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# Eco-logistics development directions: Future of sustainable freight solutions

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**Abstract**
The future of sustainable solutions in freight transport is crucial for ecology and sustainability. As cities become increasingly more crowded, it is necessary to look for innovative transport methods that reduce emissions and are more energy efficient. The implementation of new technologies, such as intelligent transport management systems and intermodal solutions, allows for the optimization of freight transport and the reduction of emissions. Social involvement and promoting awareness of sustainable transport are essential for city residents to support green initiatives. Cooperation between the public and private sectors, investments in modern infrastructure, and support for scientific research are crucial to overcome barriers, such as the costs of implementing new technologies, financial constraints, and problems related to outdated infrastructure. Care for the environment and economic sustainability are foundations that must be taken into account when planning future transport solutions. The introduction of alternative energy sources and the modernization of railway infrastructure are priorities that can significantly improve the efficiency and capacity of freight logistics. The aim of this study is to analyze the possibilities of developing ecological and sustainable freight transport in cities. This study engaged 53 experts with experience in low-emission green technologies to examine the factors influencing the development of sustainable solutions in freight transport. The results of the analysis emphasize the importance of social involvement, economic sustainability, care for the environment, administrative efficiency, and solid infrastructure. Initiatives related to the circular economy and pollution prevention have proven to be important. However, numerous barriers are encountered, such as gaps in public awareness, economic challenges, environmental problems, administrative difficulties, and outdated infrastructure. The key technologies indicated by experts are intelligent transport management systems and intermodal transport. Priority investments concern alternative energy sources and the modernization of railway infrastructure, which are necessary to improve the efficiency and capacity of freight logistics. This study highlights the multifaceted challenges and opportunities in eco-logistics, pointing to the need for collaboration and strategic investment in sustainable transport solutions.

## Introduction

Urban agglomerations perform various key roles in the operation of logistics supply chains. As a result of their specific characteristics, cities can be customers of the effects of the goods flows through the supply chain and can also provide the labor force for the different steps in the logistics process. Innovative

solutions in urban logistics offer not only the optimization of goods flows, which reduces the congestion of urban supply transport, but can also be an area offering new workplaces, new professional competencies, and increased social satisfaction. The logistics functions performed directly for the urban agglomerations mainly concern:

- a significant number of workplaces, defined as a benefit for the city,
- an increase in tax revenue for the local budget,
- needs related to the movement of employees between their place of residence and place of work,
- long- and short-distance transport needs within the urban agglomeration.

The size of a city or a cluster of cities in a specific region has a direct impact on both the type and volume of goods that are stored and transported, thus, being the primary demand generator for logistics services for the entire region. On the other hand, accessibility to the region's transport infrastructure affects the ability to satisfy the logistical needs of the agglomeration, as well as the ability to satisfy the needs of the region and other surrounding urban agglomerations.

The process complexity of urban logistics is, therefore, caused by the specificity of the functioning of urban agglomerations at the operational and current activities level, as well as by strategic activities, which globally affect the resilience and responsiveness of supply chains.

The aim of this study is to analyze the possibilities of developing ecological and sustainable freight transport in cities. This publication consists of six parts: introduction, literature analysis, description of methodological assumptions, analysis of results, discussions, and conclusions.

## Literature review

Urban logistics has become a very important analytical field of academic research and business practice research. The COVID-19 pandemic (Franjkovic, Botkuljak & Dujak, 2022; Dablanc, 2023) highlighted new aspects of urban logistics development based on last-mile delivery optimization (Kawa, 2020; Wei et al., 2024), the development of reverse logistics (Ivanova, Rogaczewski & Lutsenko, 2022; Nanayakkara et al., 2022), the impact of the carbon footprint (Dubisz, Golinska-Dawson & Zawodny, 2022; Dubisz, Golinska-Dawson & Koliński, 2022), the reuse of packaging (Dubisz, Golinska-Dawson & Koliński, 2023), and modern technologies (Büyüközkan & Ilıcak, 2022; Tubis et al., 2024) that improve the goods and people flow as a result of disruptions in global supply chains (Nagy, Foltin & Ondryhal, 2022; Tundys & Wiśniewski, 2023).

In the scientific literature, there are various scopes of ecological urban logistics. Based on the database ScienceDirect.com, an analysis was carried out on the degree of research focus on "ecological urban logistics." The research concerns papers classified as "Review Articles" and "Research Articles," published between 2018 and 2024 (status as of 15.03.2024). The details are presented in Table 1.

Ecological urban logistics is becoming increasingly more frequent each year as a subject of scientific research – both in the literature and research and development. Despite differences in the trends of change for the various areas of research carried out, it can be concluded that the general trend is based on environmental, biological, energy, engineering, ecological, and business sciences, with

**Table 1. Analysis of the research interest in ecological urban logistics (ScienceDirect Base, March 2024)**

| | Ecological urban logistics | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024* | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| Article type | Review articles | 35 | 43 | 63 | 105 | 111 | 128 | 56 | 541 |
| | Research articles | 291 | 332 | 412 | 587 | 632 | 719 | 353 | 3326 |
| Subject areas | Environmental Science | 156 | 172 | 250 | 316 | 351 | 380 | 170 | 1795 |
| | Social Sciences | 119 | 151 | 177 | 226 | 213 | 261 | 103 | 1250 |
| | Energy | 87 | 104 | 113 | 183 | 186 | 205 | 95 | 973 |
| | Agricultural and Biological Sciences | 57 | 60 | 83 | 113 | 92 | 111 | 36 | 552 |
| | Engineering | 31 | 38 | 50 | 80 | 100 | 109 | 50 | 458 |
| | Business, Management and Accounting | 29 | 30 | 39 | 56 | 83 | 66 | 42 | 345 |
| | Decision Sciences | 25 | 29 | 36 | 52 | 47 | 66 | 39 | 294 |
| | Earth and Planetary Sciences | 20 | 21 | 43 | 38 | 49 | 50 | 27 | 248 |
| | Economics, Econometrics and Finance | 17 | 32 | 19 | 46 | 38 | 43 | 26 | 221 |
| | Computer Science | 10 | 14 | 12 | 25 | 29 | 37 | 21 | 148 |

an emphasis on decision-making and optimization of logistics processes. Both the trend and the number of publications in the field of ecological urban logistics indicate the relevance of the problem in research and practice.

It should be noted that ecology is also related to the sustainable development goals (SDGs), which were established by the United Nations, in the context of implementing future sustainable solutions in freight transport. These goals are a comprehensive plan of action to improve life on Earth and cover a wide range of economic, environmental, and social aspects. The introduction of sustainable transport solutions not only supports the implementation of these global goals, but also contributes to the creation of more effective ecological and responsible logistics systems. In this way, the development of eco-logistics becomes an integral part of the pursuit of sustainable development at a global level.

Conducting research among experts as part of the EIT Urban Mobility projects, carried out by the Lukasiewicz Research Network – Poznan Institute of Technology and the Poznan School of Logistics between 2021 and 2023, a set of innovative solutions has been assembled as a perspective for the development of ecological urban logistics:

- electric freight vehicles,
- autonomous delivery vehicles,
- intelligent transport management systems,
- hydrogen vehicles,
- intermodal freight transport,
- telematics technologies and the Internet of Things (IoT),
- recycling and reuse of packaging.

On the basis of such a compilation of innovative solutions in urban logistics, both the following literature research and statistical analyses have been carried out, which are presented in the next sections of this paper. In analogy to the systematic literature review of ecological urban logistics, this research also concerns papers classified as "Review Articles" and "Research Articles." Table 2 presents a literature survey on the degree of interest in research papers for selected innovations between 2018 and 2024 (status as of 15.03.2024).

