From space to personal attitudes: understanding car dependence in Lombardy (Italy)

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SHORT SUMMARY

Car dependence is a prevalent barrier to sustainable and inclusive mobility which emerges from complex interactions between spatial and individual determinants. This research aims to bridge both approaches using spatial bivariate classification of car dependence and a subsequent exploration of inhabitants' attitudes and perceptions. This is especially suitable at the research's case study location, the Italian Lombardy region, which presents a diversity of spatial and socio-economic settlements. The results reveal heterogeneity within and across different car dependence spatial clusters, challenging deterministic assumptions about car dependence based solely on socio-spatial factors. Key findings show that car dependence patterns become more diverse where car dependence attributes intensify, while personal insights add critical nuances to spatial metrics. In particular, results suggest that car dependence takes on different meanings across spatial contexts. The insights underscore the interplay between spatial and subjective dimensions of car dependence, offering a wider understanding of the phenomenon.

Keywords: car dependence, attitudes, perceptions,

1. INTRODUCTION

Understanding car dependence involves a diversity of approaches and metrics that make it a complex and multifaceted concept. On one side, car dependence develops from space, activities and personal levels (Mattioli et al., 2016), while many features relate to it in literature, from transport supply and territorial morphology to socio-demographic characteristics (Sierra Muñoz et al., 2024). Other authors make a difference between being car-dependent out of preferences or not having real alternatives (Lucas, 2009), also appointing it as a path-dependent phenomenon (Pokharel et al., 2023). After all these studies, the operationalization of car dependence in its wide extension is still an open matter, while addressing it becomes urgent due to current environmental and urban challenges.

The first approaches to car dependence focused on the urban form (Newman & Kenworthy, 1989), making clear that transport demand is mainly determined by the spatial context. However, the discussion about the concept cannot be limited exclusively to that matter, especially when the subjectivity of individuals plays an important role in car dependence (von Behren et al., 2018; Zhao, 2011). By integrating both perspectives, this research aims to bridge the gap between individual and territorial levels into car dependence research. Taking the Lombardy region (Italy) as a case study, the research combines spatial attributes of car dependence, which enable clustering of territorial patterns across the region, with survey data. Respondents' attitudes and perceptions

are analysed through different car dependence-related spatial conditions, aiming to provide a nuanced understanding of how citizens' subjectivity aligns with or diverge from spatial patterns of car dependence.

2. METHODOLOGY

The study's methodology develops in two phases. First, the spatial classification process employs a set of spatial variables to systematically assess how cause-and-effect metrics relate within the car dependent process, resulting in the classification of transport zones into different clusters. Second, the qualitative perspective is examined through these clusters using surveys' results, with a particular focus on how varying attitudes and perceptions relate with respondent's self-identification of car-dependent feeling.

