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Mobility of care in daily trip chaining: an exploratory analysis in Turin, Italy

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ABSTRACT

The Mobility of Care (MoC) has been gaining increasing interest in transportation research. Previous studies have contributed to the identification of some recurring characteristics of the MoC, like its prevalence in daily mobility, gendered role, tendency to imply short and frequent trips, inclination to be performed by car or by walking, and its tendency to be organised in chains. While many of these aspects are explicitly analysed, the extent and manner in which the MoC is chained on daily basis is still under-observed. This study aims to fill this gap, by investigating the role of the MoC in daily trip chaining through an exploratory analysis of the daily routine of a sample of Turin (Italy). To this end, we first establish a set of *activity, trip-segment, trip-chain and tour* categories based on previous literature. Then, we define an approach to trip-chaining analysis focused on the MoC. This includes descriptive statistics and Multiple Correspondence Analyses to reveal potential relationships between activity-travel patterns and sociodemographic, geographic and travel traits. Results reveal that over 40% of daily tours include at least one care activity. About 65% of these have a simple primary conformation (home-care-home), 25% show a complex trip-chaining pattern (e.g. home-work-care-home), while 10% are simple secondary tours performed before or after another home-based tour (e.g. home-work-home-care-home). Simple tours are typically associated with females and unemployed older people living in small households, people residing in the belt area, and people mainly travelling by transit or car. Complex tours with chains are instead especially linked to employed (male) adults in larger households, people living in the city centre and urban area, and people mostly traveling by car. These results provide novel details on how the MoC is chained within daily routines, enriching our understanding of its potential influence on daily activity-travel patterns.

1. Introduction

"Care" may be defined as the unpaid labour needed to sustain households and communities (Daly and León, 2022; Daly & Lewis, 2000). Despite its key social role, care has long been undervalued due to a dominant capitalist viewpoint that tends to place economic interests first (Collective et al., 2020). Despite that, several studies have focused on care in the last 30 years. For instance, gender studies discuss the disproportionate assignment of care duties to women and consequent effects on their participation in the workforce (Lynch et al., 2021; Tronto, 1993). Welfare-state studies examine the role of social care systems in modern societies (e.g. Daly & León, 2022). Even mobility and spatial-planning studies address care, e.g. by discussing how it generates mobility burdens for women, with implications for their wellbeing and social equity (e.g. Castañeda et al., 2024; Schwanen, 2007). In this context, the term "Mobility of Care" (MoC) was introduced by Sánchez de Madariaga (2013) to indicate all the activities and trips made by adults for the purpose of care labour. As such, the MoC typically includes trips for escorting or visiting others in need, grocery shopping, and household-serving errands.[1] As emerged from previous studies, the MoC represents an important part of adults' daily life, but it is still largely under-considered in transport planning. For instance, the MoC

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[1] We use three terms in this study: (1) "Mobility of Care (MoC)" indicates the overall phenomenon, i.e. the set of activities and trips made for the purpose of care labor; (2) "Care activities" indicate the daily activities performed at given locations for the purpose of care labor; (3) "Care trips" indicate the daily performed trips having a care activity as origin and/or destination.

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encompasses ca 30 % of all the daily trips made by adults, which is a share roughly as large as the one of work commutes (De Madariaga & Zucchini, 2019; Passman et al., 2024; Ravensbergen et al., 2023; Soto-Villagrán, 2024). Nevertheless, mobility surveys often underrepresent the MoC, e.g. by labelling it under misleading purposes or by skipping it if care trips are very short (De Madariaga, 2013). These issues contribute to the ancillary role of the MoC in transport policies, which mostly address work and school commutes (Smith et al., 2025).

These issues have raised the interest around the MoC, with several studies investigating its characteristics and needs. For example, works like Chizzali et al. (2025), Ravensbergen et al. (2020), or Sersli et al. (2020) apply qualitative approaches like the Social Practice Theory to reveal practical needs and social norms underpinning the MoC. Instead, studies such as Chizzali et al. (2026), Murillo-Munar et al. (2023), Passman et al. (2024), Ravensbergen et al. (2023) or Soto-Villagrán (2024) use travel-diary surveys to quantitatively examine who performs the MoC (e.g. gender, age, income) and how (e.g. length, timing, travel mode). Yet, many scholars investigate the connection between gender and the MoC, revealing how this plays a key role in gender mobility disparities (e.g. Gonzalez-Alvo & Czytajlo, 2022; Hernández & de los Santos, 2020; Porath & Galilea, 2025; Scheiner & Holz-Rau, 2017). Altogether, these studies have contributed to the identification of some recurring characteristics of the MoC. For instance, care trips are (i) predominantly made by women; (ii) tend to be frequent, short and spatially scattered; (iii) often imply carrying people and/or items; (iv) are mostly performed by private car or by walking if distances are short; and (v) are often chained with each other and with other trip purposes to optimise schedules. While many of these aspects are explicitly explored in the studies mentioned above, analytical evidence about the role of the MoC in daily trip chaining is still limited (see Section 2). Specifically, studies that systematically analyse the extent and manner in which the MoC is chained on daily basis are rare, with exceptions like Porath and Galilea (2025) and Scheiner and Holz-Rau (2017).

To cover this gap, this study addresses two intertwined questions: (a) *how is the MoC embedded within the trip chains of urban dwellers?* and (b) *how does such embedment varies across sociodemographic, geographic and travel factors?* To answer these questions, we deploy a travel-diary dataset collected from a representative sample in the Turin metropolitan area (Italy) and we analyse it in four steps. (1) We establish activity, trip-segment and trip-chaining categories based on previous literature so as to organise the complexity of trip chains into standard patterns. (2) We recognise trip-chaining categories within our sample and analyse the role played by the MoC descriptively. (3) We perform Multiple Correspondence Analyses (MCA) to investigate associations between MoC trip-chaining patterns and sociodemographic, geographic and travel traits of sample members. (4) We discuss our results in relation to literature and reflect on their potential policy implications.

This study is relevant for both policymaking and scientific debate. As for policymaking, past studies have proved that the way we chain daily trips highly influences modal choices (Krygsman et al., 2007; Yang et al., 2016; Ye et al., 2007). In detail, complex trip chains tend to foster private car (Hensher & Reyes, 2000; Primerano et al., 2008; Schneider et al., 2021). Therefore, understanding how the MoC is included within daily trip chains is a first step to understand its influence on broader daily mobility choices. As for the scientific debate, previous MoC studies rarely addressed trip chaining systematically, and the few doing so often limited to distinguish between chained and not-chained care trips and mostly focused on gender roles (e.g. Porath & Galilea, 2025). We attempt to move a step forward by defining more specific trip-chaining categories and observing the role played by the MoC; and by exploring associations between MoC trip-chaining patterns and sociodemographic, geographic and travel traits.

The rest of the paper is organised as follows. Section 2 reviews the main approaches to trip-chaining categorisation and focuses on the studies already exploring trip chaining in the MoC framework. Section 3 describes our approach to trip-chaining categorisation and MoC analysis. Section 4 presents the results of our approach for the case study of the Turin metropolitan area. Section 5 discusses our results and the limitations of our work, while Section 6 concludes the study by highlighting future research directions.

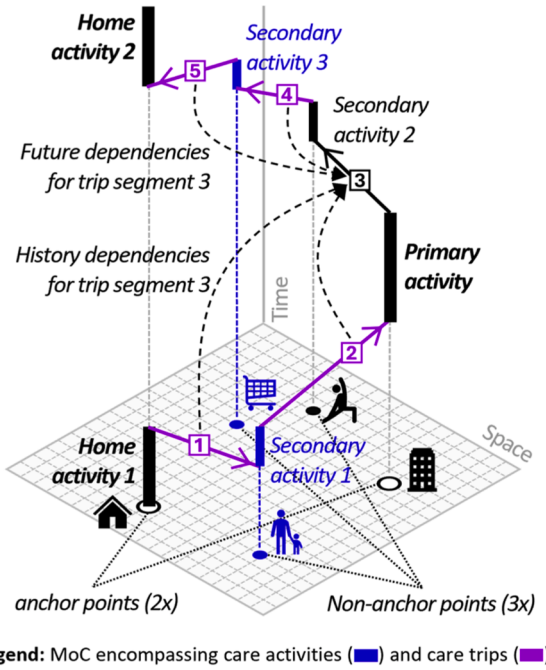

Fig. 1. Exemplificative daily routine representing the concept of trip chaining and the MoC.

2. Literature review

2.1. Trip chaining

According to Chen and Susilo (2021), there is not a standard definition of a trip chain, although common concepts exist (e.g. Adler & Ben-Akiva, 1979; Hensher & Reyes, 2000; Primerano et al., 2008; Stopher, 1992; Strathman & Dueker, 1995). In general, a "trip chain" comprises a series of "trip segments" that start and end at so-called "anchor points" while connecting "non-anchor points". If a chain starts and ends at the same anchor point, this is called "tour". Anchor points are the main nodes in the daily routine of a person (e.g. home and workplace), where the longest and most space-time constrained activities take place, called "home" (H) and "primary" (P) activities Primerano et al., 2008). Conversely, non-anchor points are additional nodes (e.g. grocery store and gym), where shorter and more space-time flexible activities occur, called "secondary" (S) by Primerano et al. (2008) .[2] Fig. 1 exemplifies this concept with a routine made up of two home activities, one primary activity, three secondary activities, five trip segments (1–5), two trip chains (1–2 and 3–5), and one home-based tour

[2] The distinction between "home", "primary" and "secondary" activities by Primerano et al. (2008) partially overlaps with the definition of "mandatory", "maintenance" and "discretionary" activities by Ortúzar and Willumsen (2024). Mandatory activities must be performed on regular basis (e.g. work, education) and offer limited flexibility in terms of location and duration; hence they overlap with primary activities. Maintenance activities must be performed regularly to maintain other activities (e.g. sleeping, eating, grocery shopping) but offer higher space-time flexibility; hence they overlap with home and secondary activities subject to higher obligation (e.g. escorting kids to school). Discretionary activities are essential for life (e.g. social, recreational, entertainment) but are flexible and not space-time constrained; hence they overlap with flexible secondary activities (e.g. dining at restaurant).

(1–5). Moreover, Fig. 1 highlights the MoC concept within such routine, with two care activities highlighted in blue (secondary activities 1 and 3) and four care trips highlighted in purple (trips 1, 2, 4 and 5).

