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Urban mobility in the future: text analysis of mobility plans

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Abstract

Sustainable Urban Mobility Plans (SUMPs) or similar documents from 17 European capitals (published between 2010 and 2021) and the European SUMP guidelines have been analysed to understand how cities shape mobility and their transport systems. Text analysis is applied to identify development tendencies in a time- and cost-effective manner, without relying on traditional deep semantic analysis techniques. In addition to traditional statistical indicators, we introduce Category Term Frequency (CTF) as a new measure in text analysis. CTF reveals the number and proportion of words belonging to the same content group, namely specific mobility-related categories. The results indicate that categories describing general aspects such as the future, general transport, environment, and society are more prominently represented compared to more forward-looking categories like automation, electromobility, and sharing. The aggregated CTF of categories describing these emerging aspects is highest in the mobility plans of Copenhagen, Helsinki, Luxembourg, and Vienna, which are considered forerunners in their implementation. In general, the analysis concludes that despite recent technological developments and new business models, the examined mobility plans barely mention terms that would imply radical changes by the 2030s. Strategic documents and, thus, urban mobility developments suggest only a slow transition towards the expected levels of sustainable and smart urban mobility. These findings may contribute to understanding and (re)considering urban and transport development strategies in Europe. Furthermore, this text analysis framework provides planners and other experts with a novel tool to identify the focal areas of mobility-related (or other) documents.

Keywords Sustainable urban mobility plans, SUMP, Urban mobility, Cities, Text analysis, Term frequency-inverse document frequency (TF-IDF), Category term frequency (CTF)

1 Introduction

The future of urban mobility is difficult to predict due to several influencing factors, including individual travel habits, sociodemographic trends, regional and economic differences, as well as unpredictable external phenomena like pandemics or crises. Policymakers and urban planners agree that making cities and communities sustainable is highly desirable [8] and that the promotion of sustainable solutions such as public transport (PT), shared mobility services, and micromobility are crucial to improving urban resilience [9] and climate-neutrality. Research findings indicate that public transport [20, 31, 48] and flexible solutions [3] remain key elements of mobility systems in the near future. Others argue that the introduction of electric and autonomous vehicles, and particularly new sharing economy-based business models can mitigate the negative externalities of urban mobility in the long run [13]. However, shared and micromobility tend to replace public transport rides (and not only

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the desired individual motorised trips), thus their positive impact may be overestimated, e.g., in case of bike-sharing [38] and e-scooters [18]. Evidently, considering all aspects of sustainability is crucial to improving urban mobility [2].

Despite significant efforts by researchers to outline the future of urban mobility [34, 51], it has remained unrevealed and uncompared how cities are actually responding to related challenges. Urban mobility policies are expected to effectively contribute to the global ambition of arriving at inclusive, safe, resilient and sustainable cities, set by the United Nations in their Sustainable Development Goals mission [52], as well as to achieve climate neutrality by making urban mobility more sustainable and healthier, set by the European Commission in its Sustainable and Smart Mobility Strategy [19]. Accordingly, the primary aim of this paper is to better understand this endeavour of cities in Europe, i. e. how do they shape mobility and their transport systems for a better future.

To address this question, similar plans of European capitals are analysed in this paper. We expect that through the specific review of their strategic documents, we can draw conclusions about the forward-thinking nature of European cities and potentially identify patterns based on their basic characteristics. The subjects of this review are Sustainable Urban Mobility Plans (SUMPs), as in line with the increasing concerns about sustainability and the growing attention to urban mobility in European transport policies since the 1990s, new principles and concepts of urban mobility planning have evolved into universal planning frameworks known under this name. The common European guideline of SUMPs was initially published in 2013 [43] and updated in 2019 [44]. The planning process described in these guidelines is based on the synthesis of existing urban and transport development plans. It aims to promote feasible, affordable, and environmentally friendly measures to make cities more liveable and sustainable. In the 2010s and 2020s, SUMPs have been widely created throughout Europe.

Thus, the focus of our analysis is to understand and compare the originality and thematic focus of urban mobility-related plans of European capitals, reveal their connection to SUMP guidelines (as common planning frameworks for making urban mobility more sustainable throughout Europe) as well as to explore whether capitals of different sizes and from different mobility cultures address specific themes. For that, we apply text analysis techniques, specifically statistical analysis of words in a text. In addition to common text analysis techniques that calculate the frequency and importance of words in the corpus or individual documents, we introduce a category-based novel approach to better identify the focal points of the analysed documents. Hence, a secondary aim of the present paper is to showcase the application of this new measure and potential for the analysis of a set of complex documents.

Drawing on a review of relevant literature, the upcoming section of the paper sets the scene for future urban mobility, planning frameworks, and previous applications of similar techniques. The text analysis method is detailed in Section 3. Subsequently, Section 4 presents the results and their discussion. Finally, the paper concludes with key findings, brief policy recommendations, and suggestions for future research directions.

2 Background

2.1 Urban mobility in the tangible future

In this research, we drew upon our previous work [34], which reviewed the recent scientific literature concerning the tangible future of urban mobility. We identified key current issues and challenges in urban transport, such as environmental impacts, particularly worsening GHG emissions, road traffic congestions, and ambivalent attitudes of users. Solutions shaping the future of urban mobility include intermodal services, Mobility-as-a-Service, and particularly shared mobility, automation, as a tool for creating smart cities and smart mobility; and low and zero-emission mobility, particularly electric vehicles. Based on the literature review, comprehensive scenarios were defined ranging from a tangible future featuring no relevant changes ('Grumpy old transport' scenario) to one dominated by shared mobility with a high level of automation ('Tech-eager mobility'). According to their findings, the most feasible paths for urban mobility by the 2030s are characterised by traditional transport modes with slow transition towards shared mobility and a massive use of AVs ('At an easy pace') or led by highly shared mobility with low levels of automation ('Mine is yours'). Consequently, according to the forecasts by the scientific community, only incremental advances can be predicted, such as a gradual shift towards shared and electric vehicle use and self-driving. However, how cities plan their future urban mobility has not yet recently been revealed.

2.2 Urban mobility planning frameworks

SUMPs aim to improve accessibility and ensure high-quality and sustainable mobility across and inside urban areas. Based on the common guidelines, they are fundamental elements of transport development in cities within the European Union and beyond [32]. Compared to traditional transport planning approaches, SUMPs introduce novel aspects such as (1) focusing on the functional ("living") urban area instead of administrative boundaries, (2) prioritising accessibility, liveability, and efficiency over planning for specific transport modes, (3) highly build on active participation and commitment of locals. Mobility plans primarily address people's mobility, but they also consider sustainable city logistics [21, 49].

This planning framework requires complex activities from planners, and recommended solutions may vary depending on the characteristics of each city. Consequently, a combination of soft measures, such as inspirational campaigns, and hard measures, such as tolling and bans, can be introduced [32]. SUMP documents are a prerequisite for accessing certain EU funds.

Due to the commitment and advocacy of European institutions, as well as the adoption of good practices by pioneering cities, SUMPs have become catalysts for mobility transitions in European cities since the late 2010s and early 2020s. European co-funding has been instrumental in establishing guidelines and methodologies, as evidenced by projects such as CH4LLENGE (2013–2016), BUMP (2013–2016) and Poly-SUMP (2012–2014), which were financed by the Intelligent Energy Europe programme. Following the publication of the first SUMP guidelines, the European Commission quickly identified challenges in their application, particularly noting that only a few authorities had conducted thorough trend analysis, developed scenarios, and provided the necessary long-term policies and focus. Consequently, additional projects were initiated to boost the uptake of good practices, including SUMPs-UP (2016–2020), PROSPERITY (2016–2019), SUITS (2016–2021) under the CIVITAS initiative, and REFORM (2017–2020) and InnovaSUMP (2017–2021) under INTERREG programmes.