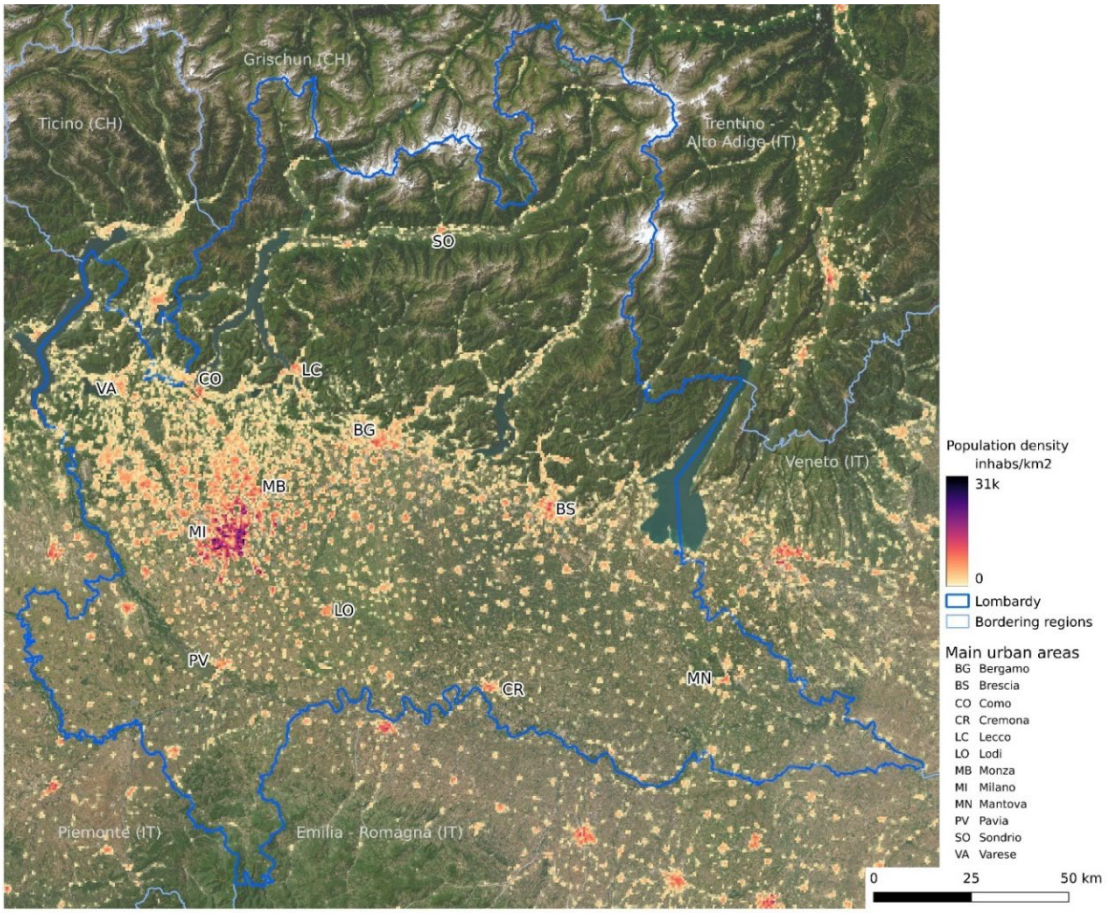

Figure 1. Population density and main regional centres in Lombardy region

Lombardy, one of Italy's largest regions in terms of size, population and gross domestic product, serves as a case study. The region is characterised by intense daily commuting, primarily centred around major urban areas, and by a well deployed public transport system. Lombardy's diverse settlement types and socioeconomic dynamics make it an ideal setting for a regional analysis of car dependence. On one hand, the region includes Milan strong centrality and its dynamic hinterland, as well as the industrial-to-agricultural transition across the Po valley plain. On the other, it encompasses rural and remote areas, such as Alpine mountain areas in the north and the Oltrepó

Pavese hills in the south. This spatial heterogeneity (see Figure 1) provides a compelling context for studying car dependence at a regional level.

Bivariate classification's spatial clustering

The spatial approach provides a classification to the 1400 transport zones of the region by exploring the bivariate associations of literature-based car dependence cause and effects variables' pairs. The exploration of these pairs yields two derived scores: First, a car dependence level which observes the alignment between cause-and-effect variables compared to literature-based correlations. For example, a high value in a cause variable (e.g., low population density) paired with a high value in an effect variable (e.g., high car usage) indicates a high level of car dependence, while low values in both variables suggest a low level. Second, the car dependence dissonance captures the deviation from those expected patterns. In particular, it assesses if low car dependence causes and high car dependence effects appear (and vice versa) or whether car dependence level varies significantly among different pairs. The results of the car dependence level are yielded as an average of the different pairs for same-cause variables, while a single dissonance value is provided as an average of all variables pairs. The values are the input for a cluster analysis, which arrange the transport zones into relatively homogeneous groups (Gore, 2000) in terms of car dependence dynamics. In particular, the research uses agglomerative hierarchical method from Python's Sklearn library (Pedregosa et al., 2011), which forms clusters iteratively by pairing similar objects (Bunge & Judson, 2005).

Cross-referenced survey analysis

The second phase of the research analyses survey data collected as part of this study and the RECAP project[1], targeting the car-dependent attitudes and perceptions of Lombardy residents. Perceptions address how respondent feels dependent on cars for daily life and their views on contextual factors such as built environment or access to activities. Attitudes, in contrast, reflect beliefs or judgements, including intention to reduce car use or opinions on car impact and use. Conducted between May and August 2024, the survey yielded 791 complete responses, forming the base sample for the current analysis.

Survey responses are linked to the regional spatial car dependence clusters using the municipality specified by respondents as their most frequent trip origin. Additionally to this domain, the survey results analysis also focus on self-perceived car dependence. It is measured from the respondent's agreement level (Likert-scaled) with the statement 'My life depends on using the car'. According to it, respondents are divided in two groups: who perceive themselves as car dependent (indicating some level of agreement with the statement) and those who do not. This classification is then cross-referenced with spatial clusters, enabling a grouped analysis of each survey variable across both domains.