This trip-chaining concept shows that daily trip segments should not be studies individually, but including their reciprocal influences (Adler & Ben-Akiva, 1979; Kitamura, 1984; Ortúzar & Willumsen, 2024). In particular, history and future dependencies are crucial (Chen & Susilo, 2021). The former indicates that a trip choice made in the present is influenced by choices made in the past (e.g. choosing to use the car in trip segments 1–2 implies using it again for the return trip segment 3; Fig. 1). The latter dependency indicates that a trip choice made in the present is influenced by the choices planned for the future (e.g. the need to use the car for multiple stops along trip segments 4–5 implies the choice to use the car also for trip segment 3; Fig. 1).

2.2. Trip-chaining categorisation

To examine trip chaining, several studies define categorisations approaches organising the wide array of trip-chaining possibilities based on diverse criteria. Four main approaches can be mentioned (Table 1):

1 ***Primary, secondary, sub tours:*** In the context of Activity-Based Models (ABM), related literature and approaches summarised inter alia by Ortúzar and Willumsen (2024) or Castiglione et al. (2015) categorise tours based on the hierarchical order of primary and secondary activities. This approach generates three main cases. "Primary tours" start and end at home, have one main destination that is their primary activity, and may include extra secondary activities chained before and/or after the primary activity (A, Table 1). "Subtours" occur within primary tours since the start and end at the location of the primary activity and have one (or more) secondary activity(es) as destination (B, Table 1). "Secondary tours" start and end at home as primary ones, but they have exclusively one (or more) secondary activity(es) as destination (C, Table 1).

2 ***Tours with chains before, during, after given activities*:** Goulias and Kitamura (1991), McGuckin and Murakami (1999), Primerano et al. (2008), or Srinivasan (2000) categorise tours based on sequential order with which secondary activities are chained with primary and home ones. This approach generates four main cases: tours where the secondary activities are performed "during" the home activity (D, Table 1), or "during" the primary activity (E, Table 1); and tours where the secondary activities are performed on the way between a home and primary activity, either "before" the primary one (F, Table 1) or "after" it (G, Table 1).

3 ***Single, multi tours*:** Kondo and Kitamura (1987) and then Nishii et al. (1988) categorise tours based on the number of home-based tours performed within a daily routine. This approach generates two main cases: daily routines made up of a "single tour" that may incorporate secondary activities within the basic home–primary–home pattern (H, Table 1); and daily routines made up of "multi tours", i.e. at least two tours performed in sequence where secondary activities occur within a home-based tour that precedes or follows the home–primary–home tour (I, Table 1).

4 ***Simple, complex, very complex tours*:**Holzapfel (1986), Primerano et al. (2008), Schneider et al. (2021), Strathman et al. (1994) or Strathman and Dueker (1995) categorise tours based on the number of activities and trips included in a single tour. This approach generates three main cases: "simple tours" comprising two trip segments within the same tour (J, Table 1); "complex tours" including three trip segments within the same tour (K, Table 1); and "very complex tours" including more than three trip segments within the same tour (L, Table 1).

Table 1
Main trip-chaining categorisation approaches derived from literature.

Approaches	Logic	Categories	Exemplificative layouts[1]	Sample references
(1) *Primary, secondary, sub tours*	Hierarchical order of primary and secondary activities	(A) Primary tour	H→P→ H	Castiglione et al. (2015), Ortúzar and Willumsen (2024)
		(B) Subtour	P→S→P	
		(C) Secondary tour	H→S→H	
(2) *Tours with chains before, during, after given activities*	Sequential order of primary and secondary activities	(D) Chain during home	H→S→H	Goulias and Kitamura (1991), McGuckin and Murakami (1999), Primerano et al. (2008), Srinivasan (2000)
		(E) Chain during primary	P→S→P	
		(F) Chain before primary	H→S→P→H	
		(G) Chain after primary	H→P→S→H	
(3) *Single, multi tours*	Number of tours within a daily routine	(H) Single tour	H→S→P→H	Kondo and Kitamura (1987), Nishii et al. (1988)
		(I) Multi tour	H→S→H→P→H	
(4) *Simple, complex, very complex tours*	Number of trip segments within a single tour	(J) Simple tour	H→P/S→H	Holzapfel (1986), Primerano et al. (2008), Schneider et al. (2021), Strathman and Dueker (1995)
		(K) Complex tour	H→P/S→P/S→H	
		(L) Very complex tour	H→P/S→P/S→P/S→H	

Notes:
[1] H: Home activity; P: Primary activity; S: Secondary activity (see Section 2.1 for the definition of these three activity types). Consider that these layouts are exemplificative and not exhaustive of all the possible combinations fitting the listed categories.

As visible in the exemplificative layouts of Table 1, these approaches have similarities and differences. Both approaches (1) and (2) focus on the role of and interplay between primary and secondary activities, although following different logics. Approach (1) aims to establish the hierarchy between types of tours, with primary tours representing the backbone of a daily routine, subtours occurring within primary tours, and secondary tours occurring before or after primary ones. Approach (2) focuses instead on the ordering of different types of activities, with particular attention to when secondary activities are performed respect to primary ones (e.g. before, after, both). Also approaches (1) and (3) are complementary. The primary and secondary tours defined by approach (1) typically combine in the daily routine of an individual, so shaping a multi tour as defined by approach (3). Conversely, approach (4) follows a different logic compared to the others, as it only considers the number of activities and trips segments, regardless of their role of primary/secondary activities, and their sequential order.

Drawing on these four approaches, we define our own categories of *activities, trip segments*, and *trip chains and tours* in Section 3.1, which we use as basis for our analyses of the MoC. In particular, our tour categorisation mainly relies on the distinction between primary, secondary and sub tours proposed by approach (1). However, it integrates also elements from approaches (3) and (4).

2.3. MoC in trip chaining

Although research on the MoC has been growing, only some studies explicitly address the role of the MoC in daily trip chaining (we identified 13 papers). They apply quantitative or qualitative approaches to investigate trip chaining in the MoC context, and they derive consequent

Table 2
Highlights from the literature on role of the MoC in daily trip chaining.

MoC in daily trip chaining: highlights from literature		Sample references
Analytical approach	Quantitative analysis of travel or time-use surveys to analyse the presence and complexity of care activities and trips within daily trip chains	Hernández and de los Santos (2020), Li and Widener (2025), Porath and Galilea (2025), Ravensbergen et al. (2023), Scheiner and Holz-Rau (2017)
	Quantitative analysis of transit fare card transactions to address two travel patterns: origin-care activity-destination (chained); origin-care activity (not chained)	Abdelhalim et al. (2024), Shuman et al. (2023)
	Qualitative analysis of in-depth semistructured interviews to understand how and why people undertake care activities and trips, including the topic of trip chaining	Chizzali et al. (2025), Ravensbergen et al. (2020)
	Critical policy review framework analysis to understand how policies consider care trips, including their mention of trip chaining or multiple destination travels	Smith et al. (2025)
Main findings	Women engage more in trip chaining than men, by making more chained trips (often including care trips), which are usually more complex and encompass diverse purposes	Abdelhalim et al. (2024), De Madariaga and Zucchini (2019), Porath and Galilea (2025), Ravensbergen et al. (2023), Scheiner and Holz-Rau (2017)
	Chained care trips register higher use of car than non-chained care trips due to car flexibility, possibility to carry items, and higher routing freedom	Chizzali et al. (2025), De Madariaga and Zucchini (2019), Porath and Galilea (2025), Ravensbergen et al. (2023)
	A relevant share of care trips is chained with work trips, with grocery shopping typically on the way back home from work, while escorting typically on the way to work	Chizzali et al. (2025), Porath and Galilea, (2025), Ravensbergen et al. (2023), 2020)
	Cycling and walking have pros/cons for chaining of care trips, as cycling eases complex chains but is unpractical to carry items while walking is low diffused in chains	Ravensbergen et al. (2023), 2020)
	Transit policies may foster sustainable chaining of care trips, e.g. by locating care amenities in the nearby of transit stops and setting convenient transit fares for chained trips	Ravensbergen et al. (2023), Smith et al. (2025)
	The number of children in the household, being single parents, and having an immigrant status tend to increase the burden of care activities and the chaining of care trips	Porath and Galilea (2025)
	Employed individuals and people living in urban cores tend to make more frequent chaining of care trips in their daily routine regardless of gender	Scheiner and Holz-Rau (2017)
	Frequent (female) small-store shoppers tend to make more chaining of care trips than large-store shoppers, who mostly make non-chained trips with lower frequency	Li and Widener (2025)

findings about the relation between the MoC and trip chaining (Table 2). Altogether, these studies show some research gaps that our work aims to address:

1 Most of the studies listed in Table 2 include some reflections on the MoC and trip chaining, but do not have the latter as their main analytical focus (e.g. De Madariaga & Zucchini, 2019; Ravensbergen et al., 2023; Smith et al., 2025). Our study focuses explicitly and mostly of the role of the MoC in daily trip chaining, thus dedicating it a deeper and specific attention.
2 Various studies deploy qualitative approaches like theoretical discussions, interviews, or policy analysis and derive insights regarding the role of the MoC in daily trip chaining (e.g. Chizzali et al., 2025; De Madariaga, 2013; Ravensbergen et al., 2020). However, they do not quantitatively analyse mobility patterns. Our study adopts instead a quantitative approach based on travel diaries and trip-chaining categories, thus providing more quantitative insights.
3 Most of the studies making quantitative analyses of travel patterns tend to use very simplified categories of trip chains (e.g. Abdelhalim et al., 2024; Li & Widener, 2025; Ravensbergen et al., 2023; Shuman et al., 2023). For instance, Li and Widener (2025) and Ravensbergen et al. (2023) distinguish only between chained and non-chained care trips; while Abdelhalim et al. (2024) and Shuman et al. (2023) focus on two cases: origin-care activity-destination, and origin-care activity. Our study considers a broader array of trip-chaining categories (based on the relevant literature summarised in Section 2.2) to gain a deeper understanding of the MoC role.
4 Only two studies adopt more articulated trip-chaining approaches in line with our study. Porath and Galilea (2025) considers the number of trip segments within the chains to show the complexity of chains involving the MoC. Schneider et al. (2021) distinguishes between simple and complex trip chains, in line with categorisations mentioned above. However, they mostly focus on gender roles and overlook interactions between the MoC and other activity/trip purposes in daily trip chaining. This is instead the approach of our analyses, where the role of the MoC in trip chains is observed in relation with the other typical purposes shaping daily life.

Based on these research gaps and the trip-chaining categorisation approaches summarised in Section 2.2, Section 3 describes our methodology in detail, while Section 4 presents its case-study application.