It is worth mentioning that some European countries have already implemented other strategic planning practices to address urban mobility challenges, predating the formalization of SUMPs. This is the case, for example, in France, where planning frameworks known as *Plans de déplacements urbains* (PDU) were created by law in 1982 and, after several developments, are now considered "the French SUMPs" [33].

2.3 Text analysis techniques

A review of relevant scientific journals indicate that text analysis techniques have been rarely applied in the field of transport or urban planning or specifically SUMPs. In many cases, word occurrence was analysed using simple counting methods with pre-defined words. The most commonly used indicator for word analysis is Term Frequency-Inverse Document Frequency (TF-IDF), which measures the importance of a word in the corpus. In instances where more complex methods were used, the goal was to create two-dimensional matrices for visualization purposes. Furthermore, the review of the literature revealed a notable research gap: it has primarily focused on the analysis of individual words rather than exploring word categories. Table 1 highlights these documents, including their aim and applied methodology.

3 Methodology

3.1 Document selection

For this research, all capitals in the EU were considered. Their Sustainable Urban Mobility Plan (SUMP) documents were searched on the CIVITAS database and Google. Only documents available in English were considered. A total of 17 documents were found. In some cases, if SUMP documents were not available, similar urban policies and plans on transport and mobility development were selected: Bratislava [46], Brussels [7], Budapest [5, 6], Copenhagen [50], Dublin [39], Helsinki [11], Ljubljana [42], Luxembourg [37], Malta [25], Nicosia [16], Paris [47], Prague [41], Riga [36], Sofia [4], Stockholm [12], Tallinn [30], Vienna [54]. In the case of Malta and Luxembourg, not only the transport plan of the capital but the whole country was considered. For Paris, the Île-de-France region (as its functional area) was considered.

3.2 Classification of cities

The capitals were classified based on two factors: (i) size and (ii) mobility culture, see Fig. 1.:

Table 1 Summary of text analysis literature in the field of transport and urban planning

Source	Documents analysed (item)	Aim	Methodology used
[28]	Smart service systems papers (5,378)	Develop a unified understanding of smart service systems	TF-IDF, spectral clustering
[45]	Voluntary National Reviews (75)	Identify country-specific thematic areas	TF-IDF, multilayer network analysis
[27]	Smart city papers (3,315)	Identify keywords, research topics, technological factors, application areas	TF-IDF, spectral clustering
[22]	Papers containing keywords defined (2,145)	Underpin sustainability of a city	Co-word matrix of frequent keywords, clustering analysis, bi-dimensional diagram
[14]	Title, abstract and keywords of papers containing pre-defined words (1,430)	Identify the co-occurrence of city categories	Counting co-occurrences
[55]	Container shipping companies' sustainability reports (33)	Explore the latent information	Co-occurrence with Latent Dirichlet Allocation (LDA)

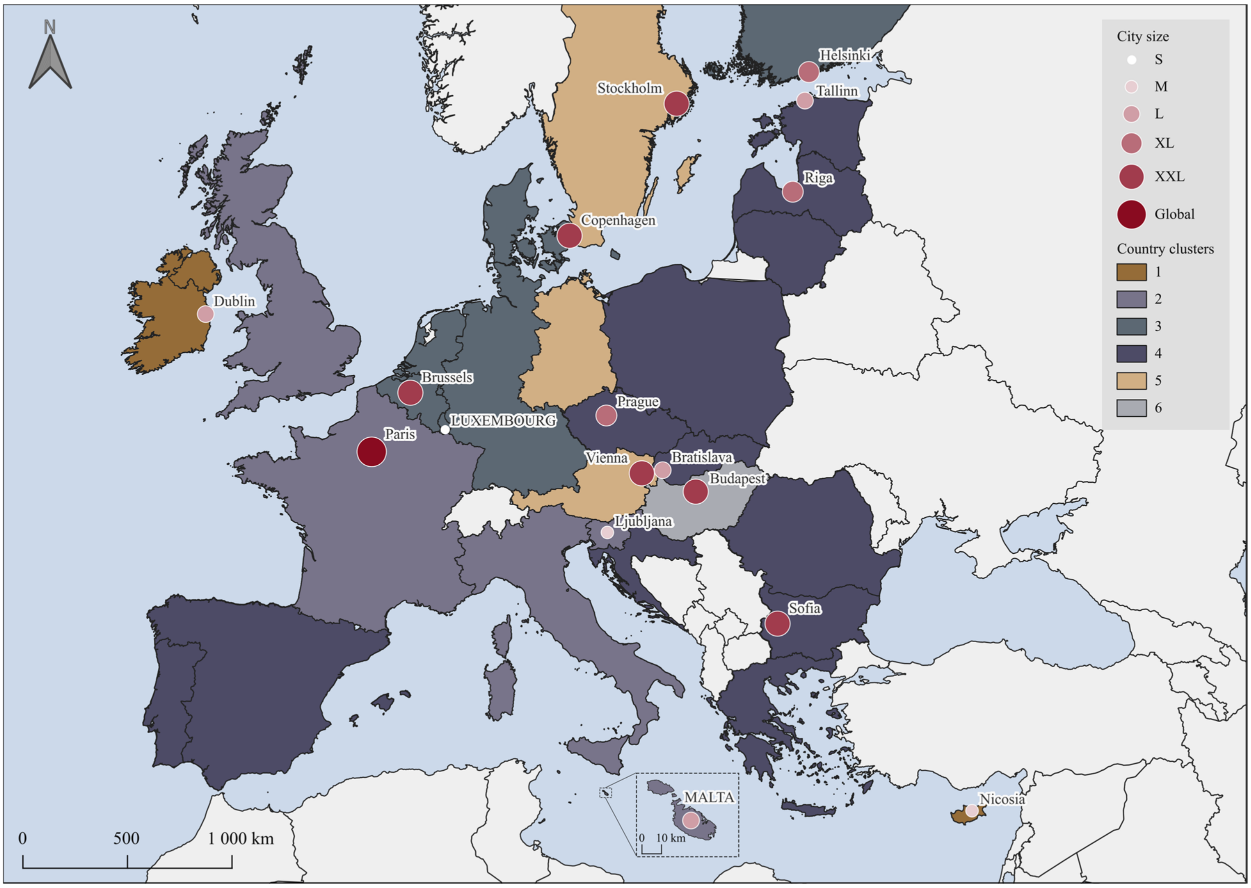

Fig. 1 Map of the considered cities classified by their city size and mobility cultures

i. The European Commission defined six groups for cities based on the population of their urban center [17]: S (50,000–100,000), M (100,000–250,000), L (250,000–500,000), XL (500,000–1,000,000), XXL (1,000,000–5,000,000), Global city (>5,000,000). It should be noted that the size of cities in official statistics may differ from the above categorization due to differences in the population of the *urban centre* and the *administrative city*. For this research, at least one city was selected from each group: S – Luxembourg; M – Ljubljana, Nicosia; L – Bratislava, Dublin, Malta, Tallinn; XL – Helsinki, Prague, Riga; XXL – Brussels, Budapest, Copenhagen, Sofia, Stockholm, Vienna; and Global city – Paris.
ii. Six country clusters were identified based on the findings of Haustein & Nielsen [24] on European mobility cultures. These clusters were formed considering aspects such as socio-economic background, IT affinity, life satisfaction, green identity, and the use of transport modes. The identified clusters are as follows: 1 – Ireland, Cyprus (and Northern Ireland),2 – France, Italy, Luxembourg (and Great Britain); 3 – Belgium, Finland, Germany (Western part), The Netherlands; 4 – Bulgaria, Czech Republic, Estonia, Greece, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia, Slovenia, Spain; 5 – Austria, Germany (Eastern part), Sweden; 6 – Hungary.

The corpus used in this study includes the selected documents (Mobility Plans) and additional information about the city size and mobility culture, as shown in Fig. 2. The letters refer to the urban centre size, and the number refers to the mobility culture-based cluster. The corpus consists of 2 guidelines (x = 2013 and x = 2019) and 17 SUMP documents (x = 1..17).