3. RESULTS AND DISCUSSION

Bivariate classification spatial clustering

The bivariate classification employs a set of five cause variables and five effect variables, following the literature-based findings presented in Sierra Muñoz et al. (2024). The variables set aims

[1] See RECAP_ Reducing car dependency through tailored policies https://www.dastu.polimi.it/prin-recap/

to combine the multiple dimensions of car dependence with well-established literature correlations among them. The cause variables are population density, amenities accessibility, railway service score, intersections' sparsity and the rate of large households, which reflect key issues related with car dependence in literature. The effects, on one side, include active modes mean distance, private-motorized modal share and average distance for commuting trips, as it solidifies mobility practices and habits (Wiersma, 2020). On the other, the two remaining effect variables refer to driving potential realization through motorization rate and driving licenses' rate, also widely used in literature. This creates a set of 25 pairs (5 causes and 5 effects variables) that produce the car dependence level and dissonance scores, source for the territorial clustering.

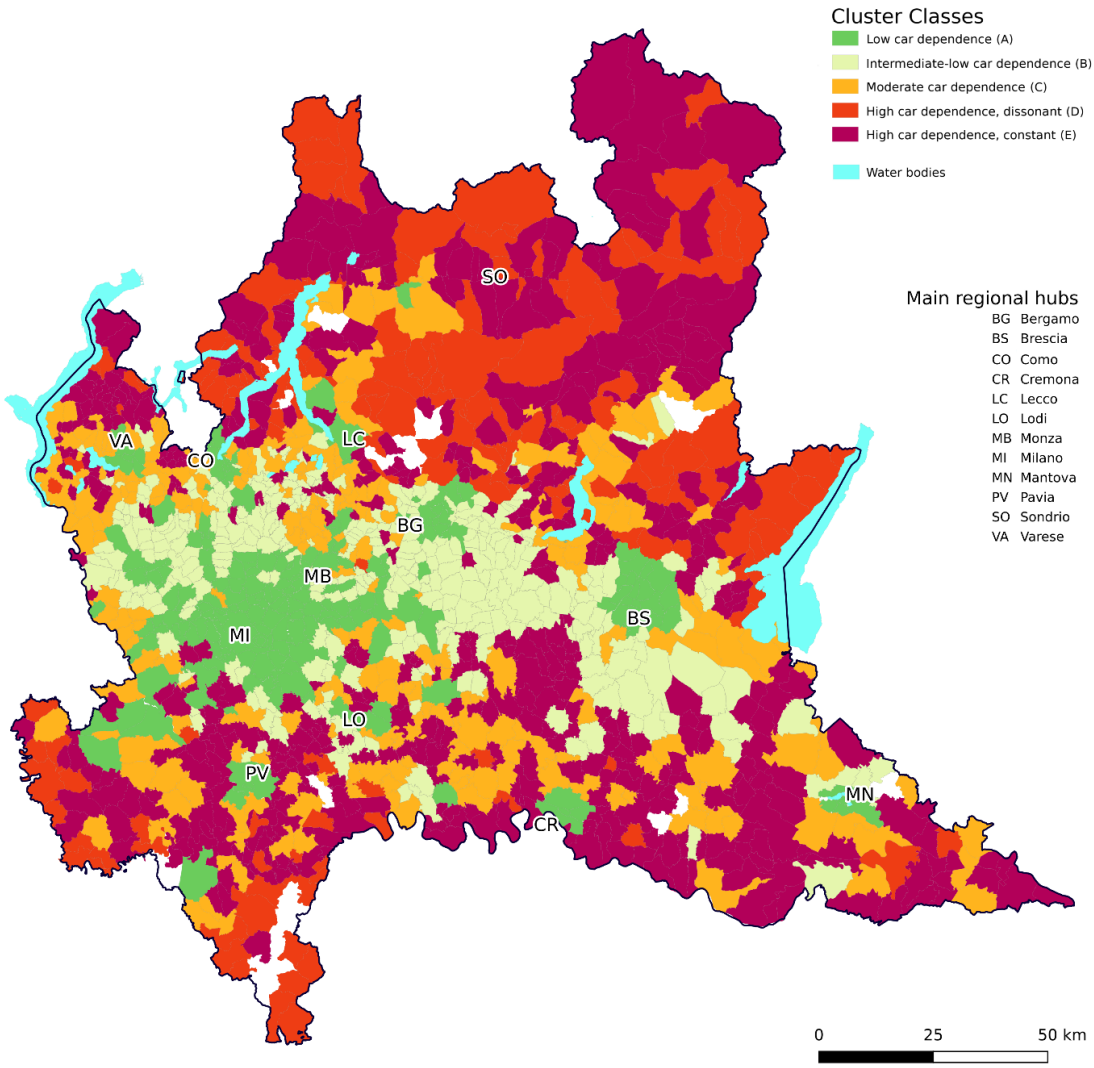

Figure 2. Division of Lombardia municipalities into spatial car dependence clusters.