3. Methodology

Drawing on Section 2.2, we first define a trip-chain classification that we use to understand how the MoC is intertwined with the general mobility practices of individuals (Section 3.1). Then, we lay out the methodology applied to single out the MoC in such different clusters of trip chains (Section 3.2).

3.1. Trip-chaining categories

At the outset, we define categories of *activities* (Section 3.1.1), *trip segments* (Section 3.1.2), *trip chains and tours* (Section 3.1.3), belonging to the daily routine of a person.

3.1.1. Activities

Activities are tasks performed at given location and time, with a given purpose. Operations made at fixed locations exclusively for the purpose of intermodality, unimodal transfer, or transit access/egress (e.g. parking the car at the station to get on the train, transferring from one bus to another, or walking from home to the transit stop) are not considered activities, but parts of trip segments.

Following our literature review, we set three activity categories (Table 3): *Home* (H), *Primary* (P), and *Secondary* (S). H refers to activities carried out at the place where one stays overnight. Each daily routine begins with an H activity from 00:00 until the first time one leaves; and it ends with another H activity from the last arrival until 23:59. Further H activities may occur during the day, anytime one stays at the overnight place (e.g. in the afternoon after morning work). Drawing on Ortúzar and Willumsen (2024), H encompasses maintenance activities

Table 3
Activity categories defined in this study.

Activity categories	Definition criteria	Examples
Home (H)	• Place where one stays overnight • From 00:00 until the first time going out, from the last time coming back until 23:59, and anytime in between during the rest of the day	• Homestay from 00:00 until the first time going out for work at 7:00 • Homestay from 14:00 to 16:00 after morning work and before afternoon duties
Primary (P)	• Given place but the overnight place (H) • Longest duration except for H, possibly broken down into multiple time periods by home or secondary activities (H, S) occurring in between	• Working at the office from 8:00 until 17:00 • Working at the office from 8:00 to 12:00 and from 13:00 to 17:00 with a lunch break at the restaurant in between
Secondary (S)	• Given place but the overnight place (H) and primary-activity place (P) • Activities with shorter duration than H and P, occurring anytime between first and last H activities	• Dropping off kids at school for 10 min on the way from home to the office • Grocery shopping for 30 min on the way back home from the office

Table 4
Trip-segment categories defined in this study.

Trip-segment categories	Examples
Home to Primary (H→P)	• Trip from home to the office in the morning • Trip from home to the office after lunch break
Primary to Home (P→H)	• Trip back home from the office in the afternoon • Trip back home from the office before lunch break
Home to Secondary (H→S)	• Trip from home to the school of kids in the morning • Trip from home to the grocery store in the afternoon
Secondary to Home (S→H)	• Trip from the school of kids back home in the morning • Trip from the grocery store back home in the afternoon
Primary to Secondary (P→S)	• Trip from the office to the restaurant during lunch break • Trip from the office to the grocery store in the afternoon
Secondary to Primary (S→P)	• Trip from the school of kids to the office in the morning • Trip from the restaurant back to the office during lunch break
Secondary to Secondary (S→S)	• Trip from the school of kids to the post office in the morning on the way to the office • Trip from the grocery store to the pharmacy in the afternoon on the way back home

like sleeping, eating at home, or resting. P is the longest activity performed on daily basis by an individual at a given out-of-home location, excluding H. P may be broken down into multiple time periods by activities occurring in between (e.g. working at the office in the morning and afternoon with a lunch break at the restaurant in between). Based on Ortúzar and Willumsen (2024), P encompasses mandatory activities like work and school (for workers and students), or maintenance activities such as a medical appointment (for groups like pensioners or homemakers). S comprises all the other daily activities but H and P, occurring at given out-of-home locations. Always referring to Ortúzar and Willumsen (2024), S includes discretionary activities occurring at flexible space and time, and out-of-home maintenance activities not classified as P.

3.1.2. Trip segments

Trip segments are single travels connecting two consecutive activities occurring at different locations. The purpose of each segment is defined by the purposes of its origin and destination activities. Moreover, each segment may include intermodal transfers (e.g. park and ride), unimodal transfers (e.g. bus-bus), or access and egress legs (e.g. walk to/from the transit stop), which are not activities. Thus, a trip segment can be made up of several trip legs, or stages, each one involving the use of a different transport mean, including walking (Ortúzar & Willumsen, 2024).

Following our definition of H, P and S activities, we set seven trip-segment categories (Table 4). They include trip segments connecting H and P (in both directions), H and S (in both directions), P and S (in both directions), and linking two different consecutive S. P-P trip segments are excluded, since only one P activity at a given location is allowed on daily basis, and it can be broken down only by H or S activities occurring in between. For workers and students, H-P trip segments typically reflect trips from home to the workplace or school and back. For other subgroups, the purpose of such segments tends to vary more broadly depending on the purpose of the longest daily out-of-home activity appointed as P. H-S segments typically represent instead trips from home to maintenance or discretionary activities and back. Finally, P-S and S-S segments reflect diverse combinations of primary and secondary activities.

3.1.3. Trip chains and tours

Trip chains are sequences of at least two consecutive trip segments always starting and ending at home-activity (H) and/or primary-activity (P) locations (i.e. anchor points). If the origin and destination of a trip chain is the same anchor point, this is a *tour*. Therefore, H-based or P-based tours may occur, a tour may include one or more trip chains, and a daily routine may include one or more tours.

To make our categorisation operational, we focus exclusively on single H-based tours, assuming that these tours may combine in sequence within a day generating multi tours (in line with approach (3) in Table 1; Kondo & Kitamura, 1987; Nishii et al., 1988). To define our categories of single tours, we use the approaches (1), (2) and (4) in Table 1, combining them at different tiers (see Table 5). In detail:

- At the highest tier, we distinguish between "primary tours without subtours", "primary tours with subtours", and "secondary tours" following approach (1) in Table 1 (Castiglione et al., 2015; Ortúzar & Willumsen, 2024). Primary tours start and end at H, are headed to P, and may include one or more S. Subtours occur only within primary tours since they start and end at P, and connect one or more S. Finally, secondary tours start and end at H like primary tours, but they do not include any P, and chain at least one S.
- At the middle tier, we distinguish between "simple" and "complex" tours following approach (4) in Table 1 (e.g. Primerano et al., 2008). Simple tours are made up of two segments (outward and return from H). Complex tours comprise three or more segments (thus at least one chain). This distinction is relevant since the higher the number of segments in a tour, the higher the tendency of that tour to be performed by car based on literature (Primerano et al., 2008; Schneider et al., 2021).
- At the lowest tier, we differentiate tours based on their sequential order of primary and secondary activities, following approach (2) in Table 1 (e.g. Goulias & Kitamura, 1991). Accordingly, we distinguish when S or P activities are performed "during H", as well as when S activities occur "before P", "after P" or "before and after P".

The combination of these three tiers leads to 10 categories (C1–10; Table 5). As example, Fig. 2 shows a hypothetical daily routine with one primary tour (complex with S chained before P), a secondary tour (simple with one S), and one subtour nested within the primary one. Reasonably, we must acknowledge that these 10 categories cannot realistically cover any kind of real-world trip-chaining patterns. However, similarly to previous categorisations like Primerano et al. (2008) or Schneider et al. (2021), our attempt is to achieve a suitable trade-off between realism and operability.

3.2. Trip-chaining analysis

Drawing on the categories presented above, we define an approach to explore the role of the MoC in daily *activities, trip segments, trip chains*

Table 5
Trip-chain categories defined in this study.

Trip-chaining categories			Description	Layouts[a]
Highest tier Approach (1) in Table 1	Middle tier Approach (4) in Table 1	Lowest tier Approach (2) in Table 1		
Primary tour without subtour	Simple	Chained P during H (C1)	It starts and ends at H, is headed to P, and has only one outbound and one return trip to and from P	H→P→H
	Complex	Chained S before P (C2)	It starts and ends at H, is headed to P, and has at least one stop in S during the outbound trip to P	H→{S}→P→H
		Chained S after P (C3)	It starts and ends at H, is headed to P, and has at least one stop in S during the return trip from P	H→P→{S}→H
		Chained S before & after P (C4)	It starts and ends at H, is headed to P, and has at least one stop in S during the outbound trip to P and at least another one during the return trip from P	H→{S}→P→{S}→H
Primary tour with subtour	Complex	Chained P during H (C5)	It starts and ends at H, is headed to P, has one outbound and one return trip to and from P, and has an extra stop during P	H→[P]→H
		Chained S before P (C6)	It starts and ends at H, is headed to P, has at least one stop in S during the outbound trip to P, and has an extra stop during P	H→{S}→[P]→H
		Chained S after P (C7)	It starts and ends at H, is headed to P, has at least one stop in S during the return trip from P, and has an extra stop during P	H→[P]→{S}→H
		Chained S before & after P (C8)	It starts and ends at H, is headed to P, has at least one stop in S during the outbound trip to P and at least another one during the return trip from P, and has an extra stop during P	H→{S}→[P]→{S}→H
Secondary tour	Simple	Chained S during H (C9)	It starts and ends at H, is headed to S (no P in the tour), and has only one outbound and one return trip to and from S	H→S→H
	Complex	Chained S during H (C10)	It starts and ends at H, is headed to multiple S (no P in the tour), has one outbound and one return trip to and from S, and trips in between	H→{S→S}→H

Notes:
[a] **{S}:** At least one S activity is included in that part of the tour; **{S→S}:** At least two consecutive S activities are included in that part of the tour; **[P] :** Subtour that starts and ends at P and is headed to at least one S activity, i.e. layout P→{S}→P.

and tours. This approach relies on descriptive analyses and Multiple Correspondence Analyses (MCA). Although this technique cannot deeply capture decision-dependent structures of daily travel (see limitations described in Section 5.3), it is quite effective to uncover the intertwined relationships among categories of several different nominal variables. Therefore, MCA seems a valid tool to exploratorily investigate the role of the MoC in daily trip chaining, which is the scope of this work. Moreover, similar descriptive non-modelling approaches are used in various MoC studies (e.g. Li & Widener, 2025; Porath & Galilea, 2025; Ravensbergen et al., 2023), allowing easier comparability of findings.

