Leading Tendencies in Transport Higher Education

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***Abstract* – Modernising transport education is vital for the transformation of the transport sector in today's complex environment. This article elucidates the leading tendencies in transport higher education as identified in the Scopus and Web of Science literature. A structured review approach and a bibliometric analysis of the conceptual structure were employed. Eight tendencies in transport higher education were identified through content analysis of the literature. These were validated and clustered using Biblioshiny 5.0's (Bibliometrix R Studio) factorial analysis feature. The evolution of these tendencies across three periods was examined utilising their chronological sequence and Biblioshiny's thematic evolution feature. The most frequently mentioned tendencies were recognised as leading, including digital transformation, e-learning and online platforms, sustainability and environmental impact, and innovative teaching methods. According to bibliometric factorial analysis, the topic of innovative teaching methods is central to this research, with digital transformation and e-learning demonstrating the highest potential for future growth. The bibliometric analysis of thematic evolution revealed that since 2023, the topic of sustainability and environmental impact has become central and well-developed within transport higher education. Additionally, the other leading tendencies have shown potential to expand within the domain of data management, an emerging subject during this period.**

***Keywords* – Higher education, transport, tendencies, management.**

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1. Introduction

Transport is of utmost importance for the existence of humans and societal development, as the movement of people and resources underpins all human activities - both economic and social. In terms of economy, the development of cities, regions, and countries is closely tied to their transport infrastructure [1], [2]. Effective transport links are vital for the growth of international trade, the advancement of tourism, and strategic investment decisions [3]. These, in turn, create the conditions needed for increasing employment, attracting financial investment, as well as improving the well-being of individuals, businesses, regions, and countries. In terms of society, well-structured transport improves connectivity between people, enhances their quality of life, protects public health and the environment, fulfils social functions, and, as a result, generally contributes to greater societal well-being [4], [5].

Currently, the operation of transport systems is contingent upon addressing numerous challenges associated with a highly uncertain and dynamic environment. These include quick technological advancements, global crises, digitalisation, as well as the demands of international policies aimed at energy conservation, preventing environmental pollution, reducing harmful emissions, and sustainable development [6], [7], [8]. The swift adaptation of transport systems to this intricate environment is crucial for the growth and successful functioning of economic and social systems.

The successful transformation of the transport sector heavily depends on the modernisation of transport education. A particular emphasis should be placed on transport higher education and its institutions (HEIs) as key drivers of innovation [9]. Currently, transport higher education is interdisciplinary, covering not only core engineering subjects but also logistics, management, marketing, policy, and other social sciences [10]. This nature further complicates the rapid adaptation of transport higher education to the present dynamic environment.

In this context, it is increasingly important to set the direction for change and development in transport higher education, highlighting the pressing need to identify leading tendencies within it. These tendencies are essential for achieving high transport efficiency, which in turn drives economic prosperity and social well-being. The review of scientific literature in the scientometric databases Scopus and Web of Science (WoS) reveals several studies focusing on leading tendencies in higher education overall [11], [12], [13]. Still, similar research in the transport field is lacking.

In this vein, this article aims to identify the leading tendencies in transport higher education as documented in the literature indexed in Scopus and WoS.

These are the research questions raised in this context:

- *Question 1 (Q1): What tendencies in transport higher education are documented in the Scopus and WoS literature?*
- *Question 2 (Q2): How have tendencies in transport higher education changed over time?*
- *Question 3 (Q3): Which tendencies in transport higher education can be considered leading?*

2. Methodology

This research relies on literature from the scientometric databases of WoS and Scopus, available as of late August 2025. Two components of the conceptual structure module, incorporated into the bibliometric analysis, and a structured review approach were employed to thoroughly explore tendencies in transport higher education. In addition, analysis, synthesis, and expert judgment methods were utilised. The bibliometric analysis was conducted with Biblioshiny 5.0, a software of the Bibliometrix R package.

The research process proceeded through three consecutive phases, as illustrated in Figure 1.

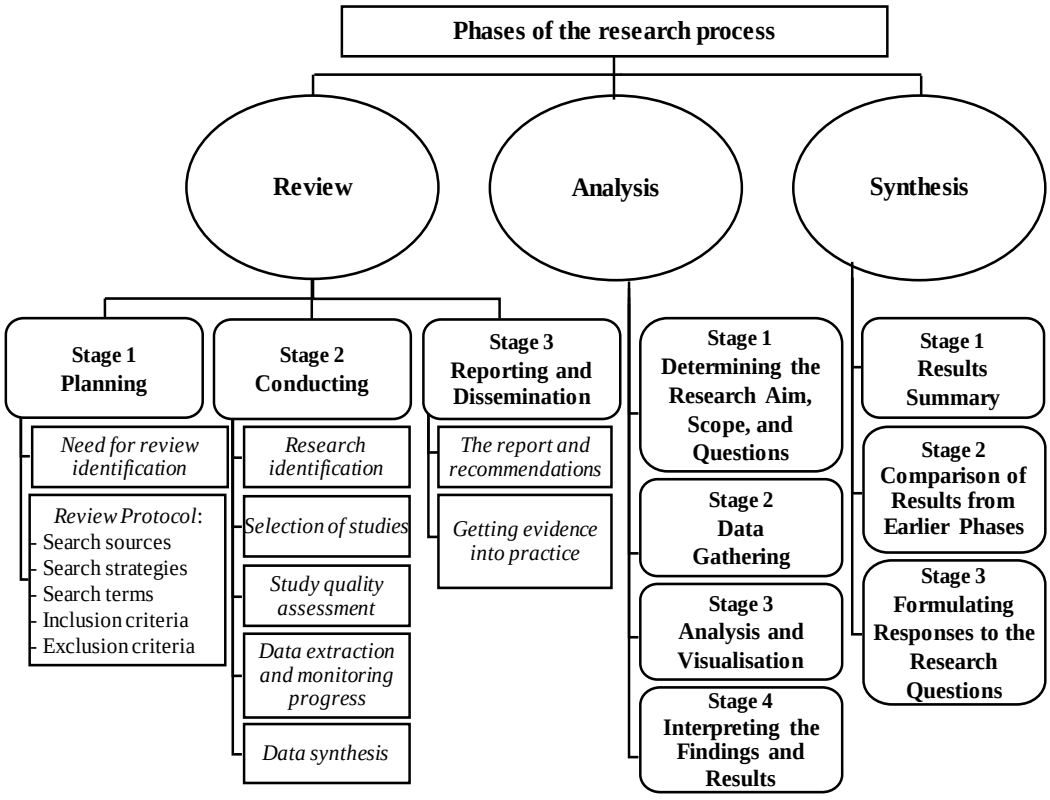


Figure 1. Research process structure

During the review phase, the recommendations from the Cochrane Reviewers' Handbook [14] and the National Health Service Centre [15] were followed. The review went through three stages, as shown in Figure 1.