The conducted analysis of the literature indicates not only a continuous growth of research interest in the indicated innovative solutions in ecological urban logistics but, above all, a focus on their

**Table 2. Analysis of the research focusing on innovative solutions in urban logistics (ScienceDirect Base, March 2024)**

| EDITION 2024* | | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|
| Electric freight vehicles | TOTAL | 89 | 137 | 166 | 231 | 250 | 308 | 115 |
| | Review Articles | 7 | 5 | 5 | 21 | 20 | 34 | 9 |
| | Research Articles | 82 | 132 | 161 | 210 | 230 | 274 | 106 |
| Autonomous delivery vehicles | TOTAL | 70 | 112 | 156 | 202 | 256 | 288 | 132 |
| | Review Articles | 9 | 15 | 21 | 33 | 37 | 54 | 25 |
| | Research Articles | 61 | 97 | 135 | 169 | 219 | 234 | 107 |
| Intelligent transport management systems | TOTAL | 150 | 239 | 325 | 340 | 437 | 487 | 210 |
| | Review Articles | 24 | 22 | 23 | 49 | 64 | 76 | 43 |
| | Research Articles | 126 | 217 | 302 | 291 | 373 | 411 | 167 |
| Hydrogen vehicles | TOTAL | 54 | 77 | 91 | 144 | 171 | 223 | 114 |
| | Review Articles | 5 | 13 | 18 | 43 | 43 | 55 | 30 |
| | Research Articles | 49 | 64 | 73 | 101 | 128 | 168 | 84 |
| Intermodal freight transport | TOTAL | 55 | 71 | 113 | 87 | 95 | 123 | 39 |
| | Review Articles | 2 | 3 | 9 | 4 | 8 | 7 | 3 |
| | Research Articles | 53 | 68 | 104 | 83 | 87 | 116 | 36 |
| Telematics technologies and Internet of Things | TOTAL | 76 | 147 | 174 | 234 | 318 | 359 | 140 |
| | Review Articles | 16 | 16 | 28 | 52 | 67 | 75 | 41 |
| | Research Articles | 60 | 131 | 146 | 182 | 251 | 284 | 99 |
| Recycling and reuse of packaging | TOTAL | 344 | 425 | 498 | 726 | 858 | 888 | 366 |
| | Review Articles | 56 | 61 | 78 | 154 | 178 | 184 | 89 |
| | Research Articles | 288 | 364 | 420 | 572 | 680 | 704 | 277 |

implementation in business practice. The choice of these solutions is, therefore, reasonable from the perspective of ongoing statistical analyses of business practice results.

The empirical research presented in the following section of this paper is based on the solutions indicated, but also takes into account the factors and barriers to their application. Factors and barriers are based on earlier work (Kachniewska, 2020; Lsa & Azambuja, 2021). These parameters were verified by a quantitative literature review in analogy to the previous analysis. The results of the literature review are presented in Tables 3 and 4.

The presented analysis confirms the validity of the choice of parameters for the conducted research.

**Table 3. Analysis of the degree of research interest in factors in urban logistics (ScienceDirect Base, May 2024)**

| EDITION 2024* | | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|
| Public provision of urban services | TOTAL | 3728 | 3856 | 4689 | 5495 | 5469 | 5622 | 3327 |
| | Review Articles | 366 | 359 | 427 | 620 | 607 | 667 | 417 |
| | Research Articles | 3362 | 3497 | 4262 | 4875 | 4862 | 4955 | 2910 |
| Social responsibility and conscious citizens | TOTAL | 463 | 472 | 532 | 685 | 685 | 723 | 490 |
| | Review Articles | 38 | 38 | 39 | 58 | 57 | 52 | 56 |
| | Research Articles | 425 | 434 | 493 | 627 | 628 | 671 | 434 |
| Community development, collectivism, and volunteer networks | TOTAL | 18 | 18 | 25 | 31 | 38 | 34 | 16 |
| | Review Articles | 2 | 1 | 4 | 3 | 1 | 7 | 2 |
| | Research Articles | 16 | 17 | 21 | 28 | 37 | 27 | 14 |
| Residents' involvement in the ecological and digital transformation of cities | TOTAL | 95 | 104 | 130 | 144 | 171 | 223 | 114 |
| | Review Articles | 13 | 11 | 11 | 43 | 43 | 55 | 30 |
| | Research Articles | 82 | 93 | 119 | 101 | 128 | 168 | 84 |
| Innovation, city laboratory, and research and development (R&D) | TOTAL | 991 | 1215 | 1541 | 2063 | 2478 | 3091 | 2195 |
| | Review Articles | 108 | 120 | 162 | 248 | 293 | 337 | 223 |
| | Research Articles | 883 | 1095 | 1379 | 1815 | 2185 | 2754 | 1972 |
| Economy based on knowledge and sharing | TOTAL | 9709 | 10525 | 12747 | 16305 | 17130 | 18834 | 11425 |
| | Review Articles | 785 | 810 | 1050 | 1589 | 1647 | 1914 | 1297 |
| | Research Articles | 8924 | 9715 | 11697 | 14716 | 15483 | 16920 | 10128 |
| Sustainable resource management and circular economy | TOTAL | 1009 | 1299 | 1763 | 2811 | 3625 | 4313 | 3282 |
| | Review Articles | 153 | 181 | 335 | 614 | 764 | 870 | 744 |
| | Research Articles | 856 | 1118 | 1428 | 2197 | 2861 | 3443 | 2538 |
| Benefits of implementing innovations (greening of freight transport) | TOTAL | 140 | 145 | 208 | 260 | 300 | 404 | 266 |
| | Review Articles | 15 | 14 | 18 | 34 | 32 | 52 | 28 |
| | Research Articles | 125 | 131 | 190 | 226 | 268 | 352 | 238 |
| Availability of labor | TOTAL | 115 | 129 | 111 | 171 | 152 | 163 | 95 |
| | Review Articles | 6 | 5 | 9 | 14 | 13 | 12 | 13 |
| | Research Articles | 109 | 124 | 102 | 157 | 139 | 151 | 82 |
| Energy related: renewable resources, saving initiatives, and intelligent systems | TOTAL | 85 | 100 | 130 | 164 | 200 | 274 | 274 |
| | Review Articles | 27 | 29 | 32 | 52 | 61 | 74 | 74 |
| | Research Articles | 58 | 71 | 98 | 112 | 139 | 200 | 200 |
| Pollution prevention and reduction | TOTAL | 2340 | 2787 | 3694 | 5124 | 5908 | 6890 | 4753 |
| | Review Articles | 466 | 540 | 772 | 1199 | 1330 | 1606 | 1136 |
| | Research Articles | 1874 | 2247 | 2922 | 3925 | 4578 | 5284 | 3617 |
| Implementation of ecological means of transport | TOTAL | 2827 | 3030 | 3533 | 4691 | 5072 | 5754 | 3935 |
| | Review Articles | 368 | 401 | 469 | 776 | 865 | 1018 | 886 |
| | Research Articles | 2459 | 2629 | 3064 | 3915 | 4207 | 4736 | 3049 |
| Implementation of low-emission technologies and solutions in the field of transport | TOTAL | 3617 | 4051 | 5018 | 7042 | 8359 | 9961 | 7416 |
| | Review Articles | 835 | 850 | 1130 | 1790 | 2199 | 2594 | 2137 |
| | Research Articles | 2782 | 3201 | 3888 | 5252 | 6160 | 7367 | 5279 |
| Pro-ecological projects and initiatives | TOTAL | 438 | 460 | 507 | 720 | 802 | 952 | 713 |
| | Review Articles | 60 | 54 | 77 | 117 | 130 | 145 | 104 |
| | Research Articles | 378 | 406 | 430 | 603 | 672 | 807 | 609 |