***Activities*:**

- We cluster activities reported by the sample into five main *purposes*: "work", "school", "care", "leisure", and "home". These were introduced by De Madariaga (2013) and applied in e.g. De Madariaga and Zucchini (2019). While work and school are self-explaining, care and leisure need clarification. Care regards maintenance activities (Ortúzar & Willumsen, 2024) for the care of others and household upkeep. It includes escorting individuals in need (typically due at given place and time); visiting others in need (typically due at given place but possibly flexible in time); grocery shopping for household needs (typically flexible in space but due with given frequency); household-serving errands to e.g. pharmacy, healthcare facility, post office (typically variable in space and frequency). Conversely, leisure refers to discretionary activities (Ortúzar & Willumsen, 2024) to enjoy free time, usually without obligation and space-time constrains (e.g. sport, restaurant, shopping, or visiting for leisure). This distinction of activity purposes highlights the frequency of care activities over the routines of the sample.
- In combination with the five purposes above, we observe the activities performed by the sample also based on the three activity *categories* defined in Section 3.1 for the goal of trip-chaining analysis, namely home (H), primary (P), and secondary (S) activities. The cross-observation of purposes and categories highlights how frequently care activities (as well as work, school and leisure ones) are labelled as P or S depending on their role in daily tours (e.g. being the longest activity performed at the same anchor point daily, or being a supplementary daily activity).
- Finally, we perform a MCA[3] to visualise connections among the care activities classified as P or S, and four sociodemographic traits that are supposed to play a role in the MoC: gender (male, female); age class (18–24, 25–44, 45–64, 65+); employment status (employed, unemployed but active, unemployed not active); household size (1, 2, 3, 4+ members). We focus on these four variable given their relevance in past MoC studies such as De Madariaga and Zucchini (2019), Passman et al. (2024), Ravensbergen et al. (2023). Furthermore, to describe the potential association between care activities, travel modes and geographical factors, we consider two additional variables at individual level: neighbourhood type of residence (city centre, urban area, belt area; see Section 4.1.1. and Fig. 3)[4]; and main mode of daily travel (car, public transport, active modes).

***Trip segments*:**

- Similarly to activities, we organise trip segments based on the same five *purposes* defined above, which in this case determine the origin and destination purposes of the trip segments (i.e. each segment is defined by two purposes, e.g. home-leisure and leisure-home). Based on that, we observe how frequently the commonest origin-destination couples occur across our sample. In particular, we focus on care trips (i.e. those having a care activity as origin and/or destination) to verify the prevalence of care trips and identify the purposes that are most frequently coupled with it. This analysis sets

[3] The MCA is useful to explore interdependencies with categorical variables like in this study (e.g. Diana, 2014; Greenacre, 2007).

[4] We formulate these three classes drawing on the definitions used for the Turin metropolitan area by the city Municipality (aperTO, 2026) and the Piedmont Mobility Agency (AMP, 2026). The "city centre" comprises the central historic neighbourhood and its bordering neighbourhoods within the municipality of Turin, where a lot of mobility attractors are concentrated. The "urban area" includes all the other neighbourhoods within the municipality of Turin, where larger residential neighbourhoods are located. Finally, the "belt area" includes some municipalities around Turin but within its metropolitan area, characterized by sparser urban fabric and lower supply of public transport services.

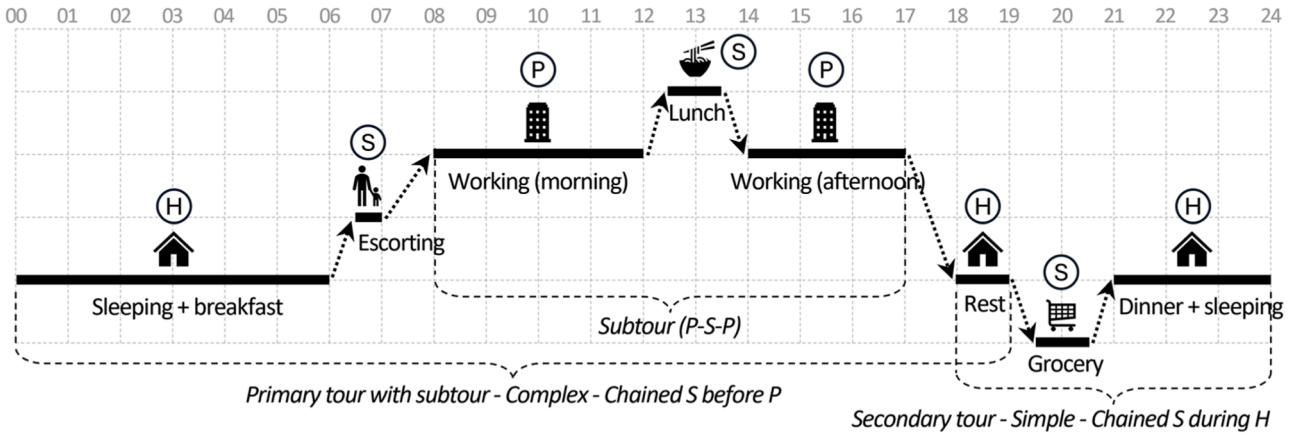

Fig. 2. Exemplificative routine including a primary tour with subtour and a secondary tour (based on categories in Table 5).

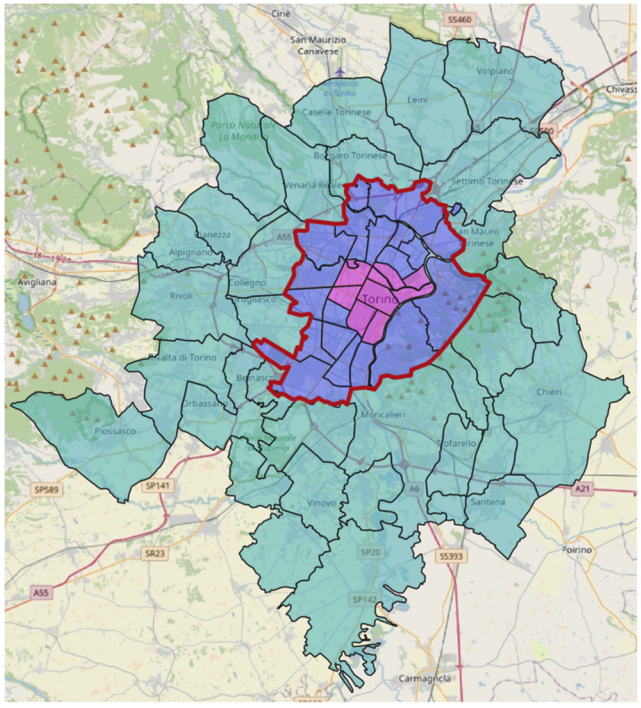

Fig. 3. Cartography of the Turin metropolitan area.

the ground for the following observation of trip chains and tours, but it also provides relevant details on the role of the MoC per se.

- In combination with the purpose-based origin-destination couples, we observe trip segments also according to the *categories* established in Section 3.1 for the aim of trip-chaining analysis (i.e. H-P, P-H, H-S, S-H, P-S, S-P, S-S). Similarly to activities, the cross-observation of purposes and categories allows showing how frequently segments involving care activities (as well as work, school and leisure) as origin and/or destination fall into the different patterns, revealing a potentially different role in daily chains and tours, specifically addressed in the following analyses.
- Finally, we perform an MCA as done with activities by focusing on the MoC. Specifically, we check for associations between all possible couples of care trips (i.e. trips having care as origin and/or destination purpose) and the six individual variables listed above (i.e. gender, age class, employment status, household size, neighbourhood type, main mode). This allows pointing out whether certain user groups tend to more consistently perform certain kinds of care trips.

***Trip chains and tours*:**

- Since we adopt H-based tours as units of analysis (Table 5), daily routines may include one or more sequential H-based tours (i.e. the multi tours defined by e.g. Kondo & Kitamura, 1987; or Nishii et al., 1988). Based on this premise, we first check for the number of tours performed by our sample, highlighting how many second (or following) H-based tours occur. This allows discussing the complexity of daily routines, regardless of the purposes of the activities involved. As for the role of the MoC, we observe how many care activities (as well as work, school and leisure ones) belong to the first or following H-based tours, to highlight trends in their allocation within multi tours. Moreover, we check how many H-based tours include one or more care activities.
- In line with activities and trip segments, we analyse tours by *purpose* (i.e. sequences of home, work, school, care, and leisure activities; for instance: home-work-care-home) and trip-chaining *categories* (i.e. sequences of H, P, and S activities; for instance: H-P-S-H), and we cross-check contingencies between these two dimensions. This enables multiple highlights. First, we show which trip-chaining categories are most frequent, regardless of involved activity purposes. Second, we focus on tours including at least one care activity (as well as work, school and leisure ones) and observe their distribution across trip-chaining categories.
- As stated in Section 2.1, so-called history and future dependencies are significant in trip-chaining dynamics (Chen & Susilo, 2021). For instance, if car is chosen for the first trip in a tour, this is likely to be chosen also for the other trips in the same tour (Ortúzar & Willumsen, 2024). As such, we analyse how many work, school and leisure activities belong to tours that include (or exclude) also care activities. This data may provide an indication of potential independencies between the MoC and other mobility kinds. Specifically, we check for the number of work, school and leisure activities belonging to tours either including at least one care activity, or without any care activities. Additionally, we investigate which categories of tours they belong to.
- As done with activities and trip segments, even with tours we perform an MCA visualising associations among the ten defined categories of tours (see Table 5) and the six individual variables above (gender, age class, employment status, household size, neighbourhood type, main mode). As in previous cases, we focus exclusively on tours including at least one care activity, so as to

highlight the role of the MoC. This investigation shows possible connections between given individual factors and the kinds of performed tours including at least one care activity.

4. Case study: Turin metropolitan area

4.1. Framework of the case study

4.1.1. Study area and dataset

The Turin metropolitan area comprises the municipality of Turin (ca 800,000 inhabitants and 23 traffic analysis zones; red border in Fig. 3) and its "belt area" (ca 544,000 inhabitants and 31 traffic analysis zones; light blue in Fig. 3). For our MCA analysis, we also distinguish between the "city centre" and the surrounding "urban area" within Turin (purple and violet in Fig. 3). A travel diary survey was performed between 2016 and 2017, with three waves to control for seasonal effects (Sep–Oct 2016, Feb 2017, Jun 2017). The survey was administered both through the web and over telephone interviews and it reached 4444 valid responses, with a final representativeness of the population above 18 thanks to the adoption of a stratified random sampling approach focused on gender (2 categories), age class (9 groups), occupational status (3 classes), and traffic analysis zone of residence (23 traffic analysis zones for the municipality of Turin + 31 zones for the municipalities of the belt area = 54 zones in total). In this study, we consider a subsample of only weekday diaries (i.e. filtering out weekends; Table 6). This leads to 2793 observed daily routines, including 9637 activities, 6844 trip segments, and 3076 home-based tours.