During the planning stage, the need for a review was identified, and consequently, a review protocol was drafted [16].

The searches were performed in the WoS (Core Collection) and Scopus, which are considered the two most reputable international databases [17], [18]. The phrase employed was *("transport education" OR "transport training" OR "transport learning" OR "transport teaching") AND (innovat* OR perspectiv* OR prospect* OR trend*)*. Specific fields were selected for searching in both databases.

These are 'Topic' for WoS, and 'Article Title, Abstract, and Keywords' for Scopus. The inclusion criteria comprised publications that featured the search phrase and were written in English. To meet the exclusion criteria, publications had to be non-open-access and irrelevant to both the research topic and the aim of this paper. Regarding the period, no exclusion criterion was set.

During the conducting stage, as noted in sources [14] and [15], five activities were performed, as shown in Figure 1. Research searches were conducted on 6 August 2025, retrieving a total of 75 records - 33 from WoS and 42 from Scopus. Using the Mendeley Reference Manager's "check for duplicates" feature, 21 duplicate entries were removed. The titles and abstracts of the remaining 54 papers were then reviewed via content analysis to assess their relevance to the research topic. Of these, 29 were judged irrelevant and excluded from the review, leaving 25 records for detailed examination. The full texts of four papers were unavailable. An in-depth analysis of 21 full texts was then performed using expert judgement. Papers that did not meet the inclusion criteria - 0 unrelated to the paper's aim and 2 in Portuguese and Dutch - were discarded from further consideration. The final sample for this study was assembled from the remaining nine sources, including: [19], [20], [21], [22], [23], [24], [25], [26], and [27].

During the third stage, a report on the literature sample was prepared (Table 1). Additionally, in this concluding stage, tendencies in transport higher education were identified by analysing the full texts of the sampled sources, thus answering research question Q1. To prepare for Q2, the sample was also explored chronologically by year of publication, and a timeline of these tendencies was created. For Q3, the frequency of mentions for each tendency within the sample was counted. These counts were then used in the third phase of this study to address Q3.

Table 1. The sample

Source	Authors	Publication Year
[19]	Bekiaris, E. & Loukea, M.	2019
[20]	Drozdova, M. & Fursova, E.	2023
[21]	Golunova, L., Tsvetkov, D., Privalov, A., Titov, S., & Igumnov, A.	2022
[22]	Hrustek, L., Mekovec, R., & Alexopolus, C.	2023
[23]	Jennings, A. A. & Kuhlman, S. J.	1997
[24]	Jia, L., Ma, T., Rong, H., Gao, L., Zhang, Y., & Sheng, V. S.	2025
[25]	Kabashkin, I. & Lotter, H.-J.	2009
[26]	Kuzmichev, I., Pyzhova, Z., & Karavashkina, R.	2022
[27]	Vasant, P., Kharchenko, V., Panchenko, V., Thomas, J. J., & Weber, G. W.	2021

During the second phase of this research, a bibliometric analysis was executed to explore the conceptual structure of the literature sample and the evolutionary progression of the tendencies being studied. The analysis went through four stages [28], as shown in Figure 1.

The results from the first stage (Figure 1) are set out in the Introduction section.

The data gathering for this study, known as stage 2 in [28], has been described above as part of the review procedure. An extra activity, the conversion of the sample into a CSV file, was also carried out at this stage.

Typically, the third stage begins with selecting bibliometric techniques and software [29]. Here, the methodology outlined in source [30] was adopted, and the Biblioshiny 5.0 feature of the Bibliometrix R package was utilised. The literature sample was analysed and the results were visualised with two modules of Biblioshiny: Thematic evolution and factorial analysis, as part of the conceptual structure. The thematic evolution was performed to assist in answering Q2 by illustrating the research field's temporal development and mapping high-activity topics over time. Based on the sample's chronological distribution and key global events/trends, the sample period was divided into three time slices: Stage 1 (1997-2019) — 'Pre-COVID', Stage 2 (2021-2022) — 'During COVID', and Stage 3 (2023-2025) — 'Post-COVID'. The thematic evolution utilised these parameters: field=abstracts, n-grams=1, terms=240, labels per cluster=4, min cluster frequency (per 1000 docs)=5, weight index=stability index, min weight index=0.1, clustering algorithm=Louvain, label size=0.2, and cutting points at 2 (2020 and 2022). The factorial analysis aimed to identify clusters of (sub)topics, such as tendencies in transport higher education, to help answer Q1 and Q3. It was performed with the following settings: method=multidimensional scaling, field=abstracts, n-grams=1, terms=30, min degree=5, clusters=5, label size=5, and documents=9.

In the fourth stage, the key findings were summarised, interpreted, and suggestions for future research were outlined [31].

During the Synthesis phase, results from the prior two phases were systematically summarised, critically compared, and used to draft responses to the research questions. Methods of comparative analysis, expert judgement, and synthesis were applied. For Q1, tendencies in transport higher education were summarised based on the final review stage. These trends were further validated by the factorial analysis findings. For Q2, the thematic evolution of tendencies was outlined based on changes in their timeline, which was created during the review process, along with the bibliometric analysis results.