In dictionary-based text analysis, only relevant words defined by a dictionary are analysed, rather than all words. As sustainable urban mobility planning in Europe is based on common guidelines, we utilized these guidelines to create the *basic dictionary*. Both the 2013 and 2019 guideline (hereinafter: SUMP Guidelines) were considered to capture any changes in development directions. Additionally, words that fit into the

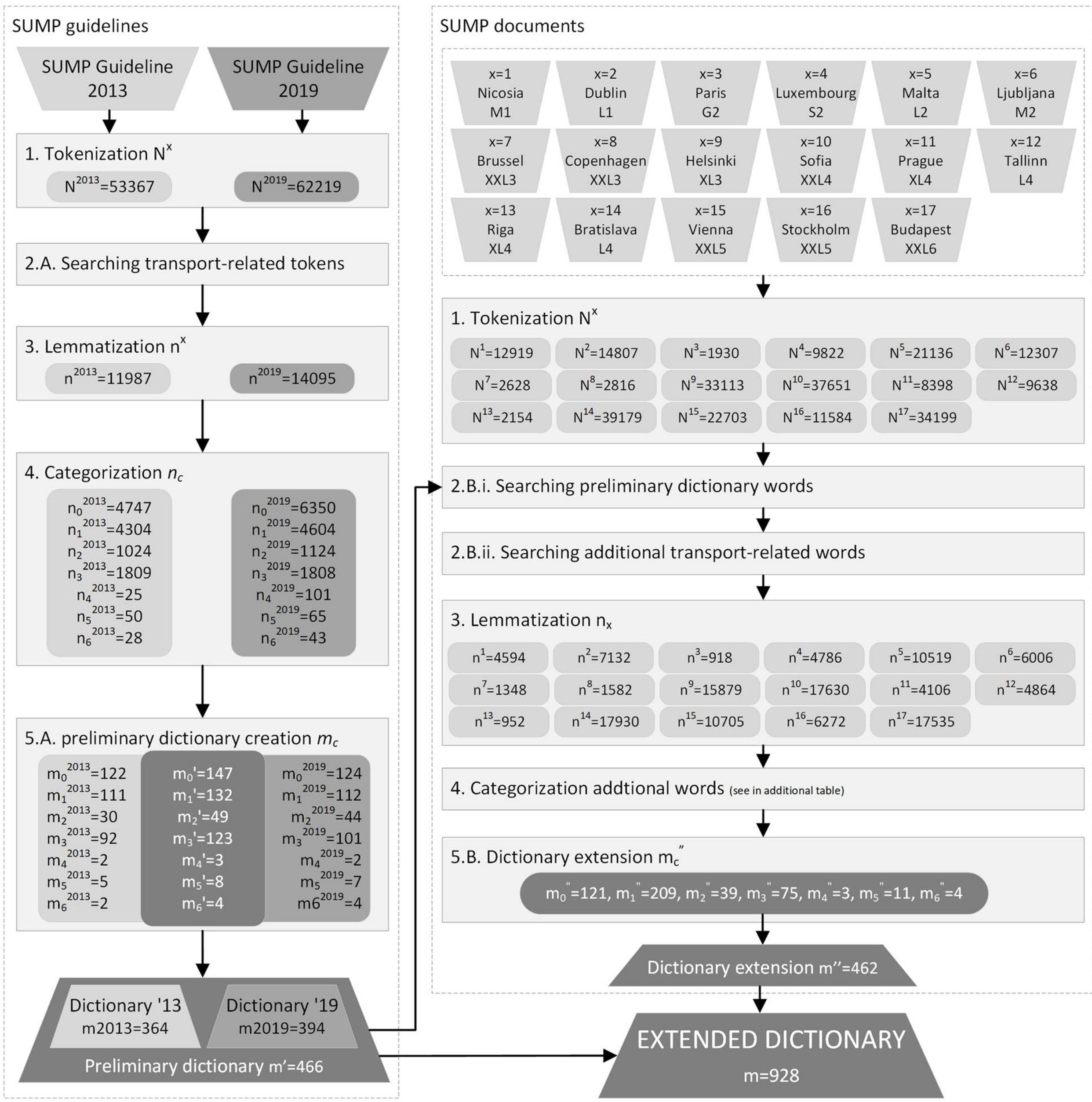

Fig. 2 Dictionary creation

basic dictionary were identified in the selected strategic documents (hereinafter: Mobility Plans), and the basic dictionary was expanded accordingly.

The following commonly used text mining tools were applied:

Tokenization: separating a document into units called tokens, which can be words, characters, or sub-words. Articles and prepositions are not counted.

Lemmatization: grouping inflected forms together into a single base form, such as singular and plural nouns, verbs, and verbal nouns.

The steps of the dictionary creation method are summarised in Fig. 2. First, the SUMP Guidelines were analysed to determine the basic dictionary. Then, the Mobility Plans were analysed. The steps involved are as follows:

1. *Tokenization* of the documents into words, excluding articles and prepositions. Determining the counts of tokenized words w in document x: $N^x = \sum f_{w,x}$, where $f_{w,x}$ is the raw count of word w in document x. *ATLAS.ti* data analysis and research software was applied.
2. *Searching mobility-related tokens*:

   2.A. In the case of SUMP Guidelines: all tokens were checked to determine if they could be considered mobility-related.
   2.B. In the case of Mobility Plans:

      2.B.i. tokens that are part of the basic dictionary were noted.
      2.B.ii.tokens that are not part of the basic dictionary were checked to determine if they could be considered mobility-related.

3. *Lemmatization*: only mobility-related tokens were lemmatized. The lemmatized tokens are verbs, nouns, or root words. The number of lemmatized tokens is $n^x = \sum f_{t,x}$ where $f_{t,x}$ is the raw count of lemmatized tokens t in document x.
4. *Categorization*: all lemmatized tokens were categorised. The number of tokens in each category was summarized by guidelines and documents; the repetitions were considered n_c^x.
5. *Dictionary creation*: token repetition was neglected; the dictionary words are marked as m:

   5.A. Basic dictionary creation based on SUMP Guidelines.
   5.B. Dictionary extension based on Mobility Plans:

      5.1 The repeated lemmatized tokens were filtered in each document, resulting in the dictionary words according to each category by guidelines and documents, m_c^x;
      5.2. The similarity in documents was identified, resulting in the words of the basic dictionary $m_c^{'}$ and dictionary extension $m_c^{''}$ according to each category.

SUMP Guideline 2013 contains $m^{2013}=364$ and SUMP Guideline 2019 contains $m^{2019}=394$ dictionary words at least once. Considering the repetition, the number of words in the basic dictionary is $m'=466$. In the Mobility Plans, 60 of these words does not appear. An additional $m''=462$ words were added to the basic dictionary, resulting in the extended dictionary containing $m=928$ words. 462 words appear only in the Mobility Plans, while 406 words are common between SUMP Guidelines and Mobility Plans.

3.3 Categorisation

The aim of creating categories is to include a set of related words that may describe the thematic focus of documents. The themes that were identified as influencing factors of the tangible future of urban mobility in a previous study [34] served as the basis for defining the categories. With the exception of 'sharing', the themes were translated into more general titles, such as 'environment' (derived from 'GHG emission') and 'electromobility' (from 'electric vehicles'), or even more general categories like 'general transport' and 'society'. The category of 'future' was added to ensure that all relevant words describing the forward-looking nature of cities are considered.