In the survey, respondents reported their trips and activities of the last 24 hours. They were asked to focus on activities rather than trips, by reporting their purpose, location, starting and ending time. Previous authors highlighted that this approach contributes improving accuracy of responses, since individuals are typically more familiar with reporting activities than trips (Ampt & Ortuzar, 2004). The survey included a specific feature to capture trip chaining: after reporting the first activity, respondents were asked to report the following one. After that, the survey asked respondents whether they made any intermediate stops between the two previously registered activities. This "recall module" allowed registering all the minor stops that respondents could overlook (like dropping off kids at school, stopping at the cafe for breakfast, or going at restaurant for lunch break). In this way, the accuracy of activity sequences was ensured and even the smallest activities (relevant for trip chaining) were registered. This makes such mobility survey a sound dataset for the aim of our work. Beside the activity diaries, socio-demographic data was collected from each responded, together with address of residence and information on the means of transport most frequently used on daily basis (this data is used in this study for the MCAs mentioned in Section 3.2). Additional details on this experimental activity can be found in Ceccato (2020).

4.1.2. Identification of the MoC within the dataset

The original survey was not conceived considering the MoC concept. As such, original activity purposes need interpretation in order to identify care activities. Originally the survey included 13 activity purposes (Table 7, left side). To establish which of them are ascribable to the MoC, we rely on the MoC conceptual framework provided by De Madariaga (2013). Based on that, activities can be clustered into five groups (mentioned in Section 3.2): *work, school, care, leisure, home*. The *care* group includes two main sorts of activities: (a) care activities responding to "domestic responsibilities"; and (b) care activities responding to "caregiving responsibilities". The former comprise grocery shopping, organisational errands, and household upkeep tasks needed for the functioning of the house. The latter encompass escorting mobility-dependent people (e.g. kids), and visiting people needing caregivers' support (e.g. the elderly). Besides that, Orjuela and Schwanen, (2023) argue that even self-care activities (like own medical appointments) and homestays due to care duties (like housecleaning) should be labelled as care activities. However, especially the latter are typically hard to identify in travel diaries, as home activities are often labelled only as "home" without more granular distinctions (limitation that applies also to our dataset).

Grounding on this conceptual distinction by De Madariaga (2013), we identify two out of the 13 original activity purposes that clearly fall into the MoC domain: "*In a hospital or a doctor's office for treatment or medical visits*" and "*Running errands or accompanying/picking someone up*" (respectively n.6 and 7 in Table 7). Moreover, we link one original purpose to the *home* domain, three original purposes to the *work* domain, one original purpose to the *school* domain, and three original purposes to the *leisure* domain (Table 7, right side). However, three original purposes (n.11–13 in Table 7) are ambiguous since they could fall both into the *care* and *leisure* domains. As example, "*Visiting relatives and friends*" (n.12 in Table 7) is a care activity if it responds to the caregiving

Table 6
Addressed subsample from the Turin metropolitan area.

Stratification variables[a]		Subsample		Population	
Variable	Subgroup	Number	Share	Number	Share
Gender	Male	1436	51 %	634,906	47 %
	Female	1357	49 %	709,094	53 %
Age class	18–20	63	2 %	40,186	3 %
	21–24	151	5 %	56,582	4 %
	25–29	145	5 %	80,237	6 %
	30–34	214	8 %	96,902	7 %
	35–44	529	18 %	253,748	19 %
	45–54	492	18 %	235,334	19 %
	55–64	437	16 %	208,186	15 %
	65–74	435	16 %	191,923	14 %
	75+	327	12 %	180,902	13 %
Occupational status	Employed	1522	54 %	631,814	47 %
	Unemployed A[b]	769	28 %	65,453	5 %
	Unemployed B[c]	502	18 %	646,733	48 %
Total		2793	100 %	1344,000	100 %

Notes:
[a] See Ceccato (2020) for details regarding the stratification by traffic analysis zone of residence;
[b] Unemployed but belonging to the workforce (e.g. people seeking a job);
[c] Unemployed and economically inactive (e.g. pensioners, students, homemakers).

Table 7
Logic for the conversion of activity purposes (based on De Madariaga, 2013; De Madariaga and Zucchini, 2019).

Purposes (original survey)	Purposes to deal with the MoC (this study)
1. At home	Home (100 %)
2. At work in my usual workplace	Work (100 %)
3. At work not in my usual workplace	Work (100 %)
4. Engaged in a work activity involving the transport of people or goods	Work (100 %)
5. At the school or university where I study	School (100 %)
6. In a hospital or a doctor's office for treatment or medical visits[a]	Care (100 %)
7. Running errands or accompanying/picking someone up[a]	Care (100 %)
8. At a café or restaurant as a customer	Leisure (100 %)
9. Practicing sports or other cultural, leisure, community, religious activities	Leisure (100 %)
10. Out without a specific destination	Leisure (100 %)
11. At a market, store, or shopping mall for shopping or just to look around[b]	Care (67 %) + Leisure (33 %)
12. Visiting relatives or friends[b]	Care (33 %) + Leisure (67 %)
13. Other[b]	Care (33 %) + Leisure (67 %)

[a] Original purposes converted into care activities based on the conceptual framework by De Madariaga (2013)
[b] Original purposes converted into care or leisure activities based on the verified hypotheses by De Madariaga and Zucchini (2019).

responsibility of helping someone in need (e.g. bringing grocery items to old parents). Whereas it is a leisure activity if this is done for the sake of spending some free time (e.g. visiting friends for a birthday party). To handle these ambiguous cases, we rely on some hypotheses already tested and successfully verified by De Madariaga and Zucchini (2019). Specifically, a random subset of 2/3 of the activities classified as "*At a market, store, or shopping mall for shopping or just to look around*" are converted into *care* to represent grocery shopping for household needs, while the remaining 1/3 into *leisure* to represent recreational shopping (n.11 in Table 7). A random subset of 1/3 of the activities labelled "*Visiting relatives or friends*" are converted into *care* to cover visits to support family members that require help, while the remaining 2/3 are labelled *leisure* to represent visits to enjoy free time (n.12 in Table 7). The same proportion applies to "*Others*" (n.13 in Table 7).

Clearly, these hypotheses may generate some disturbances for our result. Therefore: (a) we examine the impacts of these hypotheses on our results in the sensitivity analysis presented in Section 4.3; and (b) we include and discuss these hypotheses among the limitations of our work in Section 5.3.

4.2. Role of the MoC in daily trip chaining

4.2.1. Activities

In our study area care activities cover 15 % of all the activities carried out by the sample (total including Home, Table 8). However, if we exclude home activities from the analysis, thus considering only out-of-home purposes, this share grows up to 39 % (total excluding Home, Table 8). These figures align with the prevalence of the MoC already highlighted in previous investigations (see Section 5.1) and point out the general relevance of the MoC for our sample. Our trip-chaining classification of home (H), primary (P), and secondary (S) activities reveals further details. Care activities represent the second most frequent primary activity in the sample after work activities (911 and 1050 respectively), and the most frequent secondary activity followed by leisure (467 and 441 respectively). From a different angle, this means that about 2/3 of the reported care activities are also the primary activity of our sample members (991 out of 1458), while the remaining 1/3 consists of secondary ones (467 out of 1458). This trend potentially highlights a dichotomy in the role of care activities in daily routines: for many sample members, care activities represent the longest (and likely most relevant) activity daily performed out of home; whereas another smaller but still significant share has care activities as secondary duty, mostly beside work.

The results from the MCAs represented in the correspondence plots[5] (Fig. 4) show how the dichotomy in care activities mentioned above are associated with six sociodemographic, geographic and travel traits of our sample: gender, age, employment status, household size, neighbourhood type, main mode. Females are moderately more associated than males with primary care activities. Youngest and oldest people (18–24 and 65+) are sharply the most associated with primary care activities. The same applies to unemployed individuals, both active (i.e. seeking a job) and in inactive (i.e. pensioners and homemakers); as well as to people living in small households (up to two members). In addition, the MCA related to neighbourhood type highlights that people residing in the city centre are more associated with secondary care activities, while belt and urban areas are more associated with primary care activities, even if with a lower extent. Car is similarly linked to both primary and secondary care activities (i.e. 77 % of sample members having car as main mode perform primary care activities, in line with the whole-sample value of 78 %). Whereas public transport is closer to care activities labelled as primary (i.e. 82 % of sample members having public transport as main mode perform primary care activities, above the whole-sample value of 78 %). These patterns of association highlight that retirees and young unemployed people living in small-size households, represent the typical group performing care activities as primary daily out-of-home activity, such as grocery shopping, healthcare appointments, or caring for grandchildren. Instead, adult workers with children (usually aged 25–64, employed, belonging to households of 3+ members, living in central areas, and frequently travelling by car) typically perform care activities as secondary ones, coupled with work as their typical primary activity. It is worth mentioning that retirees and young unemployed people cannot have systematic purposes (work or school) as primary activities and we observed that they tend to travel less than workers (2.35 trips per unemployed person against 2.55 trips per employed person). As such, the association between employment status and care activity type is expected.

4.2.2. Trip segments

Figs. 5–7 (and Appendix A) focus on trip segments, i.e. origin-destination couples of home (hm), work (wr), school (sc), care (cr), and leisure (ls) purposes. Care trips (i.e. those with a care activity as origin and/or destination) cover 41 % of all the trips reported by our sample (2824 in Appendix A). As benchmark, this value is higher than work trips, which reach about 30 % of the total (2139 in Appendix A). Care-home and home-care trips are the two most frequent couples covering 35 % of all trips (Fig. 7). The remaining 6 % is distributed across other seven couples: care-leisure and leisure-care trips (2.4 %), care-work and work-care trips (2.1 %), care-care trips (1.3 %), care-school and school-care trips (0.1 %). This highlights how the majority of care activities are performed right after or before home activities, typically (but not exclusively) occurring at the beginning and end of the day. When cross-checking purposes (columns in Fig. 7) with trip-segment categories (colours in Fig. 7), further details on the MoC emerge. Home-primary and primary-home trips jointly represent 65 % of all care trips, followed by home-secondary and secondary-home trips (21 %), and primary-secondary and secondary-primary trips (13 %; Appendix A). This trend is confirmed when observing the most diffused purposes involving care: care-home and home-care (Fig. 7). For both, home-primary and primary-home are the two most relevant categorises, covering about 70–80 % of relevant trips; while home-secondary and secondary-home cover 30–20 %. This distribution aligns with the one of primary and secondary care activities highlighted in Section 4.2.1.