Regarding Q3, tendencies in transport higher education were ranked according to their mention frequency. Based on these results, the top three tendencies were identified as leading. Additionally, bibliometric analysis findings were utilised to help interpret these conclusions and to identify emerging topics within the studied field.

3. Results and Discussion

The results of the study, along with their interpretations, are presented in this section. Its organisation follows the research questions.

3.1. Regarding Research Question Q1

As of August 2025, eight tendencies in transport higher education were identified from the full texts of sampled sources found in the Scopus and WoS (Core Collection) literature. These are listed alphabetically in Table 2, in response to research question Q1. Table 2 provides details of the sources used to derive these tendencies (columns 1 to 9), the total number of mentions for each tendency (column 10), and the ranking of tendencies by mention count (column 11).

Table 2. Tendencies in transport higher education based on full source texts

Tendency	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	Total Mentions	Rank
	1	2	3	4	5	6	7	8	9	10	11
Digital Transformation	v	v				v	v	v	v	6	1
E-Learning and Online Platforms	v	v	v		v	v				5	2
Innovative Teaching Methods	v	v						v	v	4	3
International Collaboration and Globalisation	v			v			v			3	4
Multimodal Learning		v				v				2	5
Policy and Strategic Planning		v		v			v			3	4
Sustainability and Environmental Impact	v	v				v			v	4	3
Sustainability Integration into the Curriculum		v								1	6

Digital transformation appears as the first tendency in alphabetical order in Table 2. Under this tendency, HEIs are adopting various digital technologies and tools to modernise and improve their learning environments [20]. Digital tools are used to facilitate the relocation of teaching settings, support lifelong learning, and boost student mobility [25]. Artificial Intelligence and the Internet of Things are employed to revolutionise educational methodologies.

Within the second tendency, e-learning and online platforms are included, such as browser-based mobile technologies and customised applications. According to [19], these technologies provide access to educational content regardless of time and location and, as a result, improve time management efficiency and collaboration within e-learning environments.

The third tendency is characterised by innovative teaching methods, e.g., Augmented and Virtual Realities [27]. These assist students in grasping complex subjects, boost their engagement, and ultimately drive the development of transport-related higher education.

The fourth tendency encompasses international collaboration and globalisation in the transport domain, including transport services, processes, and systems within a growing complexity. In this context, transport training and education have to revise their curricula, shifting from traditional approaches to network-based settings to incorporate globalisation and international aspects [25].

Multimodal learning is the fifth tendency. The integration of multimodal aspect-based learning techniques is rapidly gaining prominence through the utilisation of optimal transport learning. The aim is to optimise computational resources and enhance classification efficacy in sentiment analysis [24].

The sixth tendency concerns policy and strategic planning. Implementing effective policies and strategies is essential for establishing efficient systems and advancing education in the transport sector at both national and international scales. An example of such a strategy is the setting up of the Innovative Virtual European Transport Training Agency (IVETTA). It is a European network of institutions and individuals dedicated to transport education through ICT [25].

Sustainability and environmental impact form the seventh tendency. In urban transportation networks, intelligent energy management systems based on deep reinforcement learning are becoming increasingly important for advancing fossil fuel-free transport and improving the efficiency of hydrogen utilisation [26].

The eighth tendency is sustainability integration into the curriculum. Nowadays, it is essential that skilled professionals are trained to manage logistics systems efficiently and in a sustainable manner [20].

Most tendencies in transport higher education, as identified from source full texts (Table 2), were validated by the factorial analysis findings (Figure 2), which relied on the source abstracts.

First, the digital transformation tendency emerged as a distinct cluster in Figure 2, which can be designated as ‘digital development of universities’. This cluster is highlighted in purple and located in the upper left quadrant. Second, the authors of this study observed that the tendency of e-learning and online platforms falls into two distinct clusters in Figure 2. The e-learning component appeared in the light green cluster in the upper right quadrant, and can be described with the words ‘course’, ‘electronic’, and ‘growing’. The online platforms component can be classified as belonging to the blue cluster in Figure 2, situated in its lower right quadrant. These platforms are associated here with the words ‘technologies’, ‘data’, ‘models’, and ‘machine’. Third, the tendency of innovative teaching methods in transport higher education explicitly pertains to the central red cluster in Figure 2. It can be characterised by the words ‘innovative’, ‘transport’, ‘educational’, ‘education’, and ‘training’ from that central cluster. Fourth, the tendency of international collaboration and globalisation can be ascribed to the light blue cluster, situated in the lower left quadrant of Figure 2.

This correlation is somewhat indirect. The words within this cluster: ‘network’, ‘processes’, ‘market’, and ‘creation’ - can be utilised as evidence. Fifth, the multimodal learning tendency is represented in the lower right quadrant cluster in Figure 2, associated with the words ‘learning’, ‘models’, ‘transformation’, and ‘analysis’. Sixth, two references related to the tendency of policy and strategic planning were identified: The first is the word ‘future’ in the lower right cluster, and the second is ‘ivetta’ in the central cluster of Figure 2. Since the latter pertains to a transport education strategy, the authors assign this tendency to the central cluster in Figure 2. Seventh, sustainability-related tendencies, specifically, sustainability and environmental impact, as well as sustainability integration into curricula -formed part of the lower right cluster in Figure 2. These tendencies are represented by the words ‘ecosystem’, ‘technologies’, ‘transformation’, ‘energy’, ‘industry’, and ‘sector’ within that cluster.