By cluster analysis, these variables allow to spatially classify Lombardy's transport zones into five different groups (shown in Figure 2) which represent different dynamics of car dependence across the case study. A first cluster (A) involves low car dependence values within Milan's municipality first rings as well as the other provincial capital and main cities of the region. Cluster B, showing increasing spatial car dependence, aligns with suburban, metropolitan expansions, while cluster C, with intermediate levels of car dependence, extends to periurban areas. The latter clusters D and E, with strong car dependent dynamics, are more peripheral and less influenced by

metropolitan dynamics, mainly placed in northern mountain areas and the southern part of the region. Both rural clusters differ mostly on their dissonance index values, which is higher in cluster D, driven by less large households. This cluster also shows better proximity services and belongs to areas which match relevant touristic destinations, especially in the Alps. Cluster E, instead, has worse values for urban population density, accessibility and more fragmented urban fabrics. In both clusters, different trends in car-dependent are shaped by rural centralities (mostly at cluster D) or limited urbanity and isolated settlement patterns (more shaping cluster E). Table 1 presents the average values of causing variables for each cluster, revealing a consistent trend: as clusters' car dependence increases, density, accessibility and transport supply decrease while intersections sparsity rises.

Table 1. Cluster variables average values and standard deviation

Cluster	A	B	C	D	E
Urban Pop. density (pop/km2)	4692 (2934)	2245 (915)	1390 (572)	668 (678)	638 (371)
Accessibility Score	159,6 (235,8)	38,3 (27,9)	24,9 (20,2)	28,6 (34,0)	11,4 (10,5)
Train accessibility score	1763 (1828)	677 (573)	389 (314)	53 (77)	175 (187)
Households with over 2 persons share	0,333 (0,046)	0,414 (0,027)	0,375 (0,028)	0,301 (0,048)	0,381 (0,052)
Intersections' sparsity	4,32 (0,16)	4,48 (0,17)	4,67 (0,2)	5,05 (0,34)	5,00 (0,27)
Car dependence dissonance index	0,36 (0,22)	0,9 (0,24)	0,58 (0,2)	1,37 (0,27)	0,81 (0,28)