Beside purposes and categories, we observe also the modal split of trip segments as this is an important part of our policy recommendations in Section 5. Fig. 6 shows the distribution of the three main modes (active modes, car, public transport) for the whole sample, by the four out-of-home purposes (work, school, leisure, care), and by the three neighbourhood types (city centre, urban area, belt area). To analyse the modal split by purpose, we aggregate all segments with a given purpose as origin or destination. Work and school trips show respectively higher and lower reliance on car respect to the whole sample (76 % for work and 25 % for school), while active mobility plays a very minor role in both cases (<5 %). Compared to work, both leisure and care trips show a lower share for car and higher for public transport. This applies especially to care trips: 66 % by car; 32 % by public transport. These figures confirm previous MoC studies (e.g. De Madariaga & Zucchini, 2019; Soto-Villagrán, 2024; see Section 5.1.1). Geographically, sample members living in the city centre have the lowest share of car trips and highest one of trips by public transport (52 % and 42 %, respectively), in line with the higher transit-network density. Conversely, urban and belt areas around the city centre show a higher car dependency, also linked

[5] Correspondence plots (Figs. 4-8–12) can be interpreted as follows. (1) Categories of observed variables are displayed as points in a plot. In our case, categories of sociodemographic, geographic and transport variables are blue dots, while categories of activity, trip-segment and tour variables are red triangles. (2) The distance of blue dots and red triangles from the origin of the plot (0,0; marked by dashed lines) represents the distance of each category from the average individual in the dataset. (3) The distance between blue dots and red triangles within the plot reflects the strength of their association in the dataset: the closer the points are, the stronger their correspondence.

Table 8
Contingency table of activities by purpose (rows) and trip-chaining category (columns).

	Home (H)		Primary (P)		Secondary (S)		Total		
	Count	Share	Count	Share	Count	Share	Count	Share (including Home)	Share (excluding Home)
Home (hm)	5869	61 %	–	–	–	–	5869	61 %	–
Work (wr)	–	–	1050	11 %	24	0 %	1074	11 %	29 %
School (sc)	–	–	113	1 %	3	0 %	116	1 %	3 %
Care (cr)[a]	–	–	991	10 %	467	5 %	1458	15 %	39 %
Leisure (ls)	–	–	679	7 %	441	5 %	1120	12 %	30 %
Total	5869	61 %	2833	29 %	935	10 %	9637	100 %	100 %

Notes: – Not possible by definition.
[a] Relevant row for the topic of the MoC.

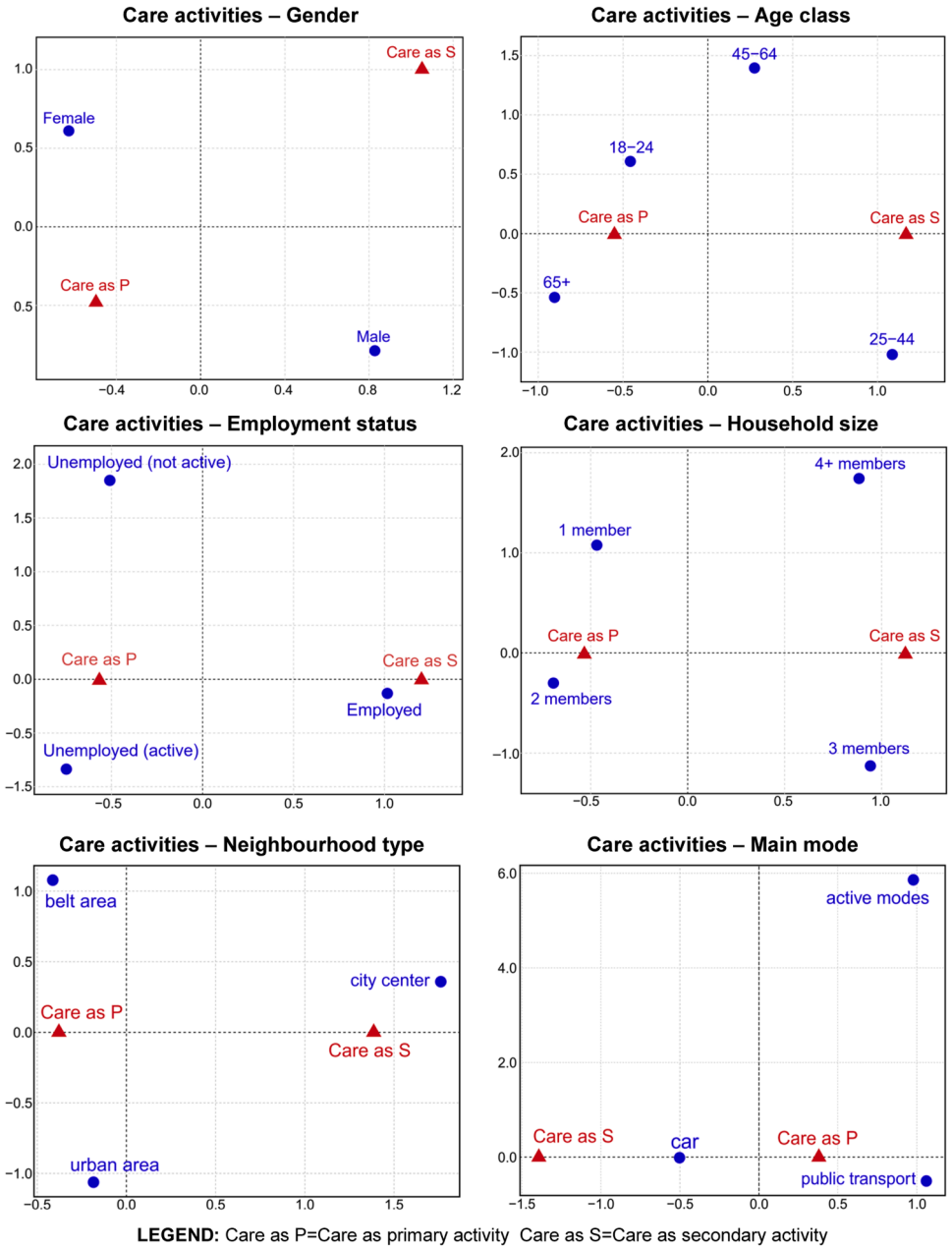

Fig. 4. Correspondence plots of care activities as P or S (triangles) and sociodemographic, geographic and travel traits (dots).

to the lower availability and density of transit lines and stops.

MCAs in Fig. 8 focus on care trips and the six individual variables already addressed for activities (gender, age, employment status, household size, neighbourhood type, main mode). Females are more associated with home-care and care-home trips than males, while the opposite applies to work-care and care-work trips. As pointed out by

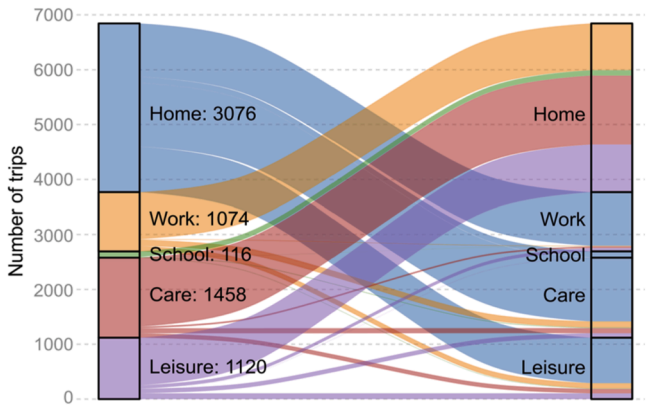

Fig. 5. Sankey diagram of trip segments by purpose (colours).

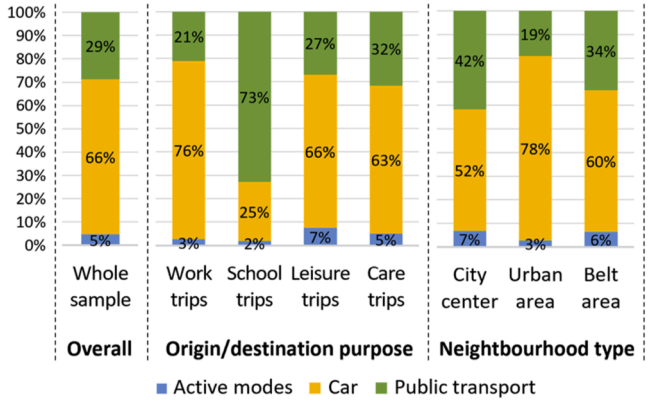

Fig. 6. Modal share: overall, by purpose and neighbourhood type.

previous authors, this pattern might be linked to the social roles typically assigned to males and females and feeding a gender divide broadly stressed in literature (e.g. Daly& León, 2022; Hernández & de los Santos, 2020; Murillo-Munar et al., 2023; see Section 5.1 for the related discussion). As expected, people aged 18–24 are the most associated with school-care trips, while people aged 65+ are especially associated with trips linking care with home activities, leisure and other care activities. Interestingly, younger adults aged 25–44 are the subgroup most clearly linked to care-work trips, while this connection is weaker for adults aged 45–64. This difference might be explained by the different life stages expected for these age groups, highlighted in previous works on the topic (e.g. Plyushteva & Schwanen, 2018; Susilo et al., 2019): younger adults more likely have young children who imply more care activities combined with job ones. As expected, the MCA confirms that employed individuals have a higher association with care-work trips, while unemployed ones are closer to home-care and home-leisure trips. Moreover, household size shows heterogeneous trends. However, people from larger households emerge as the most associated with work-care and care-work trips, indirectly recalling the influence that children caregiving may have on the need to combine work and care activities over the daily routine. Furthermore, people living in the city centre are more associated with leisure-care trips, whereas residential locations in belt and urban areas are more associated with home-related trips (i.e. care-home and home-care, respectively). Concerning the contribution of the main mode, both car and public transport are closer to home-based care trips, as well as leisure-care trips.

4.2.3. *Trip chains and tours*

Table 9 reports the 3076 home-based tours according to their chronological order. As visible, only 9 % of the sample makes a second daily tour, and less than 0.5 % performs three or more tours. In the first and second daily tours, care activities respectively represent 1310/9034*100 = 15 % and 138/832*100 = 17 % of all activities, slightly more than leisure activities (11 % and 16 %). Conversely, the incidence of work activities drastically decreases in the second daily tours compared to the first ones: from 12 % to 4 %. This suggests that second and following daily tours (when present) tend to be more headed to care and leisure activities. Table 10 shows instead how many of the 3076 reported tours include one or more care activities. Values show that 56 % of registered tours do not include any care activity, 40 % of them include one care activity, while only 4 % of them comprise two or more care activities. This highlights that the MoC affects a significant share of the tours carried out by our sample, but this rarely implies the presence of more than one care activity within the same tour.