The set of categories is expected to be inclusive in terms of the relevant themes while allowing for proper analysis of the thematic focus of mobility plans. The words in the categories are the mobility-related tokens. The following categories were introduced for text analysis (c = 0..6):

#0: future: words describing progress, steps, and impacts, e.g., 'develop', 'implement', 'phase', 'plan', 'target', 'vision'.
#1: general transport: common terms related to urban transport and mobility, e.g., 'city', 'mobility', 'traffic', 'transport', 'urban'.
#2: environment: words related to the natural environment and eco-friendliness of transport systems, e.g., 'airpollutant', 'emission', 'environment', 'pollute', 'sustainable'.
#3: society: terms describing people's activities in cities and in planning processes, as well as social aspects of transport, including safety, e.g., 'accident', 'citizen', 'participate', 'stakeholder', 'user'.
#4: sharing: words directly related to shared transport modes, e.g., 'bikeshare', 'carsharing'.
#5: automation: in a broad sense, words related to intelligent technologies in transport, e.g., 'CAV' (connected and automated vehicles), 'digital', 'driverless', 'drone', 'smart'.
#6: electromobility: all words directly related to electric vehicle use, such as, 'charge', 'electrify', 'electromobility'.

3.4 Words analysis

The texts were analysed using the following methods: (i) individually, (ii) by comparison, and (iii) according to a dictionary. The statistics were calculated using MS Excel.

The analysis considered the lemmatized tokens (Step 3) and the lemmatized and categorized tokens (Step 4). The following indicators were determined (refer to Fig. 3).

Term Frequency (TF): for normalisation purposes; the relative frequency of a mobility-related word (or term) t in document x, namely the number of times a term occurs in a document considering the length of the document (1).

$$tf(t,x) = \frac{f_{t,x}}{\sum\limits_{t' \in x} f_{t',x}} \tag{1}$$

TF is between 0 and 1. The higher the TF is, the more the term occurs in the document. $\sum\limits_{x} tf(t,x) = 1$ according to a document.

Inverse Document Frequency (IDF): to enhance the importance of unique and infrequently occurring words, IDF measures the amount of information provided by a term. IDF is calculated as the logarithmically scaled inverse fraction of document x, where the number of documents in the corpus is divided by the number of documents that contain the term being analyzed (2).

$$idf(t,X) = \log \frac{D}{|x \in X : t \in x|} \tag{2}$$

where D is the total number of documents in the corpus $D = |X|$, thus $|x \in X : t \in x|$ is the number of documents where the term t appears. The higher the IDF is, the more unique the term is; 0: each document contains the term, idf_{max}: only one document contains the term.

Term Frequency-Inverse Document Frequency (TF-IDF): to express how important a term is to a document considering the corpus (3).

$$tfidf(t,x,X) = tf(t,x) \cdot idf(t,X) \tag{3}$$

TF-IDF increases proportionally to the number of times a term appears in a document, but it is balanced by the number of documents in the corpus that contain the given term. As a result, the importance of frequent words is lower. A high TF-IDF value indicates that the term has a high frequency within a document and a low frequency across the entire corpus.

We have introduced *Category Term Frequency (CTF)* as an extension to the previous indicators to express the importance of category c within a document. CTF (4) represents the relative frequency of terms in category c, considering all mobility-related terms. In other words, it measures the number of times a category occurs in a document.

$$ctf(t,c,x) = \frac{\sum_{c,x} f_{t,c,x}}{\sum_{x} f_{t,x}} \tag{4}$$

where $f_{t,c,x}$ is the relative frequency of term t in category c in document x; thus, $f_{t,,x}$ is the relative frequency of terms t in document x. The sum value of CTF in a document is 1.

4 Results and discussion

4.1 Basic and extended dictionary

The basic dictionary consists of two components: the SUMP Guidelines from 2013 and 2019. The 2019 document is more extensive, with a 16.5% increase in length. However, it is not just the number of terms that changed between the two versions. There is a slightly higher number of different mobility-related terms, accounting for 8.4% and 10% of the total in 2013 and 2019, respectively. These terms are frequently used in both guidelines, comprising 22.5% and 22.7% of the total word count, respectively.

Table 2 provides a summary of the number and raw count of terms for each category. Over the span of 2013 to 2019, new terms have emerged across all categories, totalling 101 new items. The relative increase is particularly notable in category #6, which includes terms like 'electrify' and 'electromobility', as well as in category #2, which includes terms like 'ecological', 'energy', and '$PM_{2.5}$'. However, there are also a significant number of words (71) that are only present in the 2013 guideline and not in the 2019 version. These words come from three categories and include terms like 'barrier', 'challenge', 'revitalise' (#0), 'motorist', 'port', 'waterway' (#1), 'casualty', 'family', and 'forum' (#3).

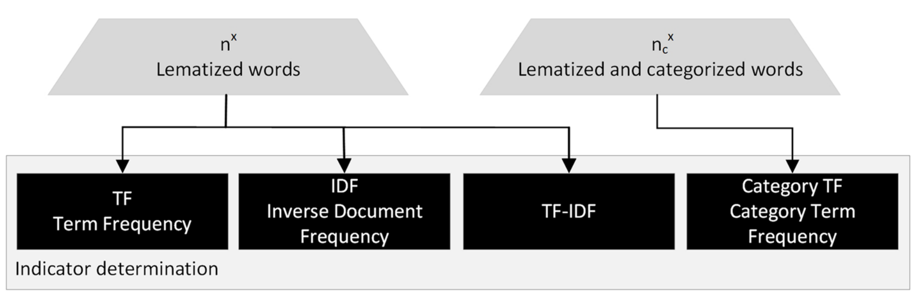

Fig. 3 Indicators

Table 2 Relative frequency and frequency of tokens in categories

	N	$n = f_{t,x}$	*N*	$n = f_{t,x}$
	2013		2019	
0: future	4782	122	6362	124
1: general transport	4257	111	4522	112
2: environment	994	30	1122	44
3: society	1865	92	1901	101
4: sharing	29	2	102	2
5: automation	32	5	43	7
6: electromobility	28	2	43	4
Mobility-related tokens	11,987	364	14,095	394
Tokens	53,367	4358	62,219	3955
Share of mobility-related tokens	22.5%	8.4%	22.7%	10%

Although the absolute number and proportion of terms in categories #4, #5, and #6 are relatively small, there has been an increase in their proportion, as well as in category #0. On the other hand, there has been a decrease in the proportion of terms in categories #1, #2, and #3. These changes can be observed when comparing the data from 2013 to 2019, as shown in Fig. 4.

Terms from Mobility Plans were considered to create the extended dictionary. In the 17 Mobility Plans, a similar number of new elements (462) were added to the list of individual tokens from the two guidelines in the basic dictionary (466). These new elements span across all categories, with the majority appearing in categories #1 (209 new tokens, such as 'logistics', 'transfer', 'stop') and #0 (121 new tokens, such as 'estimate', 'result', 'concept'). Mobility Plans also contribute new tokens to other categories in the extended dictionary, including categories #5 (11 new tokens, such as 'autonomous', 'digitalization', 'contactless') and #6 (4 new tokens, including 'battery', 'chargeable', 'fastcharge', 'recharge'). In terms of relative proportions, Mobility Plans predominantly introduce new tokens in category #1, which represents 45% of the extended dictionary (compared to 28% in the basic dictionary), followed by category #0 (26% vs. 32%) and category #3 (16% vs. 26%). The share of new tokens in categories #4 to #6 is only 1–2% across all documents and dictionaries. Words in the basic dictionary that are not mentioned in any of the 17 Mobility Plans include some relevant technical terms, e.g. cost-effectiveness (#3), free-floating (#4), and driverless (#5). The number of considered mobility-related tokens and the size of the dictionaries are summarised in Table 3.