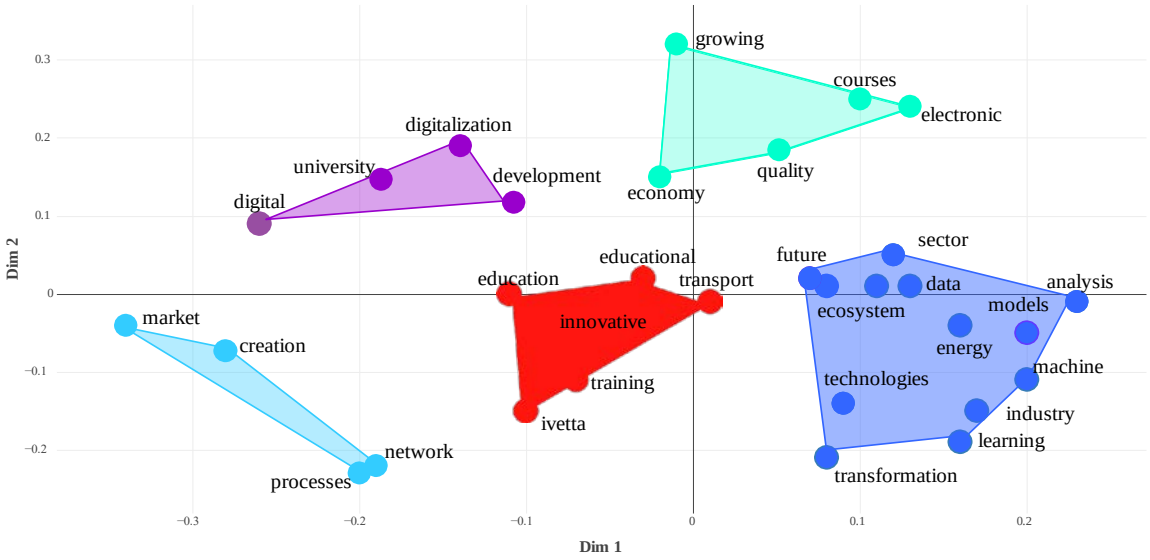


Figure 2. Factorial analysis of topics in transport higher education based on source abstracts

Answer to Q1: Eight tendencies in transport higher education were identified based on literature from the Scopus and WoS (Core Collection) databases as of August 2025, including digital transformation, e-learning and online platforms, innovative teaching methods, international collaboration and globalisation, multimodal learning, policy and strategic planning, sustainability and environmental impact, and sustainability integration into the curriculum. These tendencies emerged from an in-depth content analysis of the full texts from the sampled sources. They were further validated by factorial analysis of the source abstracts, using Biblioshiny 5.0 within the Bibliometrix R package.

3.2. Regarding Research Question Q2

The evolution of tendencies in transport higher education is explained here from two perspectives. The first outlines tendencies over the years, grounded in the complete texts of sampled sources and their publication chronology sequence. The second classifies these tendencies into three periods aligned with key global trends/events, utilising the thematic evolution feature of the Biblioshiny tool from the Bibliometrix R package and source abstracts.

The distribution of sources within the sample by year is illustrated in Figure 3. The sources were published from 1997 to August 2025.

Most were issued annually, except for 2022 and 2023, when two papers appeared each year.

No papers were published between 1998 and 2008, 2010 and 2018, 2020, and 2024.

The data indicate that 2022 and 2023 had the highest number of published documents within the sample.

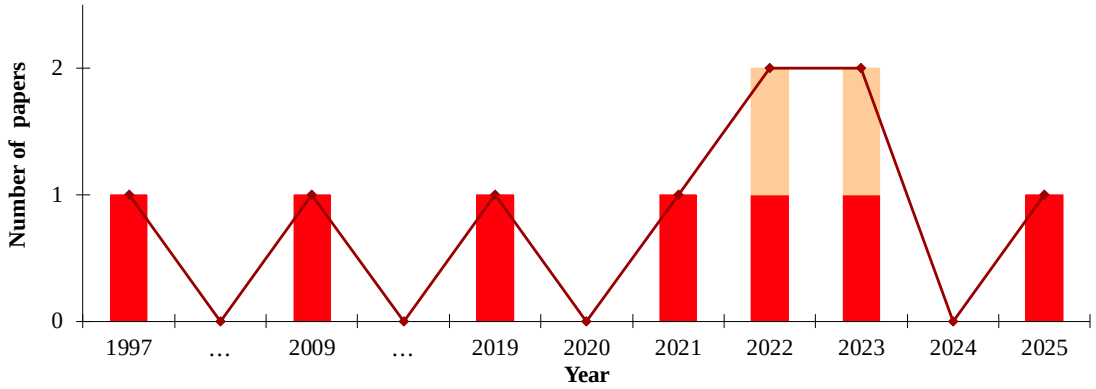


Figure 3. The sample by years

From the first perspective, Figure 4 illustrates tendencies in transport higher education over the years, along with their timelines from 1997 to August 2025. Bullet points denote the appearance of tendencies in specific years, while straight lines represent the timelines of these tendencies.

The results show that the most frequently mentioned tendency per year was policy and strategic planning, with two mentions in 2023. All other tendencies were mentioned only once in their respective years.