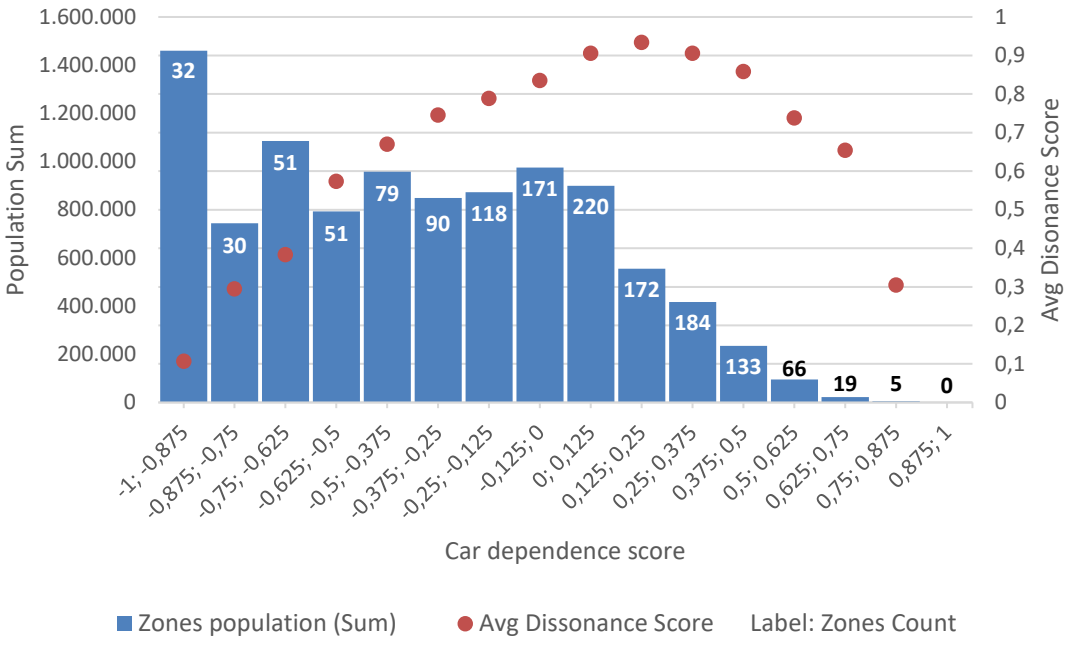

Figure 3. Population and zones' quantity distribution of comprehensive car dependence score and its average dissonant scores

The cluster analysis results show a direct connection between car dependence and the morphological conditions of the settlements. However, the dissonance results, which are higher in rural settings being mainly driven by large households values, exhibits that urban-centric explanations might not be applicable across all contexts. On the other hand, Figure 2 illustrates the population

and zones count distribution of average car dependence together with the average dissonance score of each bin. It shows lower car dependence zones gather higher population, while the dissonance is skewed towards high car dependence values. Its distribution, from the dissonance definition, would be expected to be higher in the central car dependence score values and close to zero on the extremes. This demonstrates that the more intense car dependence, the greater its diversity is. Altogether, these findings underscore the importance for territorial characteristics through nuanced, fine-grained studies, also expanding on personal attributes and views. The survey analysis serves a suitable complement, providing additional detail to further explore these factors.

Survey

The findings from the survey enable a wide exploration of the car-dependence through the key question and spatial classes of this phenomenon. As Figure 4 illustrates, there is a relationship between self-perception and spatial measure of car dependence: respondents feel themselves more car dependent in clusters with increasing spatial-based car dependence. While this association exists, it is not direct, as the heterogeneity across the responses' distribution shows: around a quarter of respondents' self-perceived car dependence does not align with the spatial category of their residential area.

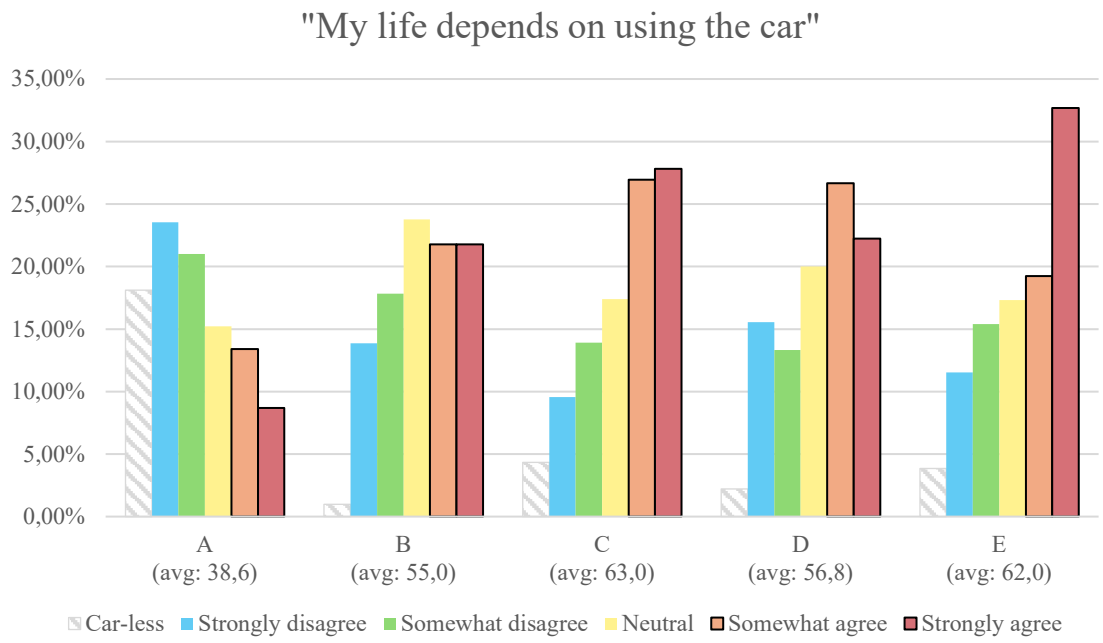

Figure 4. Distribution of survey answers to the key question ('My life depends on using the car' statement) classified by spatial car dependence clusters