4.2 TF-IDF

IDF values of the tokens (N = 868) in the Mobility Plans range from 0 (indicating the token appears in every document) to 1.23 (indicating the token appears in only one out of the 17 documents). Figure 5 presents IDF values by category, i. e. how many words of a category appear in a certain number of documents. The majority of tokens (86%) appear in more than one document (IDF < 1.23). There are 74 tokens (9%) that are used in all 17 Mobility Plans (IDF = 0). These tokens are distributed across all but two (#4 and #5) categories, including words like 'action', 'change', 'impact' in category #0 (out of 23 words in this category); 'bus', 'infrastructure', 'transport' in category #1 (38); 'environment', 'health', 'sustainable' in category #2 (3); 'access', 'people', 'user' in category #3 (8); and 'charge' and 'electric' in category #6 (2). Additionally, there are 123 words that appear exclusively in one document (IDF = 1.23), covering all categories. Examples include 'hypothesis' in Bratislava, 'masterplan' in Vienna, and 'niche' in Sofia in category #0 (out of 31 in total); 'heliport' in Malta, 'micromobility' in Budapest, and 'trimodal' in Vienna in category #1 (53); 'airpollutant' in Luxembourg, 'ecomobility' in Vienna, and 'reforestation' in Helsinki in category #2 (10); 'conversation' in

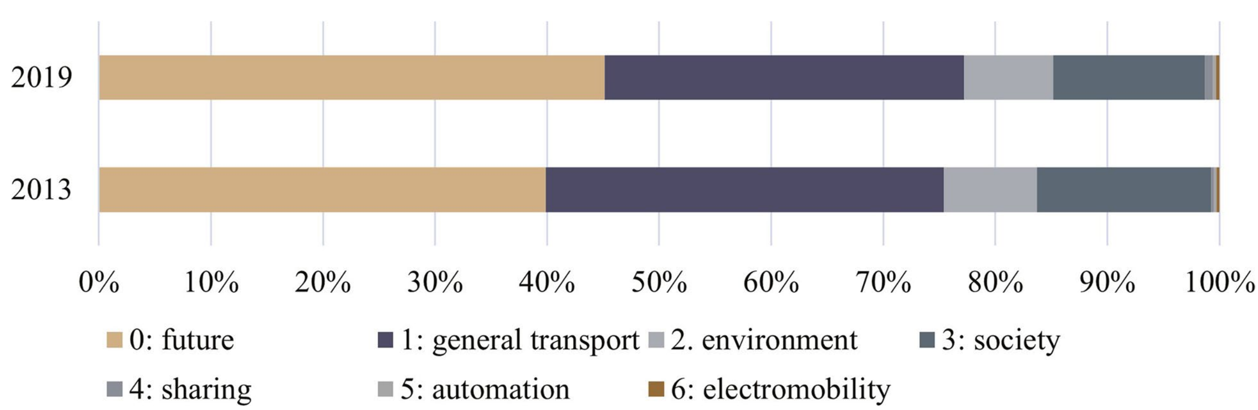

Fig. 4 Share of relevant tokens in the SUMP Guidelines of 2013 and 2019

Table 3 Number of mobility-related tokens considered and the size of the dictionaries(n = ft,x)

	SUMP Guidelines 2013	SUMP Guidelines 2019	*Basic dictionary*	Mobility Plans in total	*Extended dictionary*
0: future	122	124	*147*	121	*268*
1: general transport	111	112	*132*	209	*341*
2: environment	30	44	*49*	39	*88*
3: society	92	101	*123*	75	*198*
4: sharing	2	2	*3*	3	*6*
5: automation	5	7	*8*	11	*19*
6: electromobility	2	4	*4*	4	*8*
Total	364	394	*466*	462	*928*

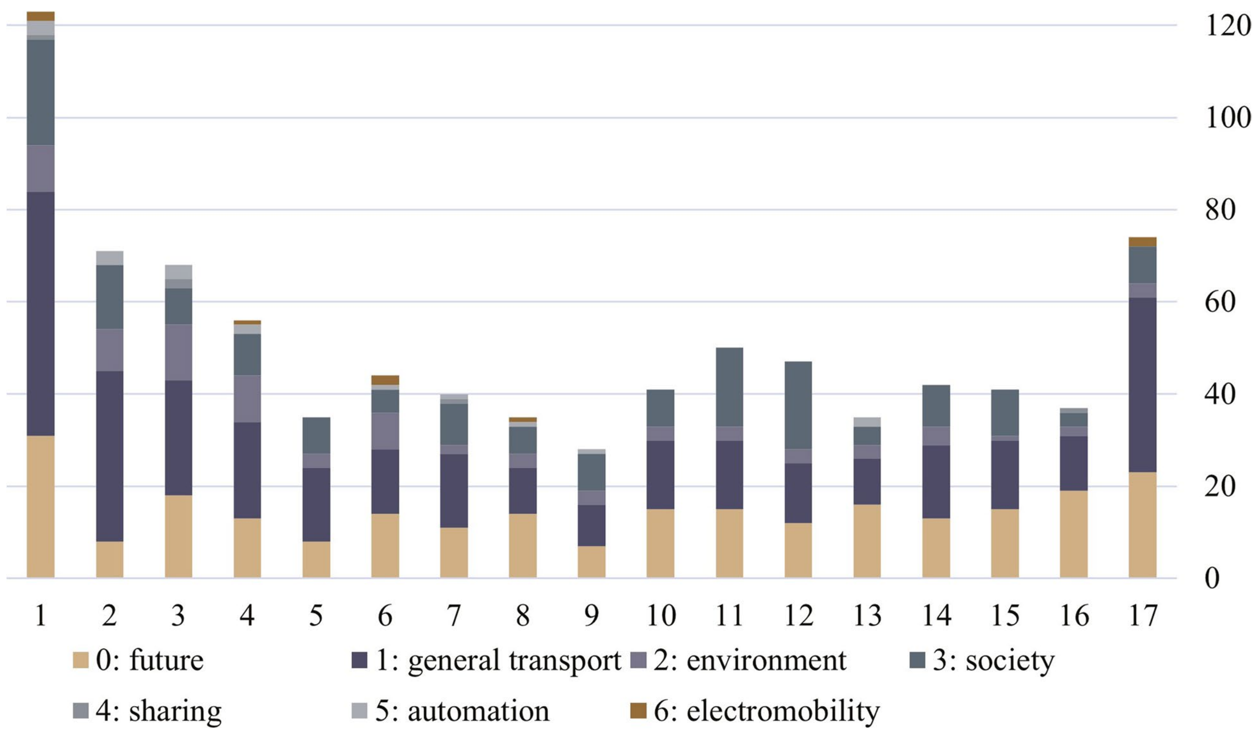

Fig. 5 Number of relevant tokens by categories and the number of Mobility Plans

Sofia, 'inequality' in Tallinn, and 'terrorism' in Malta in category #3 (23); 'ridesharing' in Tallinn in category #4 (1); 'bluetooth' in Bratislava, 'drone' in Sofia, and 'robotisation' in Bratislava in category #5 (3); and 'chargeable' in Helsinki and 'fastcharge' in Sofia in category #6 (2).

Table 4 presents the term frequency of a selected set of general transport keywords, providing an indication of their relevance in the corpus. Each Mobility Plan discusses various evident transport modes, infrastructure elements, and services, such as buses, roads, and parking. However, it should be noted that certain words may not be mentioned in some Mobility Plans due to their irrelevance in those specific cities. For example, the terms 'tram' and 'metro' may not be referenced in Ljubljana's Mobility Plan as the city's public transport system is exclusively based on buses. Similarly, the term 'trolleybus' may not be mentioned in most cases, including both SUMP Guidelines. It is important to consider that although certain ideas or concepts may not be explicitly mentioned, they could be described using alternative terms or different phrasing in some plans. For instance, the concept of 'Bike-and-Ride' may be conveyed through the description of bike parking facilities at public transport stations. These nuances and variations cannot be directly captured by the analytical technique employed in this study. It is worth