**Table 3. Analysis of the degree... (cont.)**

| EDITION 2024* | | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|
| Efficient transport systems and bicycle paths | TOTAL | 227 | 313 | 355 | 461 | 467 | 543 | 316 |
| | Review Articles | 32 | 37 | 44 | 70 | 73 | 76 | 54 |
| | Research Articles | 195 | 276 | 311 | 391 | 394 | 467 | 262 |
| Supportive government policies, political will, and synergy | TOTAL | 138 | 153 | 184 | 221 | 224 | 264 | 216 |
| | Review Articles | 18 | 21 | 24 | 30 | 33 | 45 | 35 |
| | Research Articles | 120 | 132 | 160 | 191 | 191 | 219 | 181 |
| Citizen empowerment, interactive and participatory services, co-production, co-creation, and bottom-up approach | TOTAL | 62 | 45 | 46 | 67 | 53 | 71 | 30 |
| | Review Articles | 7 | 8 | 14 | 5 | 9 | 18 | 6 |
| | Research Articles | 55 | 37 | 32 | 62 | 44 | 53 | 24 |
| Urban planning: definition of strategy and vision | TOTAL | 1050 | 1125 | 1290 | 1618 | 1690 | 1732 | 1112 |
| | Review Articles | 129 | 138 | 164 | 228 | 253 | 293 | 180 |
| | Research Articles | 921 | 987 | 1126 | 1390 | 1437 | 1439 | 932 |
| Transparency and openness | TOTAL | 6608 | 7168 | 8288 | 10375 | 11087 | 12369 | 8697 |
| | Review Articles | 942 | 1037 | 1207 | 1686 | 1868 | 2126 | 1551 |
| | Research Articles | 5666 | 6131 | 7081 | 8689 | 9219 | 10243 | 7146 |
| Capacity planning (i.e., infrastructure, costs, and human resources) | TOTAL | 3014 | 3196 | 3966 | 5125 | 5658 | 6518 | 4678 |
| | Review Articles | 478 | 479 | 590 | 864 | 1000 | 1190 | 911 |
| | Research Articles | 2536 | 2717 | 3376 | 4261 | 4658 | 5328 | 3767 |
| Definition of key performance indicators (KPIs): monitoring/ evaluation | TOTAL | 216 | 249 | 254 | 327 | 430 | 449 | 288 |
| | Review Articles | 33 | 21 | 22 | 35 | 64 | 52 | 44 |
| | Research Articles | 183 | 228 | 232 | 292 | 366 | 397 | 244 |
| Data-driven decision making and real-time data availability | TOTAL | 8137 | 8953 | 10871 | 13804 | 15100 | 17985 | 13509 |
| | Review Articles | 1010 | 1108 | 1391 | 1767 | 2047 | 2509 | 1930 |
| | Research Articles | 7127 | 7845 | 9480 | 12037 | 13053 | 15476 | 11579 |
| Proactiveness of cities in terms of flows of goods and people | TOTAL | 134 | 132 | 194 | 265 | 249 | 285 | 239 |
| | Review Articles | 18 | 17 | 25 | 41 | 34 | 50 | 37 |
| | Research Articles | 116 | 115 | 169 | 224 | 215 | 235 | 202 |
| Data management: data quality, data sharing, and data privacy policy | TOTAL | 1284 | 1497 | 2025 | 2629 | 2995 | 3433 | 2433 |
| | Review Articles | 217 | 247 | 346 | 451 | 548 | 637 | 506 |
| | Research Articles | 1067 | 1250 | 1679 | 2178 | 2447 | 2796 | 1927 |
| Physical infrastructure integration | TOTAL | 6935 | 7512 | 8994 | 11472 | 12644 | 14435 | 10833 |
| | Review Articles | 950 | 971 | 1285 | 1874 | 2173 | 2497 | 1971 |
| | Research Articles | 5985 | 6541 | 7709 | 9598 | 10471 | 11938 | 8862 |
| ICT progress and intelligent technologies in mobility services | TOTAL | 78 | 112 | 108 | 137 | 175 | 177 | 110 |
| | Review Articles | 14 | 17 | 16 | 28 | 42 | 54 | 22 |
| | Research Articles | 64 | 95 | 92 | 109 | 133 | 123 | 88 |
| Smart grid: intelligent transport management systems | TOTAL | 337 | 416 | 457 | 602 | 766 | 843 | 582 |
| | Review Articles | 77 | 83 | 97 | 154 | 229 | 274 | 195 |
| | Research Articles | 260 | 333 | 360 | 448 | 537 | 569 | 387 |
| Use of geographic information systems (GIS) | TOTAL | 3514 | 3761 | 4117 | 4694 | 4773 | 4913 | 3056 |
| | Review Articles | 236 | 253 | 304 | 356 | 402 | 445 | 274 |
| | Research Articles | 3278 | 3508 | 3813 | 4338 | 4371 | 4468 | 2782 |
| Ability to analyze data: business intelligence (BI) | TOTAL | 212 | 288 | 304 | 471 | 628 | 772 | 659 |
| | Review Articles | 33 | 40 | 42 | 75 | 107 | 139 | 119 |
| | Research Articles | 179 | 248 | 262 | 396 | 521 | 633 | 540 |
| Internet of Things (IoT) | TOTAL | 1981 | 2876 | 3926 | 4771 | 6162 | 7009 | 4324 |
| | Review Articles | 184 | 231 | 406 | 595 | 829 | 1018 | 694 |
| | Research Articles | 1797 | 2645 | 3520 | 4176 | 5333 | 5991 | 3630 |
| Big Data | TOTAL | 244 | 299 | 346 | 454 | 443 | 469 | 239 |
| | Review Articles | 16 | 17 | 24 | 31 | 35 | 30 | 17 |
| | Research Articles | 228 | 282 | 322 | 423 | 408 | 439 | 222 |