Car dependence can also relate to how the residential setting is perceived to require a car to live there. The results in Figure 5 show a rise in alignment with self-perceived and spatial car dependence, as expected. However, at cluster A, it significantly changes with car dependence self-perception: it grows from 19% to 44% for individuals who identify as car dependent, which may reflect both an urban heterogeneity and a feedback loop, where individuals more attuned to car-oriented systems are also more likely to perceive and rely on such. Besides, cluster D, which encompasses traditional rural nuclei that feature denser and more compact fabrics, show less residential-setting perception of car dependence, compared to clusters B, C and E. In that case,

cluster D may connect car dependence feelings more to a lack of specific opportunities (e.g., employment, services) and the dispersion of potential destinations rather than to qualities of the urban fabric itself.

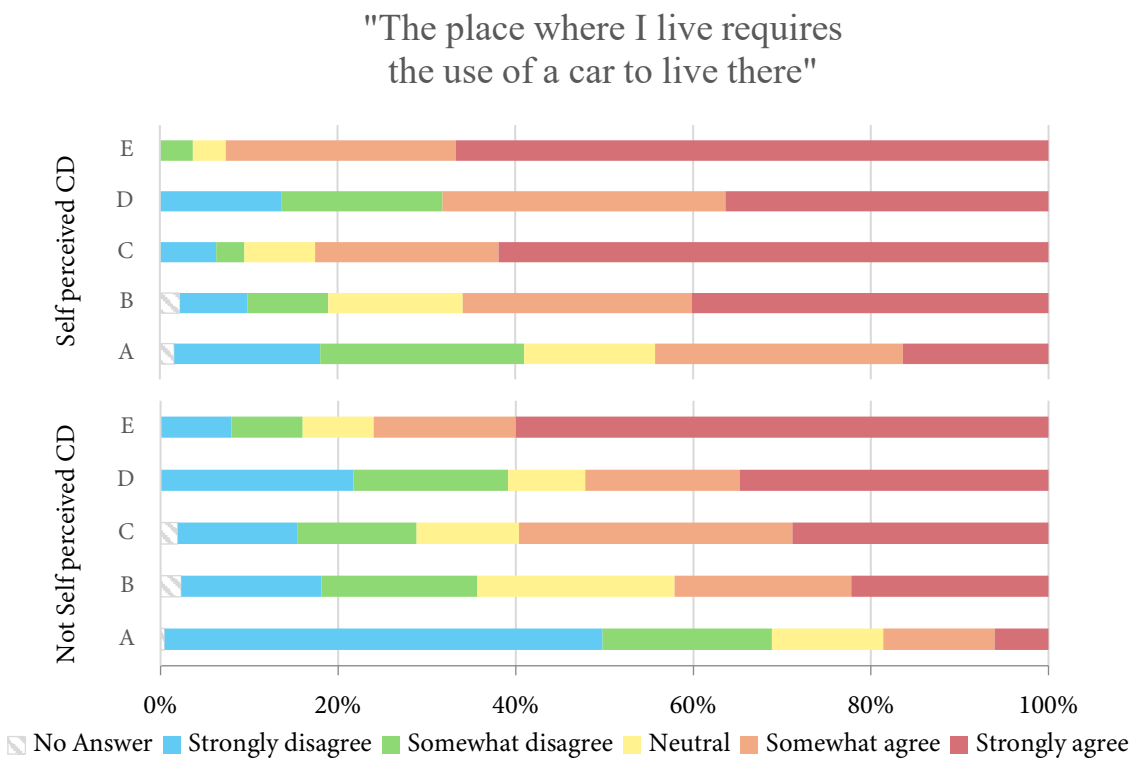

Figure 5. Distribution of responses to the question 'the place where I live requires the use of a car to live there' classified by spatial cluster and self-perceived car dependence.

Car dependence can also emerge related to fulfilling different activities. To explore this case, the survey respondents have provided their level of agreement to the statement 'Without a car, I could not...:' followed by a list of nine different activities. Figure 6 illustrates the average results for each group, showing that respondents who perceive themselves as car-dependent generally report a higher need of the car for various activities. The largest differences between who feels car dependent and who do not are observed in cluster A, likely due to its spatial and accessibility characteristics. Cluster A also exhibits the greatest disparity between self-perception car dependent groups for study and work reason (38,1 percentage points difference). This underscores the critical role of employment access as a determinant of car dependence, particularly for individuals whose workplaces are distant or involve frequent errands (e.g., home services or delivery).