Table 4 Term frequency of some transport-related keywords

Keywords	SUMP Guidelines		Mobility Plans	
	TF_{2013}	TF_{2019}	TF_{min}	TF_{max}
Bike-and-Ride	0	0.000142	0 (15 cities)	0.002192 (Prague)
bus	0.003837	0.002696	0.001134 (Helsinki)	0.041784 (Paris)
car	0.002920	0.003902	0.002944 (Dublin)	0.037927 (Copenhagen)
carpooling	0.000334	0	0 (10 cities)	0.009402 (Luxembourg)
cyclist	0.000334	0.000568	0 (Riga)	0.010746 (Copenhagen)
metro	0.000584	0.000050	0 (7 cities)	0.009359 (Sofia)
micromobility	0	0.000071	0 (16 cities)	0.000056 (Budapest)
motorcycle	0	0.000142	0 (9 cities)	0.001306 (Nicosia)
Park-and-Ride	0.000250	0.000213	0 (13 cities)	0.003897 (Prague)
parking	0.001752	0.00291	0.00296 (Helsinki)	0.0037623 (Tallinn)
passenger	0.001668	0.000709	0.000567 (Helsinki)	0.012025 (Sofia)
road	0.005506	0.005463	0.001008 (Helsinki)	0.033482 (Stockholm)
taxi	0.000167	0.0000497	0 (3 cities)	0.007619 (Nicosia)
tram	0.000751	0.000780	0 (3 cities)	0.012843 (Nicosia)
trolley(bus)	0	0	0 (12 cities)	0.005252 (Riga)
walk	0.001585	0.002838	0.000435 (Nicosia)	0.026261 (Riga)

mentioning that we have retained (and not merged) some terms with related meanings – e.g., 'motorcycle', 'motorcyclist'; 'tram', 'tramway' – to facilitate detailed analysis, while our new approach provides a full view of terms pertaining to a particular category, too.

TF-IDF serves as an indicator of a token's relevance in a document, with a high value indicating a combination of high term frequency (TF) within the document and/or low inverse document frequency (IDF) across the corpus. The top tokens, which represent 2.5% of all words in the corpus and have a TF-IDF value equal to or above 0.0025, are as follows: 'SUMP' (0.0107, Ljubljana, appearing in 5 documents), 'harbour' (0.0047, Malta, 3), 'centralise' (0.0046, Helsinki, 4), 'foster' (0.0041, Paris, 5), 'cost' (0.0040, Nicosia, 15), 'carpooling' (0.0036, Luxembourg, 7), 'ferry' (0.0036, Malta, 3), 'carbon' (0.0034, Helsinki, 11), 'scenario' (0.0033, Nicosia, 12), 'energy' (0.0033, Helsinki, 13), 'CO_2' (0.0032, Helsinki, 2), 'tramway' (0.0031, Nicosia, 6), 'version' (0.0030, Tallinn, 10), 'estimate' (0.0030, Malta, 12), 'waterway' (0.0029, Paris, 7), 'neighbourhood' (0.0029, Brussels, 10), 'trolley' (0.0028, Riga, 5), 'MaaS' (0.0027, Brussels, 6), 'liveable' (0.0027, Budapest, 2), 'emission' (0.0026, Helsinki, 15), 'subway' (0.0025, Sofia, 3), 'port' (0.0025, Malta, 10).

In this corpus, the IDF of tokens with high TF-IDF is usually below 1.23, i.e., they appear in more than one document. The word with the highest TF-IDF (0.0021) that appears in only one document (IDF = 1.23) is 'embankment' in Budapest. From the 495 mobility-related tokens in the mobility plan of Budapest, 'riverboat' (0.0009) and 'waterborne' (0.0004) are among the top 50, suggesting that inland waterways transport and its surroundings are significant in a city on two sides of a large river, namely the Danube. Other tokens with high TF-IDF may similarly characterize the mobility of the place, for instance, words describing water transport ('harbour', 'port', 'ferry') in the islands of Malta, environmental issues ('CO_2', 'carbon', 'energy', 'emission') in the climate-oriented plan of Helsinki, current transport services ('trolleybus' in Riga, 'subway' and 'metro' in Sofia), or strong ambitions about the future ('tramway' in Nicosia, 'liveable' in Budapest, 'MaaS' in Brussels, etc.). High TF-IDF values of some general keywords that are present in most of the other Mobility Plans may indicate their extreme relevance in the planning process in a specific city (e.g., 'cost', 'scenario' in Nicosia).

4.3 Category term frequency (CTF)

If we consider not only individual words but also categories, the results reveal a complex picture of Mobility Plans. Figure 6 illustrates the CTF values for each document, indicating the representation of different categories. General categories such as future, transport, environment, and society are more prominently featured compared to the other three categories (automation, electromobility, and sharing). The average CTF values for each category are as follows: #0: 0.287, #1: 0.545, #2: 0.049, #3: 0.101, #4: 0.007, #5: 0.004, #6: 0.006.

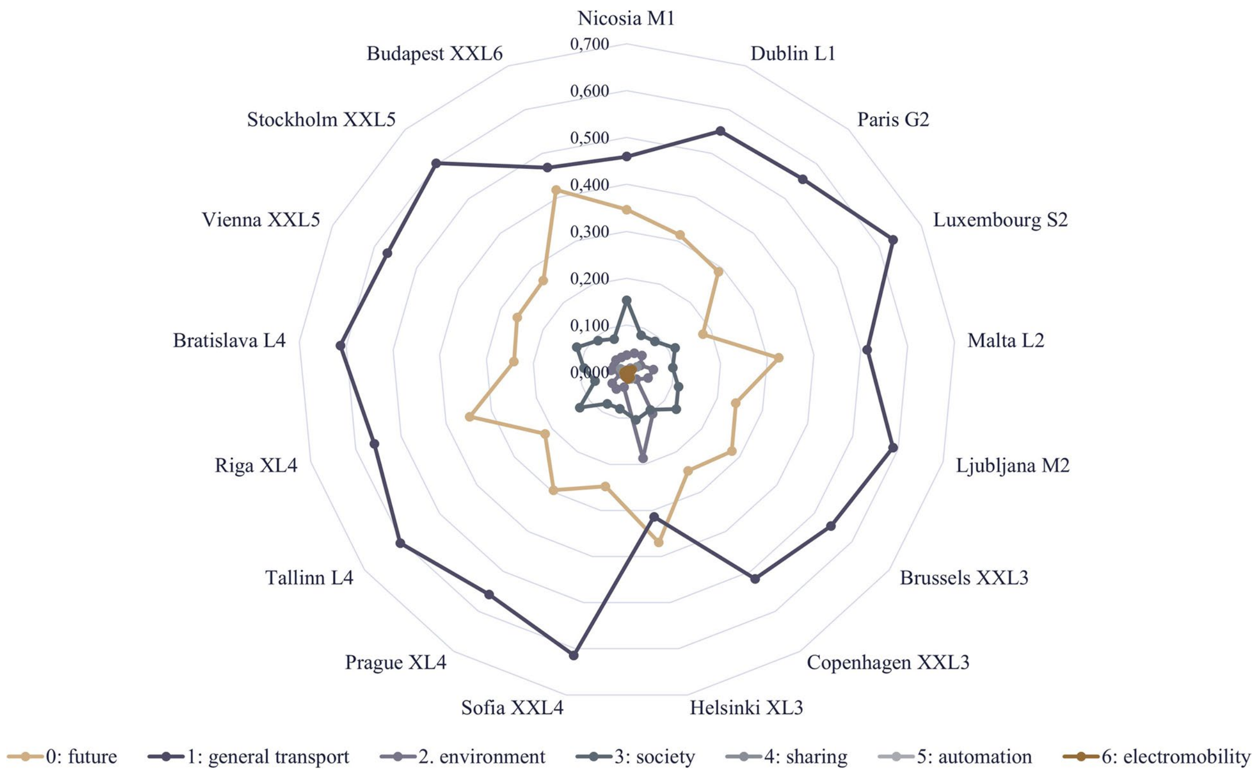

Fig. 6 Category Term Frequency of all categories

Transport-related words (#1) dominate in most documents, except in Helsinki, where environment (#2) is significantly more represented than the average. The cities with CTF values of general transport less than 0.5 are Helsinki (0.314), Nicosia (0.459), and Budapest (0.467). In most cases, where the CTF of general transport deviates from the average, the CTF of future (#0) plays a significant role (e.g., Malta, Riga, Helsinki, Budapest). The CTF values of future (#0) range from a minimum of 0.181 (Luxembourg) to a maximum of 0.416 (Budapest), with the remaining values falling between 0.219 (Tallinn) and 0.346 (Nicosia).

