student activities, which contributes to the continuous development of my leadership and team management skills.

The ESFA Congress is a prestigious scientific event with a long-standing tradition, where I served as co-organiser for the editions held at UNSTPB, Faculty of Transport. This role required the efficient coordination of a multidisciplinary team. Additionally, I contributed as a founding member and later co-organiser of the POLIAutoFest event, further strengthening my skills in planning and managing complex projects. These responsibilities have helped me develop strong communication, delegation, and problem-solving abilities within the research team. As a result, I can ensure effective and motivating coordination of groups consisting of doctoral students and collaborators.

I have acted as a reviewer on doctoral thesis defence committees and participated as a member of supervision and academic integrity teams for 26 doctoral candidates, most of whom successfully completed their theses and were awarded a doctorate in engineering sciences.

In conclusion, based on the experience and responsibilities outlined, the skills are categorised into the following areas:

1. Research skills – These skills are acquired throug:
   a. Coordinating own research contracts and participating in research teams for other contracts, gaining direct experience in managing scientific objectives and outcomes;
   b. Publishing and presenting scientific articles in journals and conference proceedings at international conferences, where the ability to communicate and disseminate research findings is demonstrated;
   c. The involvement with doctoral candidates, as a scientific advisor and member of supervisory and academic integrity committees, demonstrating expertise in rigorous evaluation and validation of scientific outcomes.
2. Scientific and Technical Competences - These competences are acquired:
   a. through in-depth work in fields such as vehicle maintenance and diagnostics, propulsion system maintenance, road traffic, reliability, and environmental pollution reduction;
   b. due to the ability to propose and validate innovative technical solutions for road transport vehicles.
3. Managerial and coordination skills – These skills are acquired through:
   a. The role of Deputy Dean, where experience was gained in leadership, student activity coordination, and management of educational programmes;
   b. Responsibilities as the person in charge of study programmes, through which academic management and curriculum planning skills were acquired;
   c. The proposal and coordination of topics for student scientific circles, diploma, and dissertation projects, providing experience in nurturing and guiding young researchers, as well as skills in motivation and human resource development.

Future Research Directions – Academic activity must always maintain a close connection with developments and demands within the relevant industry, reflecting changes in the job market offered by employers, and act as a driver of innovation and research in the field.

My active participation as a member of Commission No. 3 (Action Plan for the National Strategy on Circular Economy – Automotive Sector) under the Romanian Ministry of Economy, Entrepreneurship, and Tourism has provided valuable insights into the legislative challenges facing the road transport sector. This involvement has also highlighted opportunities for new research topics that can be pursued through partnerships. Such initiatives require the formation of interdisciplinary research teams, with doctoral students playing a crucial role in advancing knowledge and innovation.

Research in Romania should benefit more extensively from "academic-private sector" partnerships, enabling access to the latest methods, technologies, and scientific results. This is the natural context in which mixed research teams composed of academic staff, doctoral candidates, and private sector specialists can collaborate to promote the sustainable development of specialised higher education and enhance Romania's competitiveness and international standing.

The primary research focus is the continuation and expansion of investigations into the maintenance of air filters intended for road vehicles. The main systems of road vehicles that utilise air filters are, naturally, the internal combustion engine, the air conditioning system, and the pneumatic brake system.

The internal combustion engine will continue to be used alongside new propulsion technologies. [110], [112]. The current road transport methods will coexist in the future, with their use being enabled by advanced technologies focused on innovative and sustainable solutions for transport systems.

Current research directions for air filters used in internal combustion engines focus on enhancing filtration efficiency, extending service life, employing new alternative materials for the filtering medium, and optimally designing and positioning filters to improve energy performance. Investigations into new filtering materials and mechanisms aim to achieve the highest possible initial efficiency along with increased storage capacity. The study of filter materials includes nanofibre filters, filters with progressive structures, and filters made from multilayer reticulated foams, either dry and/or wetted, [6], [11], [22], [29], [75], [76], [77].