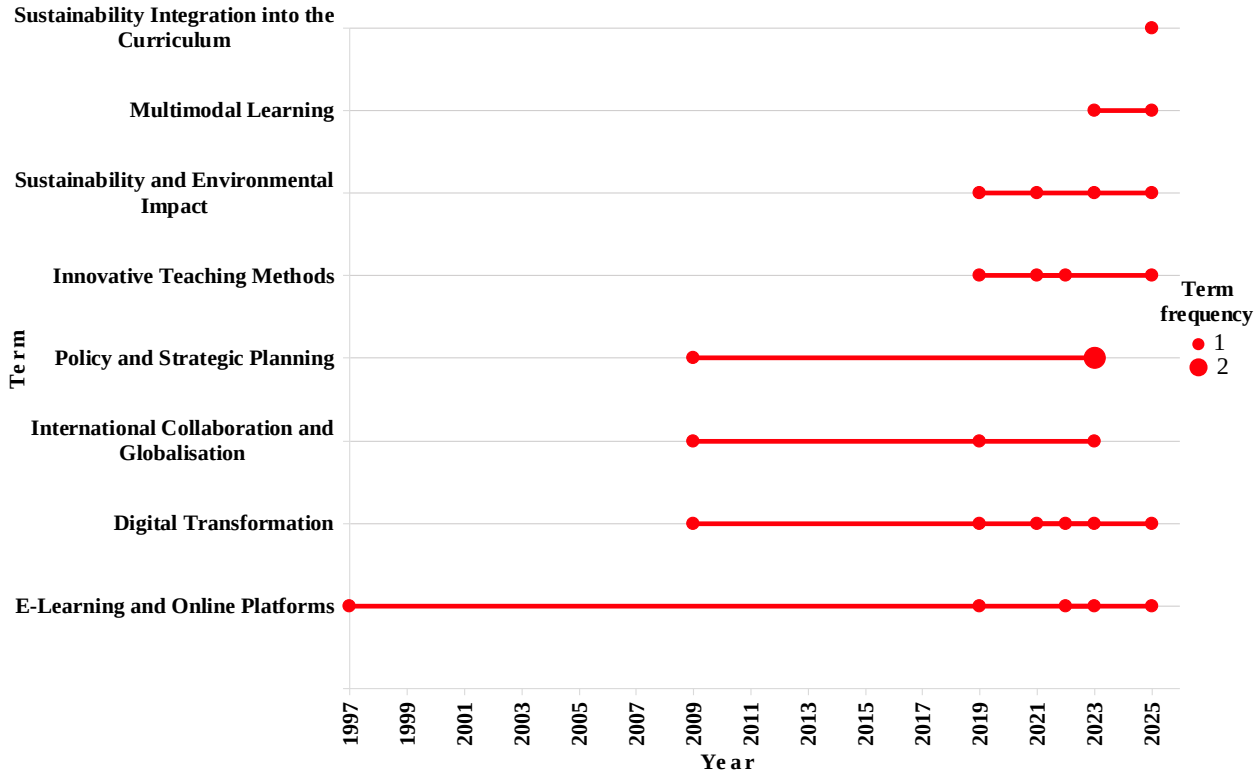


Figure 4. Timeline of tendencies in transport higher education based on full source texts

The timeline of tendencies illustrates the duration of each tendency. According to the findings, e-learning and online platforms persisted the longest, from 1997 to 2025.

Next was digital transformation, spanning from 2009 to 2025. Following that, policy and strategic planning and international collaboration and globalisation were observed from 2009 to 2023.

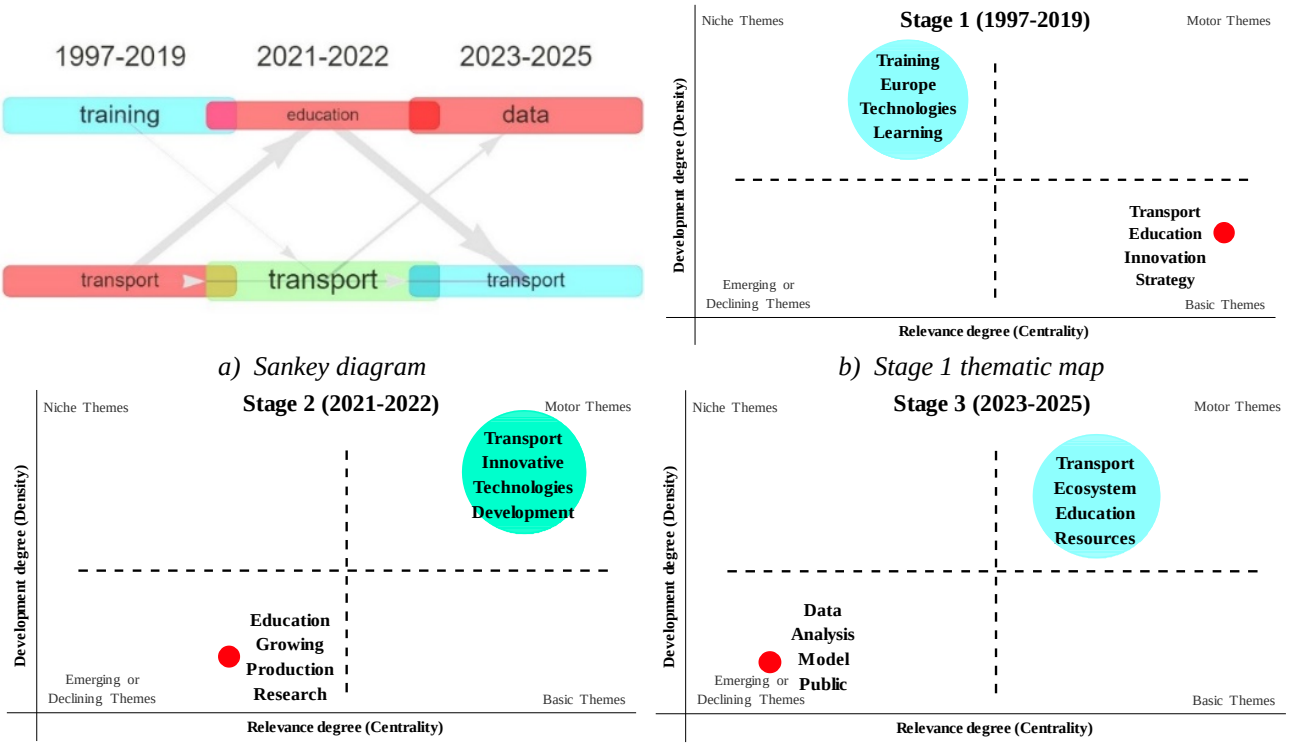
Four more recent tendencies were also identified: innovative teaching methods and sustainability and environmental impact, covering 2019-2025; multimodal learning, from 2023 until 2025; and the sustainability integration into the curriculum, which emerged in 2025.

Regarding research question Q2, it is essential to outline the timelines of tendencies in transport higher education appearing across different periods (stages).

These include:

- 1997-2019 (Stage 1): six tendencies — digital transformation, e-learning and online platforms, innovative teaching methods, international collaboration and globalisation, policy and strategic planning, and sustainability and environmental impact.
- 2021-2022 (Stage 2): four tendencies — digital transformation, e-learning and online platforms, innovative teaching methods, and sustainability and environmental impact.
- 2023-2025 (Stage 3): all eight tendencies.