The CTF of society (#3) stands out in Nicosia (0.153), Brussels (0.13), Tallinn (0.126), Vienna, and Luxembourg (both 0.115). In other documents, it ranges from 0.070 (Riga) to 0.104 (Helsinki). Environment (#2) is outstanding in Helsinki (0.19), above average in Copenhagen (0.10) and Malta (0.06), with other cities' Mobility Plans ranging between 0.025 (Brussels) and 0.048 (Paris). Riga stands out with an exceptionally low CTF value for environment (0.014), contrasting with other cities.

Figure 7 illustrates the CTF values of the categories of sharing, automation and electromobility. The CTF of sharing (#4) is high in the documents of Luxembourg (0.024), Copenhagen (0.017), Vienna (0.015), and Paris (0.011). Conversely, it is 0.003 or lower in Nicosia, Dublin, Malta, Riga, and Budapest. The generally low values of CTF for electromobility (#5) are counterbalanced by relatively high frequencies in Helsinki (0.015), Copenhagen (0.013), Luxembourg (0.012), Sofia (0.011), and Prague (0.009). The same trend applies to the CTF of automation (#6), with Brussels (0.010) and Prague (0.009) standing out, while other documents mention words from this category sparingly or almost never. The aggregated CTF of these three categories (#4, #5, #6) is well above the average of 0.017 in Luxembourg (0.039), Copenhagen (0.035), Helsinki (0.026), Sofia (0.025), and Prague (0.024). The documents with the lowest total share of the three categories come from Nicosia (0.005), Malta (0.006), Budapest (0.007), and Stockholm (0.008).

Seemingly, categories describing sharing, automation, and electromobility are correctly related to cities that may be considered forerunners in new mobility solutions. In Copenhagen, the CTF of sharing and electromobility are both much above average (but automation is not); research by Haustein [23] and Christensen et al. [10] report that free-floating car-sharing partly based on electric vehicles has been a good practice after the publication of the Mobility Plan. In the highly liveable Vienna [40], the CTF of sharing makes a difference, indicating already existing ambitions and further initiatives to make shared modes (cars, e-scooters and, particularly, active

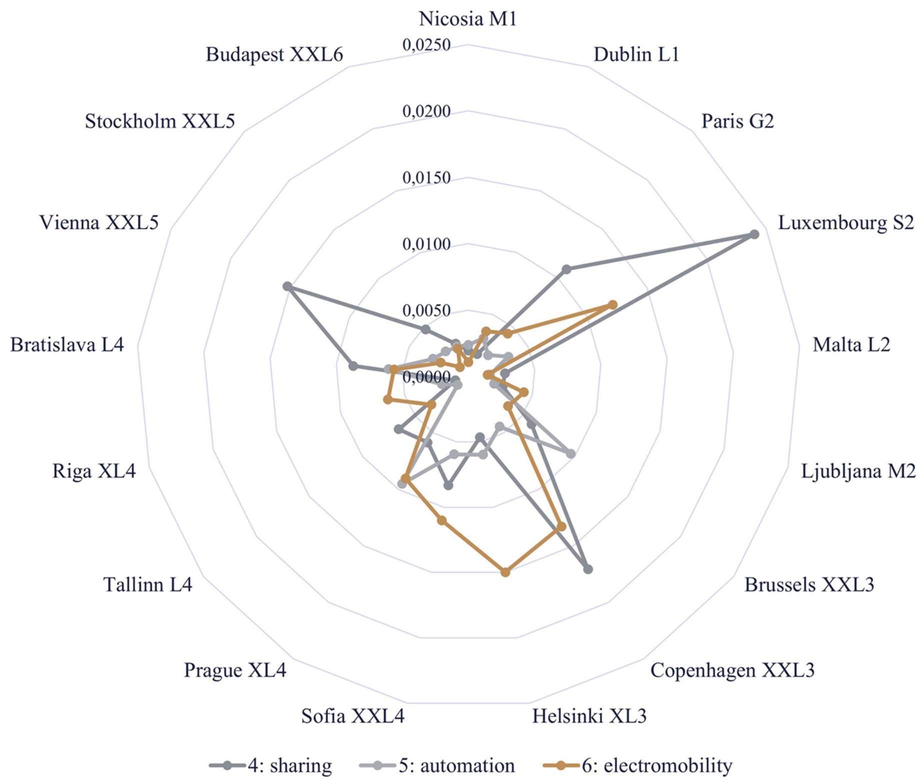

Fig. 7 Category Term Frequency of sharing (#4), automation (#5) and electromobility (#6) categories

mobility) integral parts of the transport system in connection to an extensive public transport network. In Helsinki's plan explicitly addressing climate-neutrality, both the CTF of environment and electromobility stand out, reflecting the special climate conditions and related vulnerability of the capital of Finland, recently reported by Jurgilevich et al. [26], as well as potential solutions provided by the ongoing electrification of the transport sector, particularly electric buses [15] and e-scooters [35], as well as changing the mobility culture more sustainable [1]. In other cases, high CTF values may be related not to the current but a desired situation, for instance, the CTF of sharing is the highest in the plan of Luxembourg, where car-sharing and car-pooling are considered potential solutions to mobility poverty problems of specific target groups [53].

Considering the size groups of cities (S to G), it is worth mentioning that the CTF of society (#2) tends to slightly decrease in cities with larger populations. It is above 0.011 in the S and M groups, slightly below 0.010 in the L and XL groups, and at the value of 0.089 in both the XXL and Global groups. In relation to the average (0.017), the total CTF of sharing, automation, and electromobility is higher in the S (0.040) and XL (0.025) groups, and lower in the M (0.008) and L (0.013) groups. The aggregated CTF of these three categories shows similar patterns in terms of mobility culture as well: clusters 3 (Brussels, Copenhagen, Helsinki, with a total of 0.026) and 4 (Sofia, Prague, Tallinn, Riga, Bratislava, 0.021) stand out, while clusters 2 (Paris, Luxembourg, Malta, Ljubljana, 0.014) and 5 (Vienna, Stockholm, 0.016) are slightly below average. Clusters 1 (Nicosia, Dublin, 0.007) and 6 (Budapest, 0.007) are significantly below average. It may attract one's attention that the CTF of society is lower in clusters 4 and 6 – i.e., mostly in Southern and Eastern countries, where some related aspects, such as collaborative planning approaches, are traditionally less common [29]. Moreover, the CTF of sharing, automation, and electromobility is high in clusters 3 (including some of the Western and Northern countries) and 4, where the sharing economy and the novel technological developments are more mature.

In turbulent times like the 2010s, when the first SUMPs by the common guidelines were drafted, the year of publication of a strategy or plan may also make a difference, taking into account major social and economic phenomena (like the long-lasting and regional effects of the global financial crisis of 2007–2008), related technological trends (e.g., the recent spread of shared micromobility), emerging solutions (e.g., automation), and intensifying global or local concerns (climate change, energy shortage, pandemics, etc.) at the time. In terms of the year of publication, trends can be observed in only three categories: CTF of automation is increasing over time (from 0.003 to 0.005), while society (from 0.115 to 0.088) and sharing (from 0.010 to 0.006) are decreasing. However, the aggregated CTF of sharing, automation, and electromobility does not show a linear trend. It is 0.015 in Mobility Plans published in or before 2015 (5 documents), 0.021 in the period from 2016 to 2018 (4 documents), and 0.016 in 2019 or after (8 documents). The year of publication may be relevant, on the one hand, if a mobility plan does not use many words related to sharing, automation, or electromobility due to be published before they globally came into focus (such as Nicosia, 2010, and Stockholm, 2012) and, on the other hand, if a plan seems to be straightforward in this regard even coming from a relatively early year (e.g., Copenhagen, 2013).