For categories of road transport vehicles such as heavy-duty trucks, agricultural and industrial tractors, I will study the implementation of air filter systems with one or more filtration stages, depending on their intended use and operating environment. The maintenance strategy for these vehicle categories should be proactive, based on the filter's loading status rather than on usage time or distance travelled. For vehicles with special purposes, research will focus on automatic self-cleaning filter technologies (systems that maintain filter cleanliness) that operate independently of the driver's decision, solely according to the filter's loading condition. Self-cleaning air filters (low-maintenance air filters) prevent overloading, reduce energy performance losses, avoid contamination of downstream sensors, and protect the filter material from damage. Road vehicle categories such as heavy-duty trucks, tractors, and military vehicles are equipped with combustion engines where ensuring availability with minimal maintenance is particularly important [78], [79], [80], [103].

For passenger cars, future research activities will focus on designing and developing air filtration systems that, under normal usage conditions (driving on paved roads without dust storms), have an extended service life, or 'lifetime air filters' [11]. With the downsizing of combustion engines, in the remaining space available in the engine compartment—both for conventional and hybrid vehicles—I will continue to research optimising the air intake and filtration system to enhance filtration performance, including optimising the design and placement of filters within the air intake system.

The scientific motivation for continuing this research lies in developing an innovative air filter maintenance strategy, employing a sophisticated specialised transducer with high storage capacity, and obtaining a patent for the invention of an indicator system that signals the hazardous clogging level of the filter.

Furthermore, regardless of the type of propulsion system, research in air filtration remains crucial due to the necessity of cabin air filters. Most road transport vehicles require cabin air filters to ensure that the air inside is clean and free from pollutants, allergens, and other particles.

The second research focus *is the development of new maintenance strategies based on predictive maintenance and diagnostics, as well as the use of augmented reality.*

Keeping road transport vehicles in good working order is a priority and forms a key part of road safety. Predictive maintenance and diagnostics for road vehicles utilise not only prediction techniques but also information provided by the installed sensors.

When developing new maintenance strategies, maintenance laws will be considered and their implementation sought. According to [113], the maintenance laws state that:

1. Maintenance costs are reduced by lowering the need for maintenance;
2. Neglected maintenance reappears multiplied in effect and cost.

For a technical system, it is more important to prevent faults from occurring than to reach the point of repairing them. Several key aspects must be taken into account when designing new maintenance strategies. Firstly, premature replacement of components that are still in good condition (over-maintenance) must be avoided, but neither should replacement be delayed to the point where severe consequences may arise.

The quality of materials and technologies is continually improving. The capabilities for using (automation; adjustments based on measured values) and monitoring (making decisions about technical condition based on measurements or other parameters) sensors in vehicles have significantly increased. Against this backdrop, the development of predictive maintenance techniques aims to enhance vehicle availability, especially given the ongoing rise in costs for new materials, components, labour, and services.

A new development direction in maintenance systems is based on communication between road vehicles and a central analysis hub (dispatcher). Equipped with sensors, the vehicles send information regarding changes in their technical condition to the analysis centre. At the centre, the severity of the fault is assessed alongside the type of vehicle and its specific use (priority is given to lorries carrying hazardous or perishable goods, and large-capacity passenger vehicles). The fault is identified, and then the nearest maintenance and repair unit capable of fixing the issue and possessing the required spare parts is located. All these processes happen automatically. The driver is informed via messages once an appropriate course of action has been determined. The final decision whether to follow the recommendations lies with the driver (the client).

New maintenance strategies must anticipate faults before they occur. This approach offers benefits such as faster and more accurate problem identification, reduced downtime (increasing the availability of road vehicles), improved safety and efficiency for technicians, and optimised maintenance and repair costs.