From the second perspective, the thematic evolution of tendencies in transport higher education was outlined across three periods (Figure 5a): 'Pre-COVID' (Stage 1), 'During COVID' (Stage 2), and 'Post-COVID' (Stage 3). Static results for each stage are depicted in Figures 5b, 5c, and 5d as maps of thematic clusters. The thematic map illustrates and groups the main themes of the domain into clusters using two criteria: The level of development (density) and the level of relevance or importance (centrality) of each theme within a particular domain [32], [33]. Using the combination of density-centrality values, clusters can be classified into four types [34], [35]: emerging or declining (low-low), motor (high-high), niche (high-low), and basic (low-high). Clusters encompass subthemes and were labelled according to the most recurrent words within them [30]. In dynamic terms, a Sankey diagram was used to depict the flow of tendencies, their inputs and outputs [32] - across the stages (Figure 5a).



a) Sankey diagram

b) Stage 1 thematic map

c) Stage 2 thematic map

d) Stage 3 thematic map

Figure 5. Thematic evolution of tendencies in transport higher education using source abstracts

Regarding static results, two clusters were identified, illustrating the most prominent tendencies in transport higher education for each period. Details on static results are provided in Table 3, covering cluster types, centrality, frequencies, density, and main words. In Stage 1, these clusters were labelled 'Transport' and 'Training' (Figure 5b and Table 3).

Based on its density of 350 and centrality of 12.5, the 'Training' cluster was classified as niche (upper left quadrant). In contrast, the 'Transport' cluster was categorised as basic (lower right quadrant), with a density of 213.89 and a centrality of 17.83.

Comparing the cluster subthemes (Main words column, Table 3) with the Stage 1 tendency timeline (Figure 4) reveals that the tendencies for innovative teaching methods and policy and strategic planning were fundamental, meaning central but underdeveloped, as defined by [35]. In contrast, international collaboration and globalisation, digital transformation, and e-learning and online platforms appeared as niche tendencies - developed but peripheral [35]. This is a logical result, given the prolonged length of Stage 1 in the past. In Stage 2, the clusters were labelled 'Transport' and 'Education' (Figure 5c and Table 3). The 'Transport' cluster was motor-type (upper right quadrant), with a density of 402.5 and a centrality of 14.75.

The 'Education' cluster was identified as emerging/declining (lower left quadrant), with a density of 150 and a centrality of 11.08. Comparing the cluster subthemes (Main words column, Table 3) with the Stage 2 tendency timeline (Figure 4) shows that all four tendencies during this period (digital transformation, e-learning and online platforms, innovative teaching methods, and sustainability and environmental impact) were motor, i.e., central and developed [35]. This result fully aligns with the main themes in education during the COVID period. No tendencies related to subthemes in the emerging/ declining cluster were found during this period.

Table 3. Thematic evolution of tendencies in transport higher education: static results by stage

Cluster Name	Cluster Type	Callon Centrality	Callon Density	Rank Centrality	Rank Density	Cluster Frequency	Main Words
Stage 1 (1997-2019)							
Transport	Basic	17.83	213.89	2	1	19	transport, education, innovation, strategy, educational, models
Training	Niche	12.5	350	1	2	26	training, Europe, technologies, learning, development, industry, future
Stage 2 (2021-2022)							
Transport	Motor	14.75	402.5	2	2	42	transport, innovative, technology, data, development, digital, environment
Education	Emerging/ Declining	11.08	150	1	1	10	education, growing, production, research
Stage 3 (2023-August 2025)							
Transport	Motor	4.5	170.83	2	2	17	transport, ecosystem, education, resources, potential, transformation
Data	Emerging/ Declining	3.83	125	1	1	8	data, analysis, model, public

In Stage 3, the two clusters were 'Transport' and 'Data' (Figure 5d). The 'Transport' cluster was motor (Table 3, density=170.83, centrality=4.5), while the 'Data' cluster was emerging/declining (Table 3, density=125, centrality=3.83). The comparison between the cluster subthemes (Main words column, Table 3) and the Stage 3 tendency timeline (Figure 4) indicates that tendencies related to the environment, education, and the future - sustainability integration into the curriculum, sustainability and environmental impact, innovative teaching methods, and policy and strategic planning, were motor-type. In contrast, tendencies related to data analysis/processing, multimodal learning, digital transformation, and e-learning and online platforms became emerging/ declining, i.e., peripheral and underdeveloped [35]. The results concerning motor themes reflect society's main focus after 2022 in the post-COVID era. As for data processing themes, the authors of this study consider them emerging, driven by rapid ongoing technological progress.

In dynamic terms, the most significant themes across the three stages, represented as nodes [30], [36], and the flows between them, indicated by arrows, are depicted in the Sankey diagram in Figure 5a. Insights into the dynamics of tendency flows, along with their statistical and linguistic details, are also provided in Table 4. During the transition from Stage 1 to Stage 2 (Table 4), the themes within the 'Transport' cluster (Stage 1) exerted the strongest influence on those within the 'Education' cluster (Stage 2), indicated by a weighted inclusion index (WII, representing arrow thickness [30], [37]) of 0.2. The next most significant flow (WII=0.16) was from the 'Transport' (Stage 1) cluster to the 'Transport' (Stage 2) cluster. The least significant, yet nearly comparable, flow was from the 'Training' (Stage 1) cluster to the 'Transport' (Stage 2) cluster, with a WII of 0.15. Analysing these flows against the timeline of tendencies depicted in Figure 4 and the main words listed in Table 3 led to several conclusions.

First, the strongest flow indicates that transport and education topics in Stage 1 became increasingly important for production and economic growth in Stage 2. Next, the second flow suggests that innovations in transport education, fundamental themes in Stage 1, evolved into a motor theme for Stage 2.

Moreover, in line with the third flow, developments and technologies in transport education, niche themes in Stage 1, also emerged as motor themes during Stage 2. These findings are considered valid, given the transition from the 'Pre-COVID' to the 'During COVID' stages.