**Table 4. Analysis of the degree of research interest in barriers in urban logistics (Baza ScienceDirect, May 2024)**

| EDITION 2024* | | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|
| Lack of social awareness | TOTAL | 6 | 11 | 16 | 13 | 22 | 18 | 8 |
| | Review Articles | 3 | 2 | 3 | 2 | 4 | 2 | 1 |
| | Research Articles | 3 | 9 | 13 | 11 | 18 | 16 | 7 |
| Lack of citizen involvement in the change process | TOTAL | 109 | 103 | 131 | 161 | 147 | 160 | 108 |
| | Review Articles | 12 | 9 | 8 | 14 | 16 | 16 | 10 |
| | Research Articles | 97 | 94 | 123 | 147 | 131 | 144 | 98 |
| Social exclusion and gentrification | TOTAL | 103 | 112 | 151 | 132 | 165 | 188 | 115 |
| | Review Articles | 3 | 7 | 8 | 13 | 14 | 26 | 13 |
| | Research Articles | 100 | 105 | 143 | 119 | 151 | 162 | 102 |
| Lack of connection between technological and social infrastructure | TOTAL | 1681 | 1820 | 2246 | 3010 | 3455 | 4202 | 3180 |
| | Review Articles | 231 | 217 | 291 | 450 | 483 | 633 | 489 |
| | Research Articles | 1450 | 1603 | 1955 | 2560 | 2972 | 3569 | 2691 |
| High costs of urban infrastructure and investment imbalance | TOTAL | 307 | 311 | 429 | 563 | 630 | 818 | 677 |
| | Review Articles | 45 | 44 | 50 | 93 | 103 | 122 | 95 |
| | Research Articles | 262 | 267 | 379 | 470 | 527 | 696 | 582 |
| Lack of funds and investors: short investment time horizon | TOTAL | 634 | 687 | 757 | 978 | 1041 | 1045 | 707 |
| | Review Articles | 27 | 23 | 21 | 52 | 51 | 48 | 32 |
| | Research Articles | 607 | 664 | 736 | 926 | 990 | 997 | 675 |
| Volatility of the world economy | TOTAL | 3136 | 3493 | 4441 | 5954 | 7071 | 7966 | 5065 |
| | Review Articles | 375 | 380 | 531 | 890 | 1119 | 1216 | 828 |
| | Research Articles | 2761 | 3113 | 3910 | 5064 | 5952 | 6750 | 4237 |
| Competitiveness (local against the background of regional and international markets) | TOTAL | 592 | 578 | 666 | 858 | 919 | 908 | 613 |
| | Review Articles | 54 | 46 | 52 | 93 | 93 | 79 | 61 |
| | Research Articles | 538 | 532 | 614 | 765 | 826 | 829 | 552 |
| Unemployment and lack of equal access to the labor market | TOTAL | 485 | 478 | 578 | 748 | 716 | 767 | 466 |
| | Review Articles | 14 | 20 | 19 | 31 | 44 | 23 | 29 |
| | Research Articles | 471 | 458 | 559 | 717 | 672 | 744 | 437 |
| Lack of qualified human capital | TOTAL | 728 | 830 | 940 | 1176 | 1200 | 1268 | 755 |
| | Review Articles | 56 | 70 | 67 | 108 | 119 | 106 | 77 |
| | Research Articles | 672 | 760 | 873 | 1068 | 1081 | 1162 | 678 |
| Inefficiency of resource management | TOTAL | 3390 | 3579 | 4020 | 4929 | 5563 | 6406 | 4740 |
| | Review Articles | 384 | 388 | 453 | 637 | 822 | 923 | 692 |
| | Research Articles | 3006 | 3191 | 3567 | 4292 | 4741 | 5483 | 4048 |
| Climate change | TOTAL | 15494 | 16836 | 19138 | 23948 | 26435 | 29163 | 18694 |
| | Review Articles | 1539 | 1580 | 1873 | 2805 | 3294 | 3653 | 2682 |
| | Research Articles | 13955 | 15256 | 17265 | 21143 | 23141 | 25510 | 16012 |
| Increasing resource consumption | TOTAL | 1422 | 1615 | 1877 | 2515 | 3066 | 3972 | 3187 |
| | Review Articles | 138 | 162 | 166 | 275 | 324 | 417 | 355 |
| | Research Articles | 1284 | 1453 | 1711 | 2240 | 2742 | 3555 | 2832 |
| Lack of a holistic approach to environmental sustainability | TOTAL | 2531 | 2787 | 3416 | 4815 | 5171 | 6144 | 5616 |
| | Review Articles | 445 | 515 | 650 | 1074 | 1120 | 1332 | 1271 |
| | Research Articles | 2086 | 2272 | 2766 | 3741 | 4051 | 4812 | 4345 |
| Lack of knowledge on how ICT can reduce energy consumption | TOTAL | 860 | 886 | 1038 | 1269 | 1620 | 1781 | 1098 |
| | Review Articles | 132 | 113 | 131 | 196 | 268 | 295 | 177 |
| | Research Articles | 728 | 773 | 907 | 1073 | 1352 | 1486 | 921 |
| High levels of air pollution | TOTAL | 264 | 368 | 475 | 564 | 575 | 667 | 389 |
| | Review Articles | 25 | 26 | 56 | 65 | 54 | 81 | 39 |
| | Research Articles | 239 | 342 | 419 | 499 | 521 | 586 | 350 |

**Table 4. Analysis of the degree... (cont.)**

| EDITION 2024* | | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|
| Ineffective waste management | TOTAL | 1025 | 1168 | 1317 | 1901 | 2212 | 2551 | 1769 |
| | Review Articles | 228 | 251 | 299 | 498 | 593 | 646 | 507 |
| | Research Articles | 797 | 917 | 1018 | 1403 | 1619 | 1905 | 1262 |
| Traffic congestion and an inefficient public transport system | TOTAL | 251 | 287 | 393 | 407 | 421 | 452 | 301 |
| | Review Articles | 20 | 29 | 25 | 30 | 49 | 69 | 32 |
| | Research Articles | 231 | 258 | 368 | 377 | 372 | 383 | 269 |
| Lack of planning: lack of vision and strategy | TOTAL | 1318 | 1377 | 1565 | 2036 | 2262 | 2416 | 1532 |
| | Review Articles | 225 | 219 | 289 | 387 | 469 | 548 | 366 |
| | Research Articles | 1093 | 1158 | 1276 | 1649 | 1793 | 1868 | 1166 |
| Centralized decision-making and top-down approach | TOTAL | 1081 | 1194 | 1292 | 1580 | 1629 | 1719 | 1060 |
| | Review Articles | 133 | 155 | 190 | 232 | 255 | 310 | 182 |
| | Research Articles | 948 | 1039 | 1102 | 1348 | 1374 | 1409 | 878 |
| Political instability | TOTAL | 534 | 572 | 651 | 770 | 802 | 1035 | 629 |
| | Review Articles | 44 | 46 | 41 | 76 | 74 | 74 | 62 |
| | Research Articles | 490 | 526 | 610 | 694 | 728 | 961 | 567 |
| Lack of political will and support | TOTAL | 3123 | 3163 | 3670 | 4474 | 4572 | 4582 | 2750 |
| | Review Articles | 368 | 354 | 408 | 585 | 622 | 645 | 368 |
| | Research Articles | 2755 | 2809 | 3262 | 3889 | 3950 | 3937 | 2382 |
| Lack of regulation and legislation | TOTAL | 2072 | 2120 | 2352 | 2960 | 2948 | 3075 | 1813 |
| | Review Articles | 321 | 334 | 384 | 585 | 596 | 636 | 407 |
| | Research Articles | 1751 | 1786 | 1968 | 2375 | 2352 | 2439 | 1406 |
| Deterioration of urban infrastructure | TOTAL | 1316 | 1436 | 1930 | 2456 | 2760 | 3232 | 2182 |
| | Review Articles | 145 | 157 | 211 | 310 | 347 | 419 | 284 |
| | Research Articles | 1171 | 1279 | 1719 | 2146 | 2413 | 2813 | 1898 |
| Technological infrastructure deficit | TOTAL | 557 | 577 | 725 | 960 | 1012 | 1151 | 782 |
| | Review Articles | 91 | 90 | 116 | 145 | 190 | 195 | 149 |
| | Research Articles | 466 | 487 | 609 | 815 | 822 | 956 | 633 |
| Lack of infrastructure integration and network complexity | TOTAL | 1314 | 1516 | 1765 | 2268 | 2574 | 2921 | 2369 |
| | Review Articles | 264 | 262 | 305 | 464 | 606 | 722 | 567 |
| | Research Articles | 1050 | 1254 | 1460 | 1804 | 1968 | 2199 | 1802 |
| Technology obsolescence, system failures, and infrastructure fragility | TOTAL | 7 | 5 | 5 | 15 | 6 | 9 | 3 |
| | Review Articles | 3 | 1 | 1 | 1 | 0 | 1 | 1 |
| | Research Articles | 4 | 4 | 4 | 14 | 6 | 8 | 2 |
| Lack of system interoperability and lack of integration standards | TOTAL | 272 | 353 | 367 | 462 | 584 | 637 | 421 |
| | Review Articles | 67 | 73 | 87 | 119 | 171 | 211 | 152 |
| | Research Articles | 205 | 280 | 280 | 343 | 413 | 426 | 269 |
| Lack of security of systems and invasion of privacy | TOTAL | 164 | 172 | 243 | 317 | 392 | 456 | 382 |
| | Review Articles | 34 | 41 | 54 | 95 | 106 | 164 | 135 |
| | Research Articles | 130 | 131 | 189 | 222 | 286 | 292 | 247 |
| Low quality of ICT-based services | TOTAL | 1324 | 1470 | 1701 | 2133 | 2395 | 2469 | 1402 |
| | Review Articles | 161 | 138 | 150 | 238 | 270 | 288 | 181 |
| | Research Articles | 1163 | 1332 | 1551 | 1895 | 2125 | 2181 | 1221 |

## Methodology

Development factors and barriers (social, economic, environmental, administrative, and infrastructural) will be analyzed, as well as selected aspects related to the greening of freight transport in cities.

Various methods were used in this research that depend on the phase (analysis of the subject literature, research implementation, and preparation

of results). In turn, the study used a number of methods that depend on the stage of the study (preparation, implementation, and processing of results) (Figure 1).

Below is a description and an indication of their use in individual stages of the study.

#### Research preparation phase

The authors formulated the following research questions:

- Q1: What are the factors for the development of ecological and sustainable freight transport in cities (based on expert opinions)?
- Q2: What are the barriers to the development of ecological and sustainable freight transport in cities (based on expert opinions)?
- Q3: What technologies are key to the future of sustainable logistics solutions (based on expert opinion)?