Another avenue for developing new maintenance and diagnostic strategies is the use of augmented reality. Augmented diagnostics is an advanced process for fault identification and analysis using technologies like artificial intelligence (AI), augmented reality (AR), and the Internet of Things (IoT). It combines real-time data with intelligent algorithms to enhance diagnostic accuracy and speed. Smart devices collect real-time data on temperature, vibrations, pressure, and wear levels. Algorithms analyse this data to detect anomalies, compare them with previous patterns, and predict potential faults. Experts use AR glasses or mobile applications to provide remote support, ensuring maintenance activities are performed correctly and safely. They also offer interactive instructions and detailed information specific to the systems being diagnosed.

The third research direction involves the development and application of "reverse engineering" principles using a 3D scanning and printing system. A 3D scanner assists in capturing the geometry (shape and dimensions) of components within road transport systems. This digitally captured geometry supports reverse engineering by enabling the redesign of existing components with additional features to accommodate specific sensors or other research equipment. Using a 3D scanner, the actual geometry of existing parts is compared against the ideal geometry in the CAD model. This process reveals any residual deformation of structures relative to the original design, or highlights deviations in shape compared to known reference values.

The system enables the creation of 3D models for complex assemblies, such as the ducting in air filtration systems, subsequently allowing the development of specialised fluid flow simulations to estimate aerodynamic resistance.

Career Development Directions

Teaching activity - I plan to continue adapting the knowledge delivered in the subjects I teach, both during lectures and laboratory sessions, to better reflect current trends in the design, construction, and use of road transport vehicles internationally, while also considering the specific nature of activities carried out in the transport sector.

The course "Maintenance of Vehicle Propulsion Systems" will be further developed to include a more detailed presentation of how preventive, predictive, proactive, and corrective maintenance activities are organised for hybrid propulsion road vehicles and high-capacity road transport vehicles.

I will continue to strengthen and diversify the curriculum offering by introducing new courses. A key priority is the introduction of a new course within one of the master's programmes, entitled "Filters for Road Vehicles." The course content will cover: fundamentals of air, fuel, and lubricant filtration; standards for filter testing; methods, materials, and media used in filtration; filter calculation elements; and filter maintenance.

Another priority is modernising teaching methods through the extensive use of the digital platforms provided by U.N.S.T.P.B. and advanced software applications. Efforts will also focus on completing the current teaching materials under development and creating new educational resources, including courses and exercises, to enhance the visibility of academic activities.

Research activity

I intend to continue participating in research competitions both as a coordinator/responsible person and as a member (partner) within research teams. My aim is to further develop the concepts presented in this work while encouraging and implementing innovative ideas proposed by young researchers.

I plan to establish an interdisciplinary research centre primarily focused on the use of road transport vehicles.

Developing the research laboratory dedicated to the maintenance of road transport vehicles is also a key priority.

Disseminating research outcomes is particularly important. Preparing and publishing scientific papers in journals with an impact factor enhances the credibility and relevance of the research, contributing to the strengthening of the researcher's reputation.

In the future, I wish to strengthen and broaden my connections with industry representatives to identify research topics of mutual interest, which could serve as starting points for dissertations, theses, and future doctoral research.

Activities with Students

The areas of action to be developed for the benefit of students are organised as follows:

- guidance (mentoring) in student scientific circles, diploma and dissertation projects. Works with outstanding results will receive support for the dissemination of findings through participation in conferences and publication in specialised journals;
- supervision of doctoral candidates as coordinators and members of supervisory and academic integrity committees;
- encouragement and support for students to participate in research programmes and Erasmus+ mobility schemes;
- expansion of internship programmes and study visits conducted at economic agents;
- organisation of technical competitions involving students.

Community service activities

The courses of action to be developed for the benefit of the community are structured as follows:

- participation in activities to promote the Faculty of Transport by strengthening the image and prestige of U.N.S.T.P.B. university. An active university within the community is more visible and respected, which increases its appeal to prospective students and partners.
- providing consultancy services to local authorities or companies in the fields of road safety, sustainable transport, and vehicle maintenance.
- organising short courses aimed at graduates of technical education, both with secondary and higher education qualifications.