Figure 8 illustrates the CTF of the SUMP Guidelines of 2013 and 2019, as well as the Mobility Plans of the 17 cities. From this perspective, the two guidelines are almost identical. From 2013 to 2019, only the CTF of sharing (significantly) and the CTF of future, automation, and electromobility (slightly) increased. Mobility Plans are also quite similar to the guidelines, but there are some differences. For instance, they feature fewer future, environment, and society-related words on average, but they include a greater number of general transport words.

5 Conclusions

In this research, a novel approach using text analysis techniques has addressed the ambitions of European capitals in their Mobility Plans. European SUMP Guidelines have been applied as dictionaries, i.e., the basis of text analysis.

From a methodological point of view, in addition to applying the traditional statistical technique TF-IDF, we have introduced CTF as a new indicator to reveal the number and proportion of words belonging to the same category in terms of content and meaning. The key lesson learned is that the applied set of text analysis techniques is capable of identifying the weight of relevant concepts in a time- and cost-effective manner, without the need for traditional techniques of deep semantic analysis. Although it does not address large-scale contexts (text structure, headlines, etc.) or small-scale connections (e.g., word pairs or constructs), it can be used for comparing a large number of documents or studying them in situations with limited time. However, the present application also has some limitations, such as the small number of sample elements in some of the created groups (e.g., city size), the geographical scope of documents extending beyond urban contexts in smaller countries (Malta, Luxembourg), or potential controversies related to words with multiple meanings (e.g., 'charge').

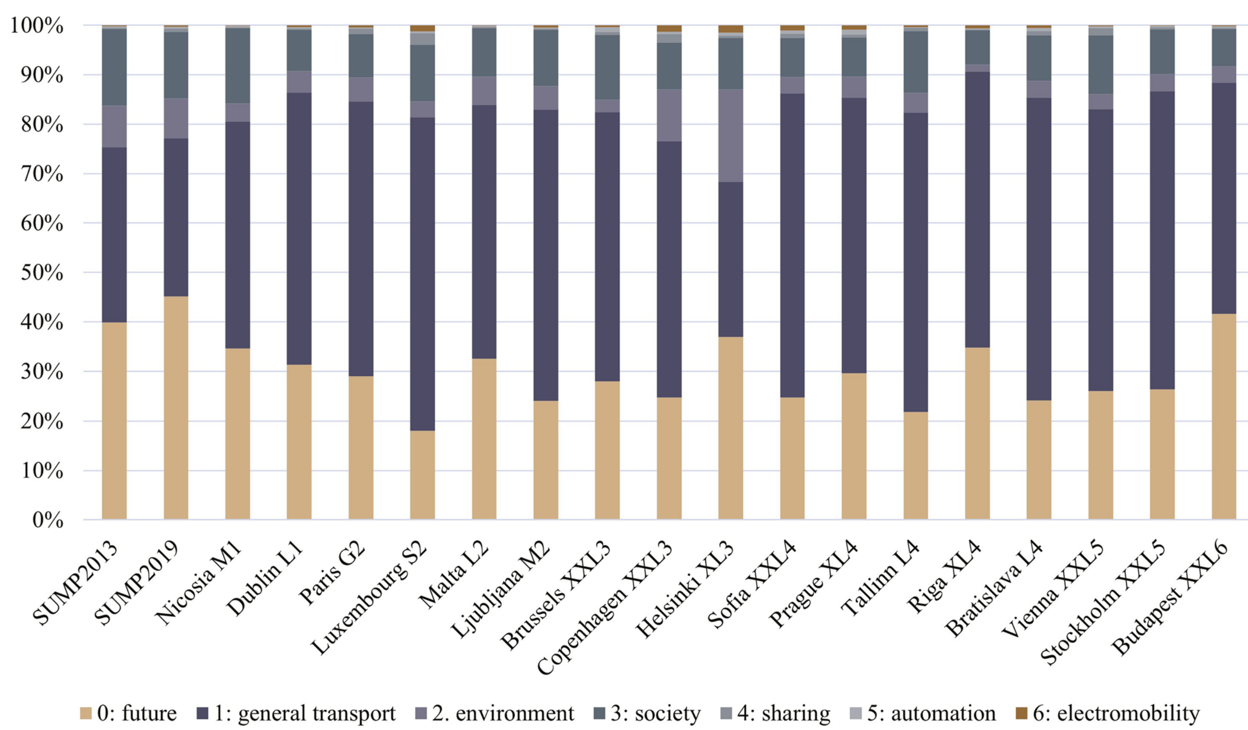

Fig. 8 Category Term Frequencies in the analysed documents

By this methodology, the approach and efforts of specific cities and their groups have been identified. It is noteworthy that despite the genuine efforts and the creation of common European guidelines, cities with different characteristics and mobility contexts have defined their plans from diverse points of view, emphasising different problems, and having their own priorities when drafting project lists. In the present case of Mobility Plans, on the one hand, the specific mobility context of a place has been identified by its TF-IDF value, such as 'trolleybus' in Riga, 'embankment' in Budapest, 'ferry', and 'port' in Malta. On the other hand, the ambitions of a city in relation to environmental and social aspects, as well as shared, automated, and electromobility have been explored by applying CTF. The results indicate that certain categories encompassing general aspects (future, general transport, environment, society) are much more represented than the other three categories with a more forward-looking character (automation, electromobility, and sharing). The categories of sharing, automation, and electromobility stand out in documents from forerunner cities like Copenhagen, Helsinki, Luxembourg, and Vienna. In terms of groups of cities, besides a slight decrease of the CTF of society, no complex patterns may be identified by city size; however, some groups are not numerous enough to draw conclusions (particularly S and Global). Mobility clusters have a more balanced representation but provide no significant evidence about patterns in mobility planning.

Regarding general tendencies in Europe, a key conclusion is that cities seem to pursue even fewer ambitions than researchers foresee in their scenarios about the tangible future. Despite the technological solutions (automation, e-mobility) and business models (sharing economy) emerging and being consolidated in the period this analysis focused on (by the 2030s), the above results indicate that European capitals have largely overlooked these new phenomena in their Mobility Plans. They barely mention technical terms that would suggest major changes in their urban and transport policies. This implies that, in most cases, the execution of urban mobility plans results in a very slow transition towards sustainability in cities, primarily relying on "good old" transport solutions. In times when one of the UN's Sustainable Development Goals aims to create sustainable cities and communities, and the EU has recently targeted 100 climate-neutral cities by 2030 and announced the need for shifting the existing paradigm of incremental change to fundamental transformation, these findings advise caution about the likelihood of achieving these endeavours. To tackle this issue, policymakers should prioritize radical changes, including new technologies and business models, in future mobility planning. Regular updates to SUMPs are crucial and should be incentivized by European and national financial programs. Furthermore, translating research findings into practical urban projects is essential, along with promoting pilot initiatives, living labs, and knowledge exchange between cities and citizens.

In future research, more Mobility Plans in each city category and cluster will be analysed to refine the findings. Furthermore, as CTF has proven to be an appropriate measure for understanding the focuses of complex documents and for characterising and comparing their emphases – especially when a large number of documents have to be analysed in a relatively short time –, the CTF will be applied in other transport-related fields (e.g., SULP, electrification strategies).

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Authors' contributions
Each author has contributed substantially to conducting the research and drafting this manuscript: AM: Conceptualization, Methodology, Analysis, Interpretation of results, Writing – original draft; DF: Conceptualization, Methodology, Software, Data curation, Analysis, Writing – original draft; MM: Data collection, Reviewing and editing, Visualization; MJ: Conceptualization, Reviewing and Editing, Investigation, Supervision. All authors read and approved the final manuscript.

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Declarations

Competing interests
The authors declare that they have no competing interests.

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