*Desk research* entails analyzing accessible data sources, focusing on compiling, cross-verifying, and processing data. This analytical process forms the foundation for drawing conclusions regarding the researched issue (Makowska, 2013; Bednarowska, 2015).

*Brainstorming* is an activating work method that is based on generating solutions to given problems spontaneously. It involves working in a group, the aim of which is to generate ideas for finding the causes of the problems, creating solutions, and selecting the best options (Gołaś & Mazur, 2010).

Both methods were used to develop an expert interview form containing questions and suggestions regarding the factors to be assessed (development factors and barriers to the greening of freight transport in cities).

#### Research implementation phase

Focus interview – expert research, also known as the expert questionnaire, involves gathering research material through a structured questionnaire and obtaining responses from participants selected based on specific criteria by the researcher. It is important to highlight that the expert interview represents a distinctive method that leverages the expertise and creativity of individuals who are authorities in a particular field (Magruk, 2005). The questions posed to respondents during the focus interview not only address facts or their attitudes but also aim to elicit explanations and predictions from them. Moreover, it is assumed that respondents who are professionally accomplished and possess expert knowledge can provide insightful analytical suggestions. Their professional expertise and ability to envision realistic scenarios enable them to offer valuable forecasts regarding the development of situations within specific domains of economic and social reality (Churchill, 2002; Babbie, 2004). The expert interviews were conducted in January–March 2024.

#### Results analysis phase

The examination of the collected data was based on a statistical analysis, including descriptive measures such as arithmetic mean, dominant, minimum value, maximum value, and range (Ręklewski, 2020):

- Arithmetic average is the sum of the value of the variables of all the units of the studied

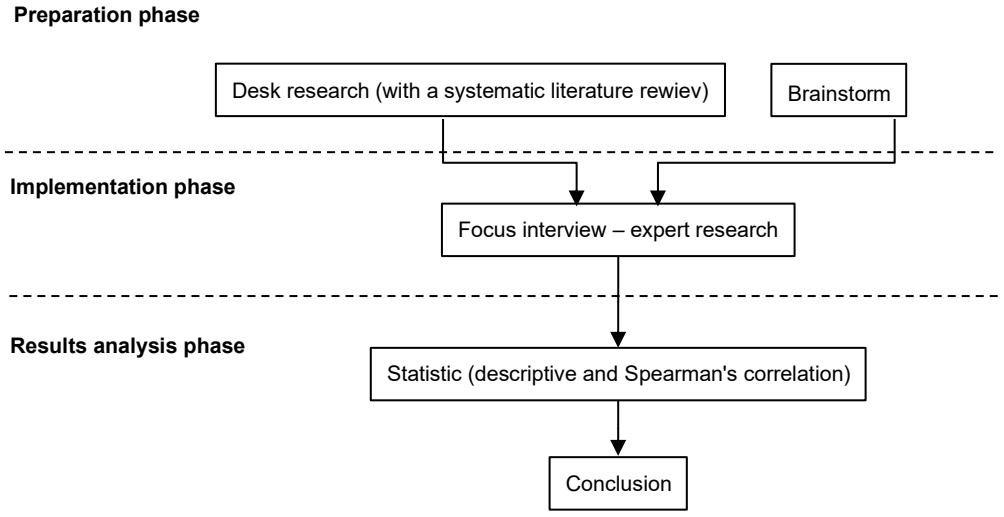


**Figure 1. Scheme of the authors' research**

population divided by the number of units of the population.
- The dominant is the value of the variable that is the most frequent (dominant or typical) in the studied community. The dominant is called a modal value or mode.
- The minimum value of the recorded responses in accordance with the adopted scale.
- The maximum value of the recorded responses in accordance with the adopted scale.
- The range is the difference between the maximum and minimum.
- Spearman's rank correlation coefficient ($r_S$ is used to describe the strength of correlation of both quantitative and qualitative features in a situation where it is possible to order their variants.

The technique of purposeful sampling was used. The selection criteria for the study were extensive practical experience in the field of ecological, low-emission, and sustainable transport solutions and technologies. These were manifested by participation in the development of strategic assumptions for the implementation of this type of solution in enterprises or a given region, international projects related to the implementation of sustainable transport technologies, development of policies, and a research agenda in this area at the European Union level. Overall, 53 experts from Poland took part in the study. Due to the subject of the study, the number of participants was not selected as representative. However, due to the importance of expert opinion, significant added value of research results can be indicated.

## Results analysis

A total of 53 deliberately selected experts took part in the study. The criterion for selecting experts was extensive practical experience in the development and implementation of solutions and technologies for ecological, low-emission, and sustainable transport. The largest percentage of experts (33.96 ) were employed in large enterprises (employing more than 249 employees). Moreover, 26.42 % were from medium-sized commercial organizations (employment from 50 to 249 employees), 22.64 % in small entities (employment from 10 to 49 employees), and the remaining 16.98 % were in commercial micro-organizations (employment of less than ten employees); 44.40 % of the experts were employed as specialists. Additionally, 16.98 % acted as directors and 15.09 % as supervisors. Moreover, business owners and managers constituted 7.84 % each, and the remaining 5.66 % were management. Referring to the professional experience of experts in the current position, the largest percentage (45.28 %) were employed for more than five years, 32.08 % were employed for 1 to 3 years, and 22.64 % for 3 to 5 years. Experts also assessed their own knowledge and experience on a scale of 1 to 5 (where 1 means a low level of knowledge and experience, and 5 is a high level of both knowledge and experience). The largest percentage indicated a grade of 3 (39.62 %), then 4 and 5 (26.42 % each), and the remaining 17.55 % indicated a grade of 2. There was no answer regarding the level 1 assessment. The average grade was 3.72 and the median was 4.

In the analysis of development factors (related to the following categories: social, economic, environmental, administrative, and infrastructural), a scale from 1 to 5 was used (where 1 meant very little importance and 5 signifies greatly important).

Referring to development factors, in the social group, the highest scores were given to residents' involvement in the ecological and digital transformation of cities (average 4.04) and public provision of urban services (3.96). In the case of the economic category, we can distinguish sustainable resource management, circular economy (4.14), and the benefits of implementing innovations (greening of freight transport) (4.04). In the case of environmental factors, the highest scores were obtained for pollution prevention and reduction (4.15) and energy-related: renewable resources, saving initiatives, and intelligent systems (4.13). The administrative factors with the highest scores included data management: data quality, data sharing and data privacy policy, and data-driven decision making and real-time data availability (both 4.23). In the last group – infrastructure – the highest scores were achieved by geographic information systems (GIS) and Big Data (both 4.53) (Table 4).

In terms of development barriers, a similar approach was used (related to the following categories: social, economic, environmental, administrative, and infrastructural), and a scale from 1 to 5 was used (where 1 meant very little importance and 5 signifies greatly important).

With regard to factors from the social category, the highest scores were given to lack of social awareness (3.91 average) and lack of citizen involvement in the change process (3.85). In the economic group, there were high costs of urban infrastructure and investment imbalance (4.32) and a lack of funds and investors: short investment time horizons (4.17).