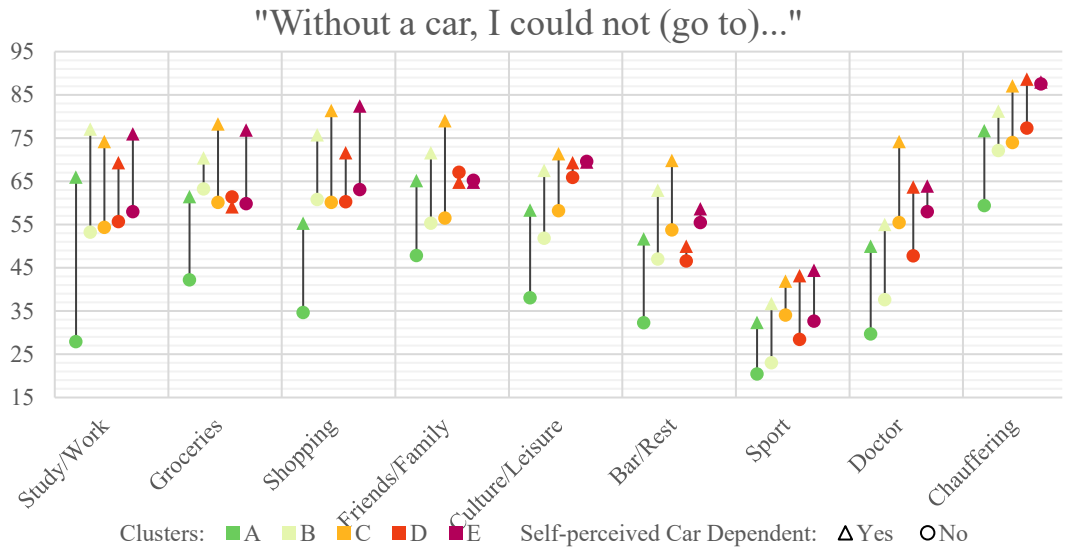

Figure 6. Average answers to the question 'Without a car, I could not…' referred to different activities and classified by spatial cluster and self-perceived car dependence.

One key insight related to car dependence is the individuals' intention to reduce it, which reflects their satisfaction with their current use of the car. This distinction was previously highlighted by Zhao (2011) and illustrated in Figure 7 for this case. It shows an inverted tendency between self-perception and spatial-based car dependence: in more metropolitan clusters A and B, the ones more willing to reduce their car use are car-dependent users, while at rural clusters D and E the ones who intend to reduce it are the ones not feeling dependent. The rest of attitudes do not show this inversion, while showing a clear difference of suburban cluster B with cluster A, being attitudinally closer to more spatially car-dependent respondents.

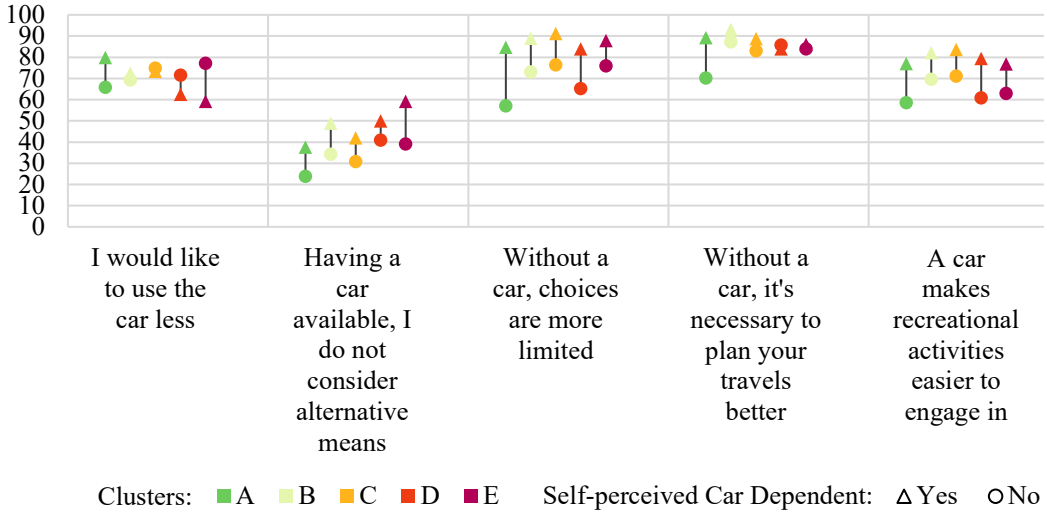

Figure 7. Average answers to car use attitudes questions classified by spatial cluster and self-perceived car dependence.