Fig. 9 focuses on the ten trip-chaining categories introduced in Table 5 (C1–10) and observes how they distribute across all the tours, as well as across four non-mutually exclusive subgroups, each including at least one work, school, care or leisure activity, respectively. Fig. 10 shows instead the tours organised by purpose (i.e. sequence of home, work, school, care, leisure activities) and trip-chaining category (see Appendix B for details). Overall, primary tours without subtour (C1–4)

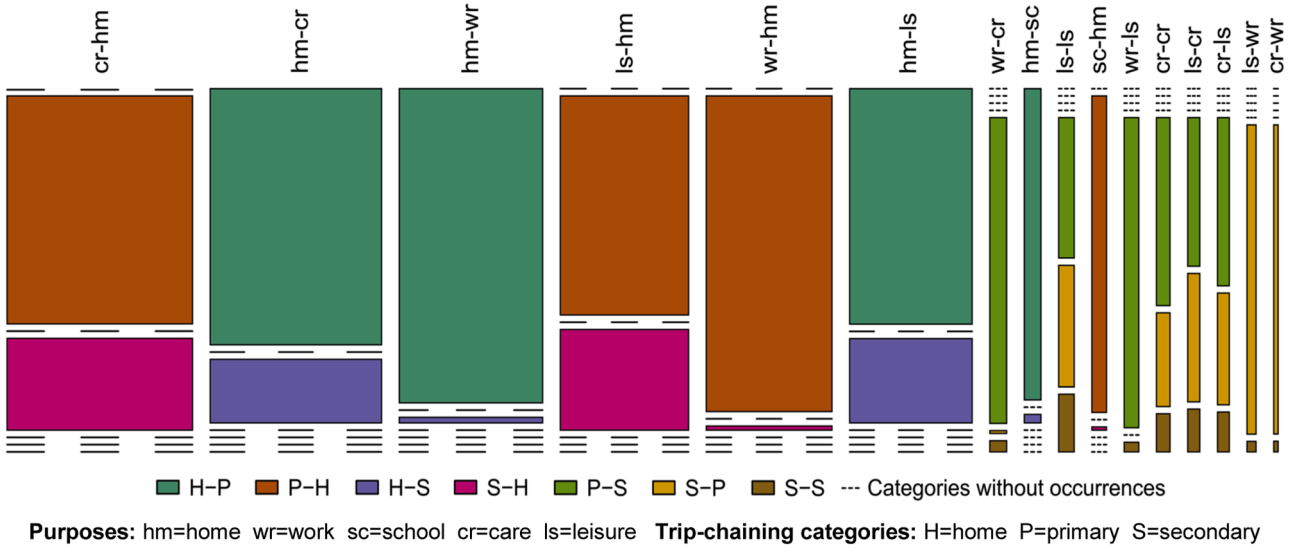

Fig. 7. Mosaic plot of trip segments by purpose (columns) and trip-chaining category (colours). Trip purposes with less than 10 occurrences are not represented.

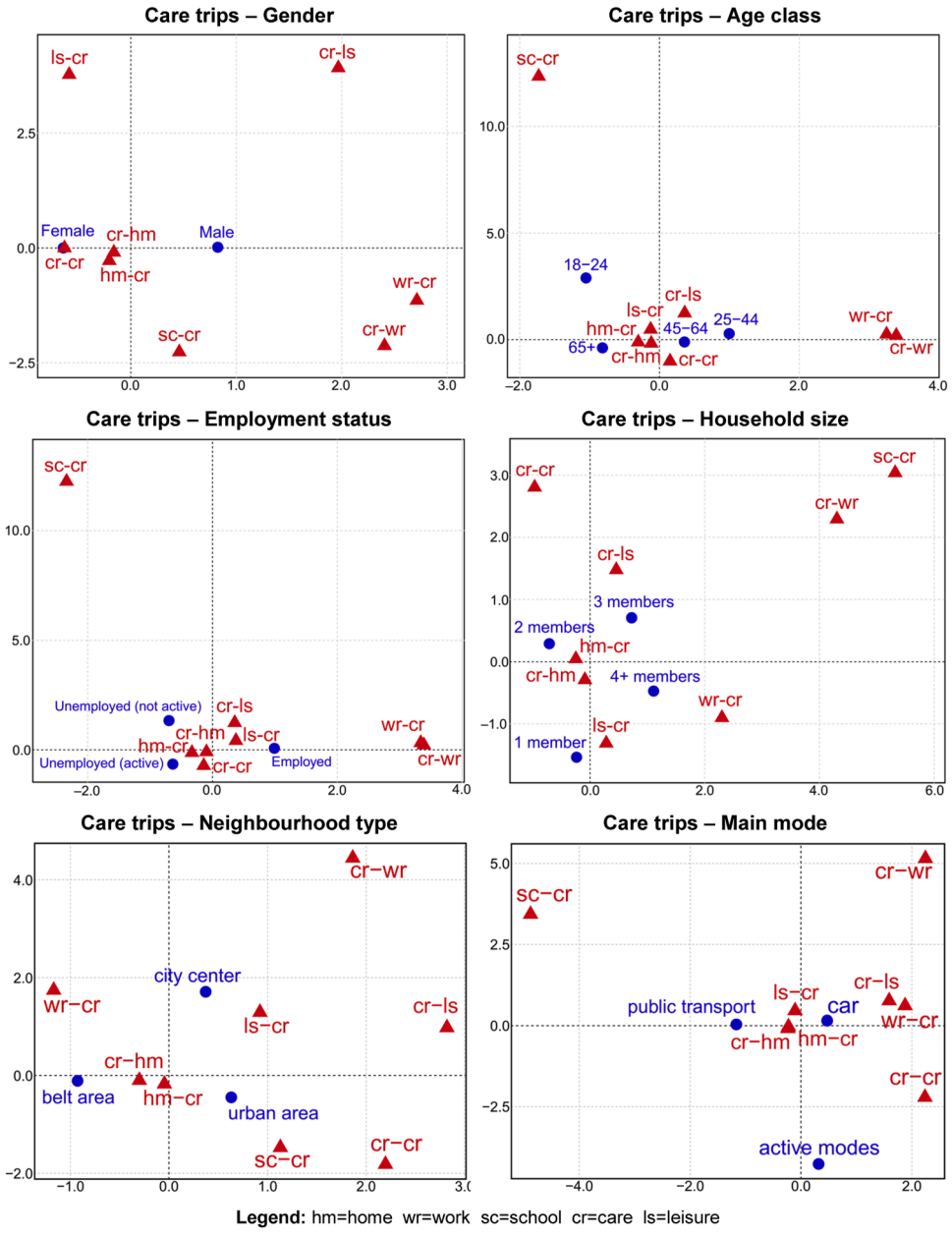

Fig. 8. Correspondence plots of care trips (triangles) and sociodemographic, geographic and travel traits (dots).

cover 91 % of all the 3076 tours performed by the sample (Fig. 9). The remaining 9 % is almost exclusively made up of secondary tours (C9–10), while primary tours with subtour (C5–8) are almost absent. Within the primary tours without subtours, simple sequences of two segments (C1) are the most diffused (73 % of the total), followed by complex tours with a trip chain after or before the primary activity (C2 and C3: 6 % and 12 % of the total, respectively). Even within secondary tours, simple sequences (C9) are more diffused (6 % of the total), while

Table 9
Number of first and following tours and number of activities by purpose belonging to the first and following tours.

	1st daily tour[a] (n=2793, 91 %)		2nd daily tour[a] (n=267, 9 %)		3rd daily tour[a] (n=12, 0 %)		4th daily tour[a] (n=3, 0 %)		5th daily tour[a] (n=1, 0 %)		Total (n=3076, 100 %)	
	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share
Home activities (hm)	5586	56 %	534	5 %	24	0 %	6	0 %	2	0 %	6152	62 %
Work activities (wr)	1043	11 %	30	0 %	0	0 %	1	0 %	0	0 %	1074	11 %
School activities (sc)	115	1 %	1	0 %	0	0 %	0	0 %	0	0 %	116	1 %
Care activities (cr)[b]	1310	13 %	138	1 %	8	0 %	0	0 %	2	0 %	1458	15 %
Leisure activities (ls)	980	10 %	129	1 %	7	0 %	3	0 %	1	0 %	1120	11 %
Total	9034	91 %	832	8 %	39	0 %	10	0 %	5	0 %	9920	100 %

[a] The numbering reflects the chronological sequence in daily routines.
[b] Relevant row for the topic of the MoC.

complex sequences cover only 1 % of all tours. Generally, these figures suggest that simple tours including one outbound and one return trip are sharply more common than complex tours including trip chains (80 % vs 20 % of the total).

If we cross-check the categories discussed above with the purposes reported in Fig. 10, it emerges that home-care-home, home-work-home, and home-leisure-home are the three most diffused purpose sequences, all belonging to C1 or C9 tour categories (i.e. H-P-H and H-S-H). If we focus exclusively on the tours including at least one care activity (Fig. 9), further MoC details emerge. In line with previous observations, simple primary tours (C1) represent the majority of tours including at least one care activity, but to a lower extent than the overall sample (62 % vs 73 %). Conversely, complex primary tours (C2, C3, C4) gain a higher relative incidence compared to all tours, representing about 26 % of all the tours including care activities. Finally, secondary tours (C9, C10) represent 11 % of the total, slightly more than the overall value of 9 % registered across all tours. These trends suggest that tours including care activities tend to be highly frequent and broadly shaped as simple H-P-H tours. However, also more complex patterns play a significant role, especially with care activities chained on the way back home after the primary activity (C3). Conversely, cases where care activities are performed within subtours (e.g. work-care-work) are almost absent in our case study.

Fig. 11 (and related Appendix C) displays how many work, school and leisure activities are carried out within tours either including at least one care activity, or without any. As visible, over 85 % of both work, school and leisure activities are performed within tours that do not include any care activity. This means that most of the trips related to these purposes are not intertwined with the MoC. However, a minor but not negligible share of work, school and leisure activities (10–15 %) are performed within tours including also care activities, suggesting how travel choices for these activities might be interdependent with the MoC. Particularly, about 10 % of work and school activities are performed as primary activities (P) before a secondary care activity (S) on the way back home (C3). In these cases, work/school trip choices experience a future dependency (Susilo et al., 2019) on choices for care trips, and vice versa.