**Table 4. Analysis of factors for the development of ecological and sustainable freight transport in cities**

| Factor | Average | Dominant | Maximal Value | Minimal Value | Range |
|---|---|---|---|---|---|
| Social | | | | | |
| Public provision of urban services | 3.96 | 4.00 | 1.00 | 5.00 | 4.00 |
| Social responsibility and conscious citizens | 3.87 | 4.00 | 1.00 | 5.00 | 4.00 |
| Community development, collectivism, and volunteer networks | 3.42 | 5.00 | 1.00 | 5.00 | 4.00 |
| Residents' involvement in the ecological and digital transformation of cities | 4.04 | 4.00 | 2.00 | 5.00 | 3.00 |
| Economic | | | | | |
| Innovation, city laboratory, research and development (R&D) | 3.81 | 4.00 | 1.00 | 5.00 | 4.00 |
| Economy based on knowledge and sharing | 3.85 | 5.00 | 1.00 | 5.00 | 4.00 |
| Sustainable resource management and circular economy | 4.13 | 5.00 | 3.00 | 5.00 | 2.00 |
| Benefits of implementing innovations (greening of freight transport) | 4.04 | 4.00 | 3.00 | 5.00 | 2.00 |
| Availability of labor | 3.85 | 4.00 | 1.00 | 5.00 | 4.00 |
| Environmental | | | | | |
| Energy-related: renewable resources, saving initiatives, and intelligent systems | 4.13 | 5.00 | 2.00 | 5.00 | 3.00 |
| Pollution prevention and reduction | 4.15 | 5.00 | 2.00 | 5.00 | 3.00 |
| Implementation of ecological means of transport | 3.91 | 4.00 | 2.00 | 5.00 | 3.00 |
| Implementation of low-emission technologies and solutions in the field of transport | 4.02 | 4.00 | 2.00 | 5.00 | 3.00 |
| Pro-ecological projects and initiatives | 3.89 | 3.00 | 2.00 | 5.00 | 3.00 |
| Efficient transport systems and bicycle paths | 3.92 | 3.00 | 2.00 | 5.00 | 3.00 |
| Administrative | | | | | |
| Supportive government policies, political will, and synergy | 3.79 | 4.00 | 1.00 | 5.00 | 4.00 |
| Citizen empowerment, interactive and participatory services, co-production, co-creation, and bottom-up approach | 3.72 | 5.00 | 1.00 | 5.00 | 4.00 |
| Urban planning: definition of strategy and vision | 3.94 | 4.00 | 2.00 | 5.00 | 3.00 |
| Transparency and openness | 3.87 | 3.00 | 1.00 | 5.00 | 4.00 |
| Capacity planning (i.e., infrastructure, costs, and human resources) | 4.15 | 3.00 | 2.00 | 5.00 | 3.00 |
| Definition of key performance indicators (KPIs): monitoring/evaluation | 4.15 | 3.00 | 2.00 | 5.00 | 3.00 |
| Data-driven decision making and real-time data availability | 4.23 | 4.00 | 2.00 | 5.00 | 3.00 |
| Proactiveness of cities in terms of flows of goods and people | 4.06 | 4.00 | 1.00 | 5.00 | 4.00 |
| Data management: data quality, data sharing, and data privacy policy | 4.23 | 4.00 | 3.00 | 5.00 | 2.00 |
| Infrastructure | | | | | |
| Physical infrastructure integration | 4.11 | 4.00 | 2.00 | 5.00 | 3.00 |
| ICT progress and intelligent technologies in mobility services | 4.25 | 3.00 | 2.00 | 5.00 | 3.00 |
| Smart grid: intelligent transport management systems | 4.43 | 3.00 | 3.00 | 5.00 | 2.00 |
| Use of geographic information systems (GIS) | 4.25 | 4.00 | 2.00 | 5.00 | 3.00 |
| Ability to analyze data: business intelligence (BI) | 4.53 | 4.00 | 2.00 | 5.00 | 3.00 |
| Internet of Things (IoT) | 4.34 | 4.00 | 2.00 | 5.00 | 3.00 |
| Big Data | 4.53 | 4.00 | 1.00 | 5.00 | 4.00 |

In the category of environmental factors, the highest scores were given to traffic congestion, an inefficient public transport system (4.19), and a lack of knowledge on how ICT can reduce energy consumption (4.1). In terms of administrative factors, the most important barriers are centralized decision-making, top-down approaches (3.83), and lack of planning: lack of vision and strategy (3.81). In the last group of infrastructure barriers, we can distinguish primarily technology obsolescence, system failures, infrastructure fragility (4.08), and technological infrastructure deficit (4.02) (Table 5).

As key technologies for the future of greening freight transport in cities (where selecting more

**Table 5. Analysis of barriers to the development of ecological and sustainable freight transport in cities**

| Factor | Average | Dominant | Maximal Value | Minimal Value | Range |
|---|---|---|---|---|---|
| Social | | | | | |
| Lack of social awareness | 3.92 | 5.00 | 1.00 | 5.00 | 4.00 |
| Lack of citizen involvement in the change process | 3.85 | 5.00 | 1.00 | 5.00 | 4.00 |
| Social exclusion and gentrification | 3.51 | 3.00 | 1.00 | 5.00 | 4.00 |
| Lack of connection between technological and social infrastructure | 3.77 | 3.00 | 2.00 | 5.00 | 3.00 |
| Economic | | | | | |
| High costs of urban infrastructure and investment imbalance | 4.32 | 3.00 | 2.00 | 5.00 | 3.00 |
| Lack of funds and investors: short investment time horizon | 4.17 | 3.00 | 2.00 | 5.00 | 3.00 |
| Volatility of the world economy | 3.66 | 3.00 | 1.00 | 5.00 | 4.00 |
| Competitiveness (local against the background of regional and international markets) | 3.55 | 3.00 | 2.00 | 5.00 | 3.00 |
| Unemployment and lack of equal access to the labor market | 3.30 | 4.00 | 1.00 | 5.00 | 4.00 |
| Lack of qualified human capital | 3.68 | 3.00 | 1.00 | 5.00 | 4.00 |
| Inefficiency of resource management | 4.00 | 3.00 | 1.00 | 5.00 | 4.00 |
| Environmental | | | | | |
| Climate change | 3.58 | 4.00 | 1.00 | 5.00 | 4.00 |
| Increasing resource consumption | 4.00 | 3.00 | 2.00 | 5.00 | 3.00 |
| Lack of a holistic approach to environmental sustainability | 3.87 | 3.00 | 2.00 | 5.00 | 3.00 |
| Lack of knowledge on how ICT can reduce energy consumption | 4.13 | 3.00 | 2.00 | 5.00 | 3.00 |
| High levels of air pollution | 3.98 | 3.00 | 1.00 | 5.00 | 4.00 |
| Ineffective waste management | 4.00 | 3.00 | 3.00 | 5.00 | 2.00 |
| Traffic congestion and an inefficient public transport system | 4.19 | 4.00 | 1.00 | 5.00 | 4.00 |
| Administrative | | | | | |
| Lack of planning: lack of vision and strategy | 3.81 | 4.00 | 2.00 | 5.00 | 3.00 |
| Centralized decision-making and top-down approach | 3.83 | 3.00 | 1.00 | 5.00 | 4.00 |
| Political instability | 3.75 | 2.00 | 1.00 | 5.00 | 4.00 |
| Lack of political will and support | 3.75 | 4.00 | 2.00 | 5.00 | 3.00 |
| Lack of regulation and legislation | 3.58 | 4.00 | 1.00 | 5.00 | 4.00 |
| Infrastructure | | | | | |
| Deterioration of urban infrastructure | 3.79 | 4.00 | 1.00 | 5.00 | 4.00 |
| Technological infrastructure deficit | 4.02 | 4.00 | 1.00 | 5.00 | 4.00 |
| Lack of infrastructure integration and network complexity | 4.00 | 3.00 | 2.00 | 5.00 | 3.00 |
| Technology obsolescence, system failures, and infrastructure fragility | 4.08 | 3.00 | 1.00 | 5.00 | 4.00 |
| Lack of system interoperability and lack of integration standards | 3.94 | 4.00 | 2.00 | 5.00 | 3.00 |
| Lack of security of systems and invasion of privacy | 3.75 | 3.00 | 1.00 | 5.00 | 4.00 |
| Low quality of ICT-based services | 3.85 | 3.00 | 1.00 | 5.00 | 4.00 |

than one answer was possible), the experts indicated, in particular, intelligent transport management systems, advanced fleet management systems that allow for monitoring and optimization of routes, which leads to reduced fuel consumption and $CO_2$ emissions (24.15 % of total responses), and intermodal freight transport: combining different modes of transport, such as road, rail, and water, can increase the efficiency of freight logistics and reduce $CO_2$ emissions by choosing the greenest transport options (17.78 % of total responses) (Figure 2).