Table 4. Thematic evolution dynamics of tendencies in transport higher education

From Cluster	To Cluster	Words	Stability Index	Occurrences	Inclusion Index	Weighted Inclusion Index
1. From Stage 1 (1997-2019) to Stage 2 (2021-2022)						
Training	Transport	technologies, development	0.03	2	0.08	0.15
Transport	Education	education	0.08	2	0.20	0.20
Transport	Transport	transport	0.04	3	0.11	0.16
2. ***From Stage 2 (2021-2022) to Stage 3 (2023-August 2025)***						
Education	Transport	education	0.08	2	0.20	0.20
Transport	Data	data, analysis	0.04	2	0.25	0.50
Transport	Transport	transport	0.04	3	0.13	0.18

In this study, the strongest influence (WII=0.5, Table 4) was observed during the transition from Stage 2 to Stage 3 - moving from the 'Transport' (Stage 2) cluster to the 'Data' (Stage 3) cluster. Its magnitude was then followed by a noticeable flow with a WII of 0.2 from the 'Education' (Stage 2) cluster to the 'Transport' (Stage 3) cluster. Finally, the least significant flow related to this transition was from the 'Transport' (Stage 2) cluster to the 'Transport' (Stage 3) cluster, with a WII of 0.18. Within the tendencies timeline (Figure 4) and the main words in Table 3, these flows can be interpreted as follows. First, there is a strong conceptual link between innovative technologies in transport education, the motor theme in Stage 2, and data analysis/models, emerging themes in Stage 3. This dominant flow reflects the ongoing challenges associated with managing big data. Second, themes emphasising the importance of transport and education for production and economic growth, observed in Stage 2 as emerging, spill over into the theme of ecological and sustainable transport in Stage 3, the motor type. Third, the 'Transport' cluster remains classified as a motor type. However, its thematic focus has shifted considerably. It moved from developing innovative technologies in transport education to addressing sustainable transformation, ecological impact, and the integration of these themes into the educational process.

A key indicator of thematic evolution is the stability index (SI), assessing how consistently a theme appears across different periods [38]. In this study, education (SI=0.08) and transport (SI=0.04) were the themes that remained stable over time (Table 4).

Conversely, technologies appeared as a transient theme (SI=0.03) during the COVID period, while data and analysis (SI=0.04) became growing themes in the 'Post-COVID' stage.

Answer to Q2: In this study, the evolution of tendencies in transport higher education was analysed across three periods: 'Pre-COVID' (Stage 1), 'During COVID' (Stage 2), and 'Post-COVID' (Stage 3). The tendencies identified by stage are as follows (Figure 4): Stage 1 featured international collaboration and globalisation, policy and strategic planning, e-learning and online platforms, sustainability and environmental impact, innovative teaching methods, and digital transformation. Stage 2 included innovative teaching methods, e-learning and online platforms, sustainability and environmental impact, and digital transformation. All eight tendencies appeared in Stage 3.

Bibliometric analysis revealed two clusters representing the most significant tendencies for each period (Figure 5), including: Stage 1 - 'Transport' (basic) and 'Training' (niche); Stage 2 - 'Transport' (motor) and 'Education' (emerging/declining); and Stage 3 - 'Transport' (motor) and 'Data' (emerging/declining). The most notable thematic shift was from the 'Transport' (Stage 2) cluster to the 'Data' (Stage 3) cluster, indicating a move from themes of innovative transport education technologies to those related to data analysis/modelling.

Concerning the 'Post-COVID' period, tendencies related to the environment, education, and the future - including sustainability integration into the curriculum, policy and strategic planning, sustainability and environmental impact, and innovative teaching methods were identified as developed and central (motor-type).

Meanwhile, tendencies related to data modelling and analysis such as digital transformation, multimodal learning, and e-learning and online platforms were recognised as underdeveloped and peripheral (emerging-type).

3.3. Regarding Research Question Q3

In this study, the leading tendencies in transport higher education were chosen based on their rankings. The ranking indicates how often these tendencies are mentioned in the full texts of the sampled sources (columns 10 and 11, Table 2). Specifically, the leading tendencies identified were those ranked first to third. The ranking of tendencies in transport higher education, arranged in descending order of importance, is shown in Figure 6.

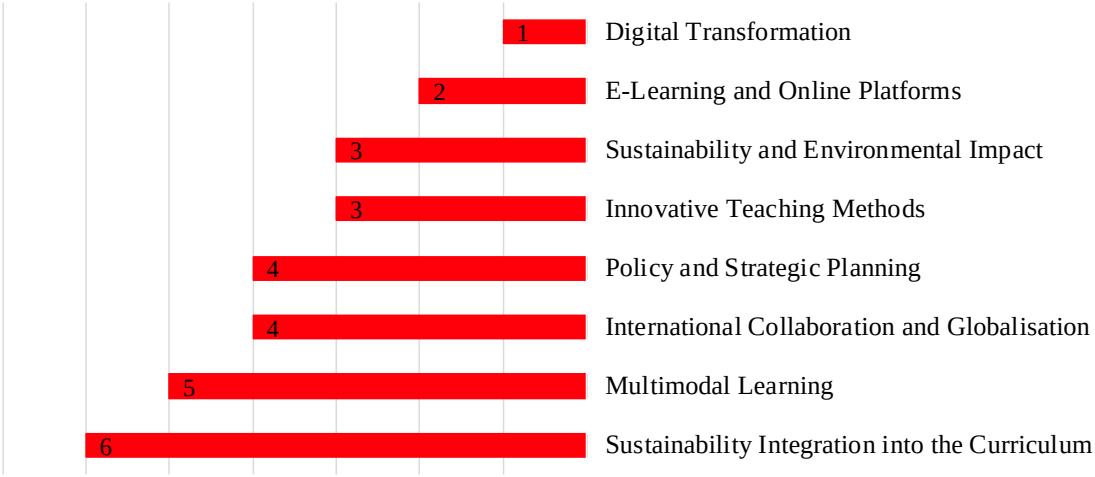


Figure 6. Ranked tendencies in transport higher education based on full source texts

According to Figure 6, the top position was for digital transformation (6 mentions). The second position was for e-learning and online platforms (5 mentions). Two tendencies tied for third place were sustainability and environmental impact, as well as innovative teaching methods (each with 4 mentions). In fourth place, there were also two tendencies: policy and strategic planning, along with international collaboration and globalisation (3 mentions each). Multimodal learning was ranked fifth (2 mentions). The lowest, sixth place, was for sustainability integration into the curriculum (1 mention). Based on these results, the leading tendencies in transport-related higher education include digital transformation, innovative teaching methods, e-learning and online platforms, and sustainability and environmental impact.