The car impacts attitudes are shown in Figure 8, showing the respondents are highly aware of the car environmental impacts, scoring lower for safety risks on vulnerable road users. However, the results show some unexpected outcomes, as some clusters show higher recognition of impacts

from self-perceived car dependent respondents. This is mainly the case for cluster B for every statement with a 10% difference, also appearing for other clusters. Such unexpected association recalls the embedded role of cars in suburban areas and the different meanings of car dependence across spatial contexts.

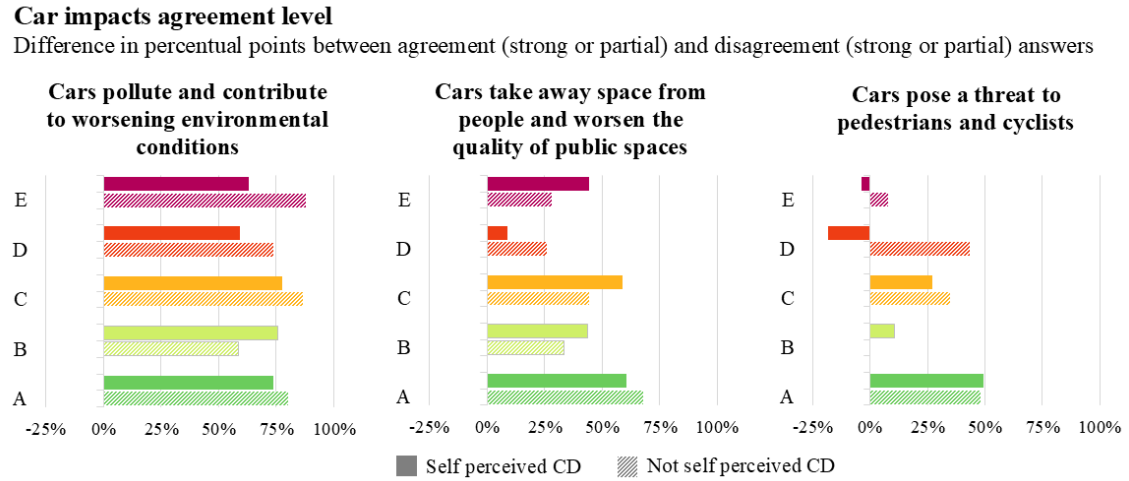

Figure 8. Agreement level to car impact statements

The survey results confirm that car dependence cannot be fully explained through spatial factors, as attitudes and perceptions add critical nuances. Findings suggest that car dependence takes on different meanings across spatial contexts: in more car-dependent clusters, individuals who do not feel dependent may still be constrained to drive, with their self-identification reflecting detachment rather than true independence from cars. Notably, in highly car-dependent spaces, even those who do not identify as car-dependent report a greater reliance on cars while expressing a desire to reduce usage. These observations raise critical questions: is the car's role in these contexts so ingrained that explicit reliance on cars is modulated? Feeling car dependent stems from an inherently pro-car attitude or develops from spatial setting characteristics? While this study cannot resolve these questions, they point to the need for further research.

4. CONCLUSIONS

The results show the interplay between spatial characteristics and individual conditions. The findings offer insights that could inform targeted policies to address car dependence in specific contexts, from increasing transport alternatives or proximity-based services to challenging cultural norms. Overall, the results suggest that reducing car dependence requires a multi-faceted approach, addressing both physical space and cultural narratives.

Further research may require advanced statistical tools (e.g., structural equations modelling) or exploring user practices through qualitative approaches, such as interviews and focus groups. This latter approach provide deeper insights into user values despite limited scalability, being increasingly applied in car dependence studies (Mattioli et al., 2016; Selzer & Lanzendorf, 2022; van Eenoo & Boussauw, 2023). Additionally, standardized opinion-based questions in transport surveys would be a significant advancement to better integrate individual perspectives into regional car dependence studies.

This study contributes to broader discussions on reimagining mobility systems, providing deeper understanding of car dependence functioning across different territorial contexts. While car dependence sustains in a far-reaching and resilient automobility system (Urry, 2004), context-sensitive strategies represent an actionable way to mitigate it in a scalable manner. Integrating car dependence spatial and individual perspectives, as this research proposes, provides a way to bridge gaps and develop more accessible and fairer transport systems in the context of current mobility transitions.

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