The areas requiring the most urgent investments (it was possible to select several messages) primarily included the development of alternative energy sources for transport (21.76 % of all answers), the modernization of railway infrastructure, increasing the efficiency and capacity of railway lines, and

developing intermodal logistics terminals (18.65 % of total responses) (Figure 3).

To carry out in-depth research, the correlation index (Spearman) was calculated between development factors and barriers for the development of eco-logistics in freight transport in cities with the highest average (based on experts' recommendations). The correlation matrix is presented in Table 6.

Using the ability of statistics to analyze the data, business intelligence (BI) correlates with a lack of social awareness ($\rho$ = 0.405, $p$ = 0.003, which indicates a moderately positive relationship) and data management: data quality, data sharing, and data privacy policy ($\rho$ = 0.372, $p$ = 0.006, which also indicates a moderately positive relationship). In the case of lack of social awareness, there was a correlation with residents' involvement in the ecological and digital transformation of cities ($\rho$ = 0.320, $p$ = 0.019, which indicates a moderately positive relationship). Moreover, the centralized decision-making, top-down approach factor correlates with the ability to analyze data in terms of business intelligence (BI) ($\rho$ = 0.342, $p$ = 0.012, which indicates a moderately positive relationship). Moreover, in the case of the variable technology obsolescence, system failures, and infrastructure fragility, a correlation was found between sustainable resource management and circular economy ($\rho$ = −0.307, $p$ = 0.026), which indicates a moderate negative relationship.

## Discussion

It should be noted that analyzes relating to the future of freight transport in cities, its greening, green transformation, and sustainability have all been carried out by other researchers.

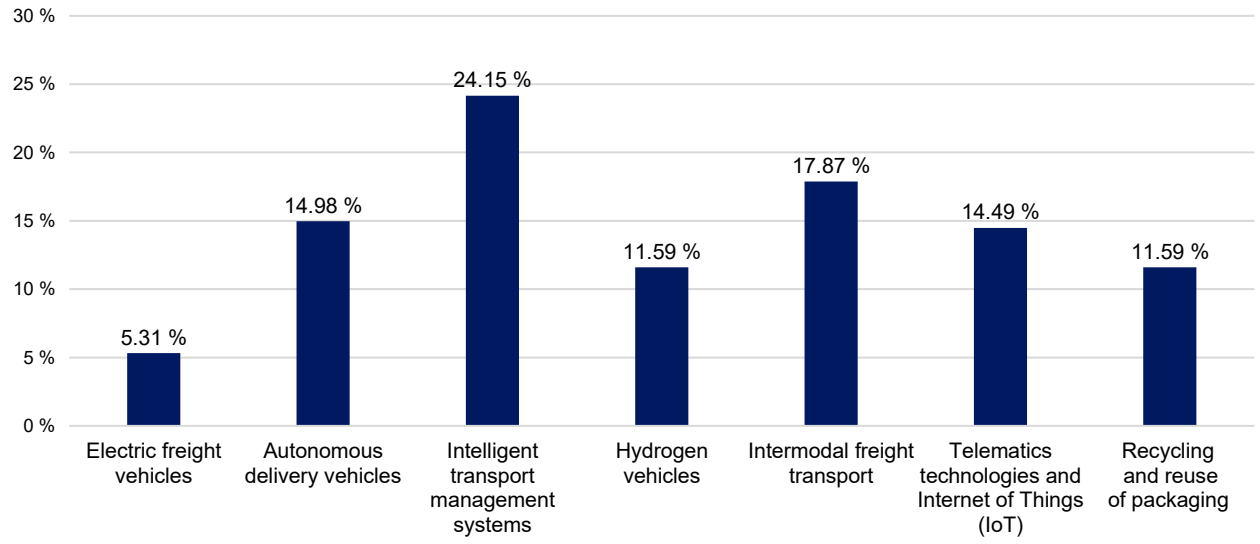


**Figure 2. Key technologies for the future of sustainable logistics solutions**

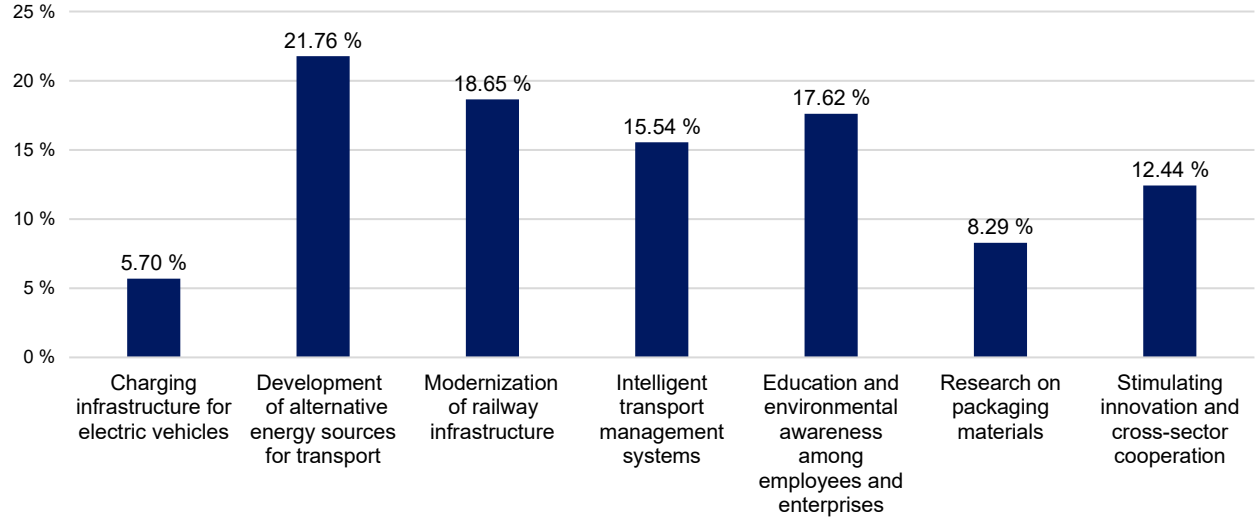


**Figure 3. Areas of ecological freight logistics requiring the most urgent investments**

**Table 6. Correlation matrix**

| | | Residents' involvement in the ecological and digital transformation of cities | Sustainable resource management and circular economy | Pollution prevention and reduction | Data management: data quality, data sharing, and data privacy policy | Ability to analyze data: business intelligence (BI) | Lack of social awareness | High costs of urban infrastructure and investment imbalance | Traffic congestion and an inefficient public transport system | Centralized decision-making and top-down approach | Technology obsolescence, system failures, and infrastructure fragility |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Residents' involvement in the ecological and digital transformation of cities | rho Spearman | — | | | | | | | | | |
| | df | — | | | | | | | | | |
| | p | — | | | | | | | | | |
| Sustainable resource management and circular economy | rho Spearman | 0.146 | — | | | | | | | | |
| | df | 51 | — | | | | | | | | |
| | p | 0.297 | — | | | | | | | | |
| Pollution prevention and reduction | rho Spearman | 0.070 | −0.024 | — | | | | | | | |
| | df | 51 | 51 | — | | | | | | | |
| | p | 0.618 | 0.862 | — | | | | | | | |
| Data management: data quality, data sharing, and data privacy policy | rho Spearman | −0.017 | −0.027 | −0.093 | — | | | | | | |
| | df | 51 | 51 | 51 | — | | | | | | |
| | p | 0.901 | 0.849 | 0.510 | — | | | | | | |
| Ability to analyze data: business intelligence (BI) | rho Spearman | 0.100 | 0.096 | 0.027 | 0.372 | — | | | | | |
| | df | 51 | 51 | 51 | 51 | — | | | | | |
| | p | 0.476 | 0.492 | 0.849 | 0.006 | — | | | | | |
| Lack of social awareness | rho Spearman | 0.320 | 0.092 | −0.117 | 0.175 | 0.405 | — | | | | |
| | df | 51 | 51 | 51 | 51 | 51 | — | | | | |
| | p | 0.019 | 0.515 | 0.404 | 0.210 | 0.003 | — | | | | |
| High costs of urban infrastructure and investment imbalance | rho Spearman | 0.147 | 0.170 | 0.119 | −0.059 | 0.195 | 0.218 | — | | | |
| | df | 51 | 51 | 51 | 51 | 51 | 51 | — | | | |
| | p | 0.294 | 0.222 | 0.396 | 0.676 | 0.161 | 0.117 | — | | | |
| Traffic congestion and an inefficient public transport system | rho Spearman | −0.014 | 0.075 | −0.036 | 0.164 | 0.159 | 0.106 | −0.094 | — | | |
| | df | 51 | 51 | 51 | 51 | 51 | 51 | 51 | — | | |
| | p | 0.919 | 0.592 | 0.798 | 0.242 | 0.255 | 0.449 | 0.502 | — | | |
| Centralized decision-making and top-down approach | rho Spearman | −0.061 | 0.164 | 0.197 | 0.086 | 0.342 | 0.125 | 0.058 | 0.133 | — | |
| | df | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | — | |
| | p | 0.665 | 0.240 | 0.157 | 0.541 | 0.012 | 0.371 | 0.677 | 0.342 | — | |
| Technology obsolescence, system failures, and infrastructure fragility | rho Spearman | 0.143 | −0.307 | 0.030 | −0.234 | 0.067 | 0.011 | 0.013 | 0.080 | −0.232 | — |
| | df | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | — |
| | p | 0.307 | 0.026 | 0.831 | 0.092 | 0.632 | 0.936 | 0.927 | 0.571 | 0.094 | — |