In the context of the factorial analysis results (Figure 2), the leading tendencies demonstrated the following characteristics: The tendency of innovative teaching methods was identified as central to this study. The conclusion is based on the observation that the tendency aligns with the red cluster, which is nearest to the origin of the coordinate system, thus reflecting the main themes (words) related to the current study [39].

The tendency of sustainability and environmental impact was associated with the blue cluster on the right, which is situated very near the central red cluster. Furthermore, most words representing this tendency have positive values on both the Dim1 and Dim2 axes, indicating that research on this topic (or tendency) exists, but there is still room for further development [40]. The tendency of online platforms was also attributed to the right blue cluster. However, the tendency was more marginal to the main focus of the current study and received less academic development. This is evident from the fact that words associated with it are positioned farther away from the central red cluster, specifically in the lower right corner of the blue cluster, with most having negative values on the second dimension (Dim 2) axis [41]. Regarding digital transformation and e-learning, these tendencies were notably more peripheral to this study's subject, as their main words are found in clusters farther from the centre. Digital transformation appeared as a separate cluster labelled 'digital development of universities', positioned in the upper left quadrant and marked in purple. The e-learning tendency was associated with the light green cluster in the upper right quadrant. The topics of digital transformation and e-learning hold significant potential for further growth.

Based on the results from the 'Post-COVID' stage in the thematic evolution of tendencies (Figure 5d and Tables 3 and 4), sustainability and environmental impact in transport higher education emerged as a motor (central and developed) type. The other leading tendencies revealed potential for future growth within the domain of data management, which has been classified as an emerging type, characterised as peripheral and underdeveloped.

Answer to Q3: The leading tendencies in transport higher education encompass the top three most frequently mentioned tendencies (Figure 6). These are digital transformation (ranked first), e-learning and online platforms (second), and sustainability and environmental impact, together with innovative teaching methods (third).

The bibliometric factorial analysis of the conceptual thematic structure showed that the topic of innovative teaching methods is central to this research. Additionally, the tendencies of digital transformation and e-learning, although farthest from this study's primary focus, held the greatest potential for growth.

The bibliometric thematic evolution indicates that, in the 'Post-COVID' era, the tendency of sustainability and environmental impact in transport higher education is central and developed. Besides, the other leading tendencies have the potential to grow within the field of data management, which is recognised as an emerging topic in this context.

3.4. Study Limitations

This study has two main limitations. The first relates to the elements of the review protocol, specifically the search phrase, search sources, open-access documents, and the exclusive use of English-language sources. The second concerns the parameters under which the bibliometric analysis was conducted, including the chosen fields, n-grams, term counts, weight index, min weight index, min degree, min cluster frequency, clustering algorithm, and the number of clusters and documents.

4. Conclusion

This article elucidates the leading tendencies in transport higher education documented in the scientific literature in the Scopus and Web of Science (Core Collection) scientometric databases as of late August 2025. It employs a structured approach for review, as well as methods of analysis, synthesis, expert judgment, and bibliometric analysis to examine the conceptual thematic structure.

This study's results can be summarised as follows. First, eight tendencies in transport higher education were identified from the full texts of the sampled sources.

These encompass digital transformation, e-learning and online platforms, innovative teaching methods, international collaboration and globalisation, multimodal learning, policy and strategic planning, sustainability and environmental impact, and sustainability integration into the curriculum. These tendencies were validated and grouped into clusters through factorial analysis, using the Biblioshiny 5.0 (Bibliometrix R Studio) module for analysing conceptual structures.

Second, utilising their chronological timeline, tendencies in transport higher education were structured into three periods (stages): 'Pre-COVID' (Stage 1, 1997-2019), 'During COVID' (Stage 2, 2021-2022), and 'Post-COVID' (Stage 3, 2023-August 2025). Moreover, these tendencies were mapped into clusters by time period, and their characteristics were analysed using the thematic evolution feature of Biblioshiny 5.0. Regarding the 'Post COVID' period, two types of tendencies emerged. The first type involved tendencies related to the environment, education, and the future, such as sustainability integration into the curriculum, policy and strategic planning, sustainability and environmental impact, and innovative teaching methods. These were recognised as developed and central (motor-type) and incorporated into the 'Transport' cluster. The second type involved tendencies related to data modelling and analysis, including digital transformation, multimodal learning, and e-learning and online platforms. These tendencies were categorised as underdeveloped and peripheral (emerging-type) and included in the 'Data' cluster. The most notable thematic shift in the 'Post COVID' period was from the 'Transport' (Stage 2) cluster to the 'Data' (Stage 3) cluster, reflecting a move from themes related to innovative technologies in transport education to those focused on data analysis and modelling.

Third, the leading tendencies were identified using their ranking according to the frequency of mentioning in the literature. The results show that the leading tendencies in transport higher education are innovative teaching methods, digital transformation, e-learning and online platforms, and sustainability and environmental impact. The bibliometric factorial analysis acknowledged innovative teaching methods as a central theme regarding this research, and outlined digital transformation and e-learning as tendencies with the greatest potential for future development. Based on the bibliometric analysis of thematic evolution during the 'Post-COVID' period, sustainability and environmental impact in transport higher education emerged as a central and developed topic. Additionally, the potential for other leading trends to develop was outlined within the data management domain as an emerging topic.

Generally, the obtained results emphasise the vital role of digital tools and data management in advancing transport higher education.

From a theoretical standpoint, this research enriches scientific knowledge in the field of transport, particularly in transport-related higher education. Practically, this article provides a foundation for developing and refining teaching tools, methods, and curricula in higher education related to transport disciplines. Furthermore, transportation regulatory agencies and managers at HEIs can utilise these results to revise their strategies concerning higher education in the field of transport.

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