- engaging in the organisation of festivals and other events, with an expansion towards activities that popularise science among the general public. Academic staff involve students in socially impactful activities, fostering values such as volunteering, solidarity, and civic responsibility.

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112 *** numarul de autoturisme in Romania, disponibil la: https://www.economica.net/bucuresti-cluj-si-ilfov-judetele-cu-cele-mai-multe-masini-electrice-inmatriculate_723356.html, accesat la 3.04.2025
113 *** numărul de autovehicule in Romania, disponibil la: Direcţia Generală Permise de Conducere şi Înmatriculări, accesat la 3.04.2025
114 *** numărul de autovehicule noi in Romania, disponibil la: Înmatriculări noi de vehicule rutiere, în anul 2024 | Institutul Naţional de Statistică, accesat la 3.04.2025
115 *** patent de invenţiei sistem de autocurăţare filtru de aer, disponibil la: 1498398637383036952-US20130239802A1, accesat la: 5.05.2025
116 *** tendinte in constructia de automobile hibride, disponibil la: 2025 Hybrid Car Trends: Sales, Models & Future Outlook
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118 ***, Ce este transportul sustenabil şi ce rol joacă acesta în combaterea schimbărilor climatice?, disponibil la: What is sustainable transport and what role does it play in tackling climate change? | UNDP Climate Promise
119 ***, Monitor PNRR, Domeniul de politică – Transporturi, disponibil la: Componenta C4. Transport sustenabil - Monitor PNRR

Lista de abrevieri

- AIS (Air Induction Systemc), sistemul de filtrare a aerului așa cum echipează motorul autoturismului;
- AIS–AF, (Air Induction Systems without Air Filter) sistemul de filtrare a aerului fără filtrul de aer;
- CRC E60 WOT – Coordinating Research Council procedure E 60, wide-open throttle – procedură de încercare;
- COC – Certificat de conformitate European;
- FTP - Federal Test Procedure (EPA) - procedură de încercare;
- H&AF, (Hausing and Air Filter), carcasa și filtrul de aer;
- HFET - Highway Fuel Economy Test (EPA) ciclu standardizat;
- IAD (intake air duct).tubul de ghidare al aerului de la gura de aspirație la carcasa filtrului;
- ITS - Sisteme de Transport Inteligente (Intelligent Transport Systems);
- KTS – echipament de diagnosticare Robert Bosch;
- LCF - low cost filter – filtru cu preț redus de achiziție;
- MVEM - (Mean Value Engine Model), AMESim. model motor MVEM calibrat pentru a simula comportamentul unui motor cu aprindere prin scânteie supraalimentat;
- NEDC - (New European Drive Cycle) – Ciclul standardizat de incercare;
- OBFCM - On-Board Fuel Consumption Monitoring-Sistem de monitorizare internă a automobilului pentru consumul de conbustibil si a distantelor parcurse;
- OBD – (On-Board Diagnostics), diagnosticare la bord;
- OEM - Original Equipment Manufacturer – Echipament de prima echipare, de origine;
- OEM_U – Echipament de origine (filtru), utilizat;
- PNRR - Planul Național de Redresare și Reziliență;
- PMF – premium Manufacturer filter, equipment (filtru) de calitate superioară;
- SS WOT - steady speed wide-open throttle - procedură de încercare;
- TEN-T - Rețeaua Transeuropeană de Transport (Trans-European Transport Network)
- TWC(Tree Way Catalyst) catalizatorul pentru post-tratarea gazelor de evacuare;
- US06 - aggressive (high speed, high load) test used to confirm emissions compliance during aggressive driving.- procedură de încercare;
- WLTC – (Worldwide Harmonized Light vehicles Test Cycle) - Ciclul standardizat de încercare.