As Gontarz and Sulich (2019) point out, transport management in the city is the most demanding type of task faced by public administration. There is a need for wise actions for sustainable development and maintaining a balance between human anthropopressure in cities.

In turn, Etukudoh et. al (2024) argue that the transition to sustainable transport is a transformation that goes beyond the usual and currently known technological progress. It requires a multifaceted approach, encompassing infrastructure development, technological innovation, policy interventions, and behavioral change. Infrastructure development is the basis for change, as it includes the creation and maintenance of extensive public transport networks, the creation of electric vehicle (EV) charging infrastructure, and alternative fuel production plants. However, cost considerations related to electric vehicles (EVs) and alternative fuel vehicles pose real barriers. Therefore, government incentives and funding for research in this area are necessary.

Global efforts toward sustainable development (e.g., sustainable development goals) and related binding legal requirements already exist in Europe at both national and supranational levels. Moreover, the mobility needs of people and goods in urban areas are accumulating and urban freight transport, therefore, plays a key role in achieving these goals. Due to the above, it is recommended that cities be positioned toward efficient and operational control of urban freight transport. This requires supporting tools (e.g., decision support systems) based on reliable and up-to-date information that enables, on the one hand, efficient operation of urban transport from a systemic point of view and, on the other hand, proactive management of potential negative side effects. In this context, it is believed that the quality and benefits of decisions for the entire urban transport network are higher from a systemic perspective, rather than from the perspective of a single actor (e.g., one freight carrier) with its individual interests (Otte, Solvay & Meisen, 2020).

According to the analyses by Ren et al. (Ren et al., 2020), emerging trends in green and sustainable logistics, such as intelligent transportation systems, consolidation centers, electric road systems, fleet optimization, and energy-efficient digital technologies, are already contributing to a significant reduction in emissions harmful to the environment. In the future, these trends will serve as the axis of change towards greener and more sustainable transport systems.

The e-commerce industry offers various solutions that replace foil and plastic with environmentally friendly options such as cardboard boxes, paper, and plant-based packaging. Adopting ecological alternatives for packaging is not just a passing trend but a significant investment in improving environmental conditions, which can yield substantial profits for companies (Paszek & Hnatyszyk, 2021). Eco-friendly e-commerce packaging strikes an ideal balance between high material quality and reduced environmental harm. These initiatives are also aligned with green logistics policies (GLP), which aim to advance green logistics, promote sustainable growth, and support sustainable development (Zhang et al., 2020).

Transport companies seeking eco-friendly solutions to enhance customer transport experiences are concentrating on optimizing vehicle loading. A considerable number of trucks are not loaded to their full capacity, leading to inefficient mileage, financial losses, and increased $CO_2$ emissions. To mitigate the prevalence of empty vehicles on the roads, drivers can leverage freight exchanges and accept supplementary orders for return trips. These eco-friendly logistics initiatives are steadily evolving, facilitating collaborative transport and packaging arrangements among companies, thereby diminishing the occurrence of trips with empty loads (Marczewski, 2019).

## Conclusions

The future of urban freight transport is definitely moving toward ecology and sustainable development. It is crucial to pursue innovative solutions, support scientific research, and promote public awareness in order to achieve a more effective and environmentally friendly transport system in cities.

To achieve the research goal relating to sustainable freight solutions, a comprehensive study engaged 53 experts distinguished by their extensive practical experience in ecological and low-emission transport technologies. An analysis of development factors highlighted the importance of social engagement, economic sustainability, environmental stewardship, administrative efficiency, and robust infrastructure. Residents' involvement in urban transformations and circular economy initiatives scored notably high, alongside pollution prevention and data management policies. However, formidable barriers obstruct progress, notably social awareness gaps, economic challenges such as infrastructure costs and funding limitations, environmental concerns like traffic congestion, administrative

hurdles like centralized decision-making, and infrastructural deficiencies including technological obsolescence and fragility. Experts identified key technologies pivotal for greening freight transport, notably intelligent transport management systems and intermodal freight transport, emphasizing optimization and emission reduction strategies. Urgent investment priorities center around alternative energy sources and modernizing railway infrastructure to enhance efficiency and capacity, which is crucial for advancing sustainable freight logistics. This study underscores the multifaceted challenges and opportunities in eco-logistics, highlighting the need for collaborative efforts and strategic investments to propel sustainable freight solutions into the future.

Based on the conclusions of this study, the following recommendations can be formulated for the development of freight transport in cities:

- Residents' involvement and awareness: encourage active participation of residents in the ecological and digital transformation of cities. This can be achieved through awareness campaigns, community engagement programs, and incentivizing eco-friendly behaviors.
- Sustainable resource management and circular economy: promote sustainable resource management practices and the adoption of circular economy principles. This includes initiatives to reduce waste, promote recycling, and optimize resource use throughout the freight transport process.
- Pollution prevention and reduction: implement measures to prevent and reduce pollution associated with freight transport activities. This may involve investing in cleaner technologies, promoting the use of renewable energy sources, and enforcing strict emission standards.
- Data management and analytics: enhance data management capabilities and leverage advanced analytics tools for better decision-making in freight transport operations. This includes ensuring data quality, promoting data sharing, and implementing real-time monitoring systems.
- Infrastructure modernization: prioritize the modernization of urban infrastructure, particularly railway infrastructure, to improve the efficiency and capacity of freight transport networks. This can help reduce congestion, enhance connectivity, and facilitate the adoption of intermodal transport solutions.
- Investment in alternative energy sources: allocate resources toward the development and deployment of alternative energy sources for transport, such as electric vehicles and renewable fuels. This can help reduce reliance on fossil fuels and mitigate environmental impact.
- Promote intermodal freight transport: encourage the adoption of intermodal freight transport solutions, which combine different modes of transport to optimize efficiency and reduce carbon emissions. This may involve incentivizing the use of rail, water, and road transport networks in a coordinated manner.
- Policy support and collaboration: foster supportive government policies, political will, and collaboration among stakeholders to overcome barriers and drive sustainable development in freight transport. This includes promoting regulatory frameworks that incentivize eco-friendly practices and foster partnerships between public and private sectors.

By addressing these recommendations, cities can work toward developing more sustainable and eco-friendly freight transport systems, ultimately contributing to the overall well-being of urban environments and communities.

## Acknowledgments

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