To conclude, Fig. 12 displays association between the six individual variables already addressed above, and the ten categories of tours discussed above (C1–4 being primary without subtour; C5–8 being primary with subtour; C9–10 being secondary tours). As in the observations of activities and trip segments, we focus on the MoC by considering only the tours including at least one care activity. First, gender differences observed for activities and trip segments are less sharp when it comes to tours. Females tend to be more associated than males with simple tours of two segments including care activities (C1, C9), while males register higher connection with complex tours (like C2 and C4), thus more consistently embedding care activities in other activities. However, the category C3 (H-P-S-H) is similarly associated with both males and females. As expected, people aged 65+ are the most associated with C1 simple primary tours (H-P-H), where care is the main out-of-home activity. Youngest sample members in the age class 18–24 are the most associated with simple secondary tours (H-S-H); this pattern could be due to school being their daily primary activity. Finally, adults aged 25–64 tend to make more complex tours including at least one care activity (like C2–4). The observation of employment status and household size is in line with the association patterns observed across age groups. Employed people are closer to complex tours (e.g. C2–3), while unemployed people are closer to simple tours (especially C1 and partially C9). Individuals belonging to small households (up to 2 members) are sharply linked to simple primary tours (C1), while members of larger households (3+ members) are more connected to complex primary tours (e.g. C2–4) as well as to secondary tours (C9). The MCA related to the neighbourhood type shows clear patterns: people living in the city centre are more associated with C2, residential locations in the urban area are closer to C3 tours, and the belt area is more associated with C1. Concerning the main mode, car is more associated with primary complex tours including chains (C2 and C3), whereas public transport is more associated with both primary and secondary simple tours (C1 and C9). The consistency of observed associations across these six individual variables describes a general picture. Older people who are not employed, live in small households, and in the belt area are more closely associated with care activities performed within a simple primary tour that does not imply the chaining with other daily tasks. Conversely, employed adults with larger households living close or within the city centre are observed to be more related to either complex primary tours including care activities, or secondary tours headed to care activities that precede or follow other tours headed to work. This consideration aligns with previous ones about trip segments and activities, showing overall consistency among the observed association patterns.

4.3. Sensitivity analysis

As described in Section 4.1.2, the analyses reported in Section 4.2 rely on the conversion of the activity purposes originally recorded in the survey into the five purposes used above (home, work, school, care, leisure). This conversion required some hypotheses applied to the original purposes 11, 12 and 13 (visible in Table 7), following an approach already successfully verified in previous MoC literature.

To verify the impact of such assumptions on our results, we perform a sensitivity analysis testing two scenarios, whose results are reported in Table 11. Scenario A assumes that 0 % of the activities with purpose 11, 12 and 13 in Table 7 are labelled as care activities, while 100 % as leisure ones. Scenario B applies the opposite, namely 100 % of such activities labelled as care ones. When comparing results, relevant variabilities regarding the prevalence of the MoC emerge. Care activities (15 % of the total in our analysis) range between 8 % and 21 % of the total in Scenarios A and B, respectively. Trip segments including care activities as origin and/or destination (41 % of all segments in our study) range between 23 % and 56 % in Scenarios A and B. Finally, tours including at least one care activity (44 % of all tours in our analysis) range between 25 % and 58 % in Scenarios A and B. These figures show the influence of our assumptions on the prevalence of the MoC in daily routines. However, when observing the distribution of trip-chaining categories (C1–10) within tours with at least one care activity, a substantial stability of our results is visible. Primary simple tours (C1) cover 62.0 % of all tours including one care activity in our study, 60.7 % in Scenario A, and 61.7 % in Scenario B. Primary complex tours (C2–8) are 26.5 % of the total in our analysis, 26.6 % in Scenario A, and 25.1 % in Scenario B. Secondary simple tours (C9) represent 10.1 % in our case study, 11.6 % in Scenario A, and 11.8 % in Scenario B. Finally, secondary complex tours cover 1.3 %, 1.2 % and 1.4 % in our analysis, Scenario A and B, respectively.

Table 10
Number of tours including one or more care activities.

	Tours without any care activity		Tours with one care activity		Tours with two care activities		Tours with three care activities		Total	
	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share
H-based daily tours	1727	56 %	1242	40 %	105	3 %	2	0 %	3076	100 %

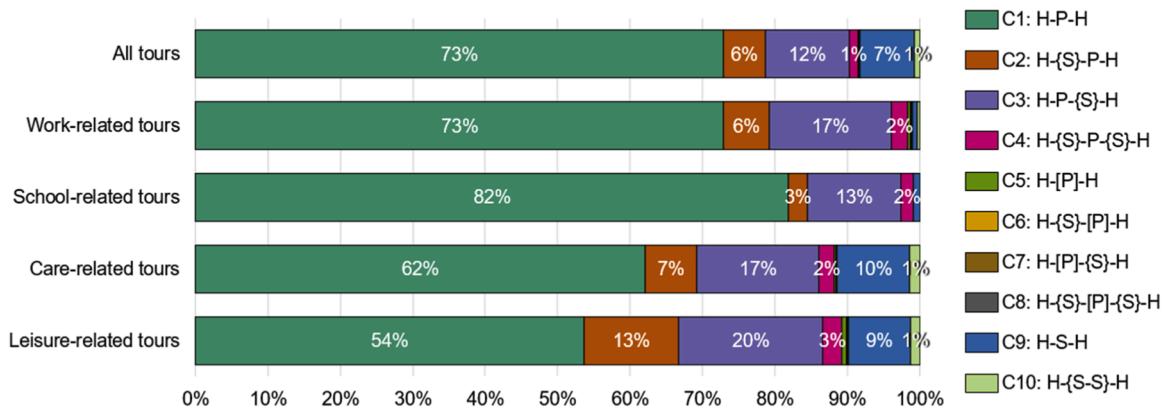

Fig. 9. Proportional bar plot of all, work-, school-, care-, leisure-related tours by trip-chaining category. See Table 5 for details of trip chaining categories C1–10.

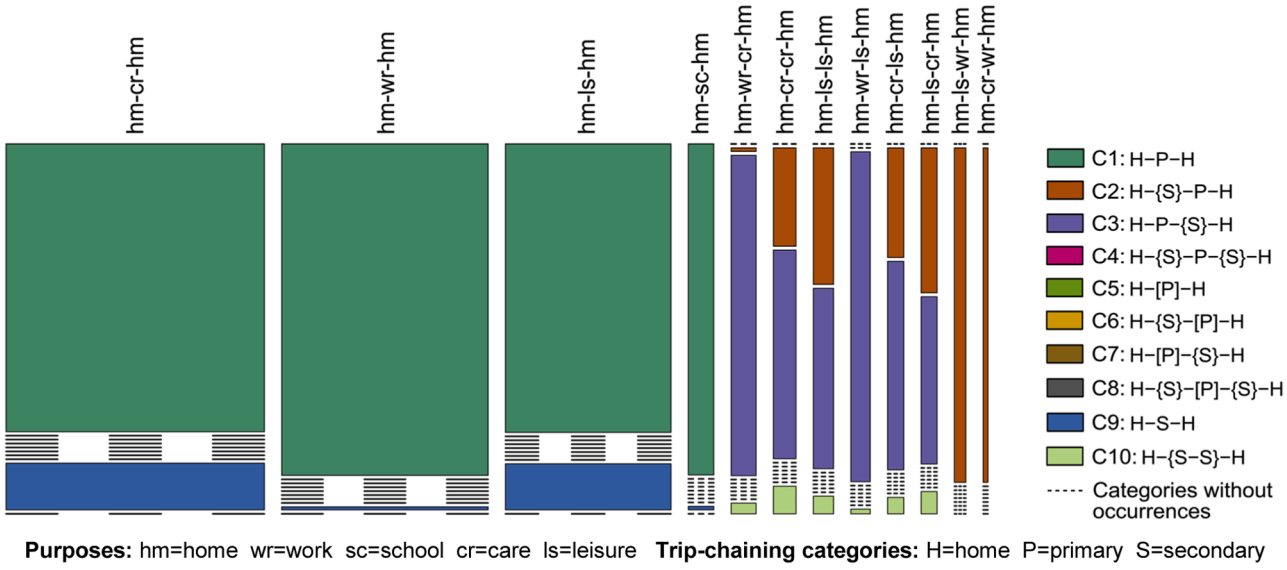

Fig. 10. Mosaic plot of tours by purpose (columns) and trip-chaining category (colours). Tour purposes with less than 10 occurrences are not represented. See Table 5 for details of trip chaining categories C1–10.

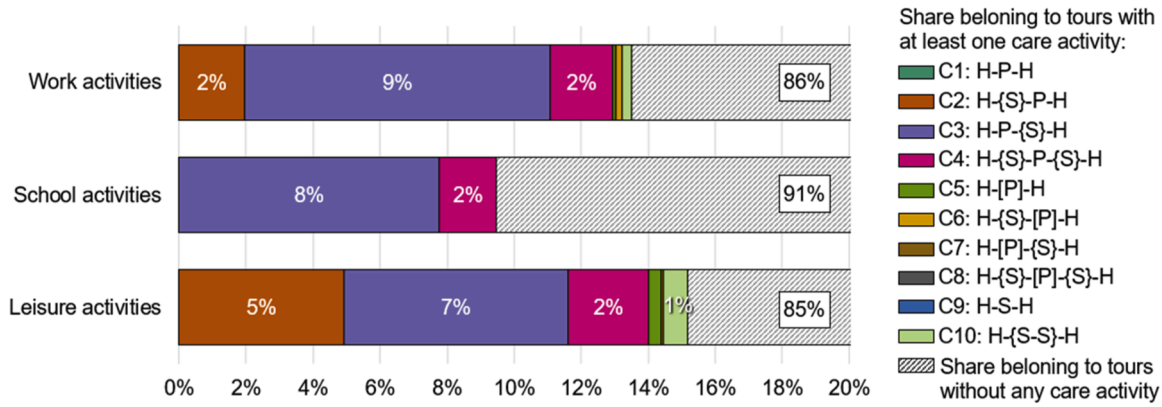

Fig. 11. Proportional bar plot of work, school, leisure activities belonging to tours with(out) care activities. See Table 5 for details of trip chaining categories C1–10.

This low variability highlights that the applied assumptions to define car-related purposes did not affect the main findings of the analysis. This confirms the general stability of our trip-chaining classification, which is key to this study primarily focused on the role of the MoC in daily trip chaining.

5. Discussion

5.1. Main findings

5.1.1. Relation of empirical findings with those from other cities/countries

Although analyses performed in this and previous MoC trip-chaining studies partially differ, an overall comparison of results across case

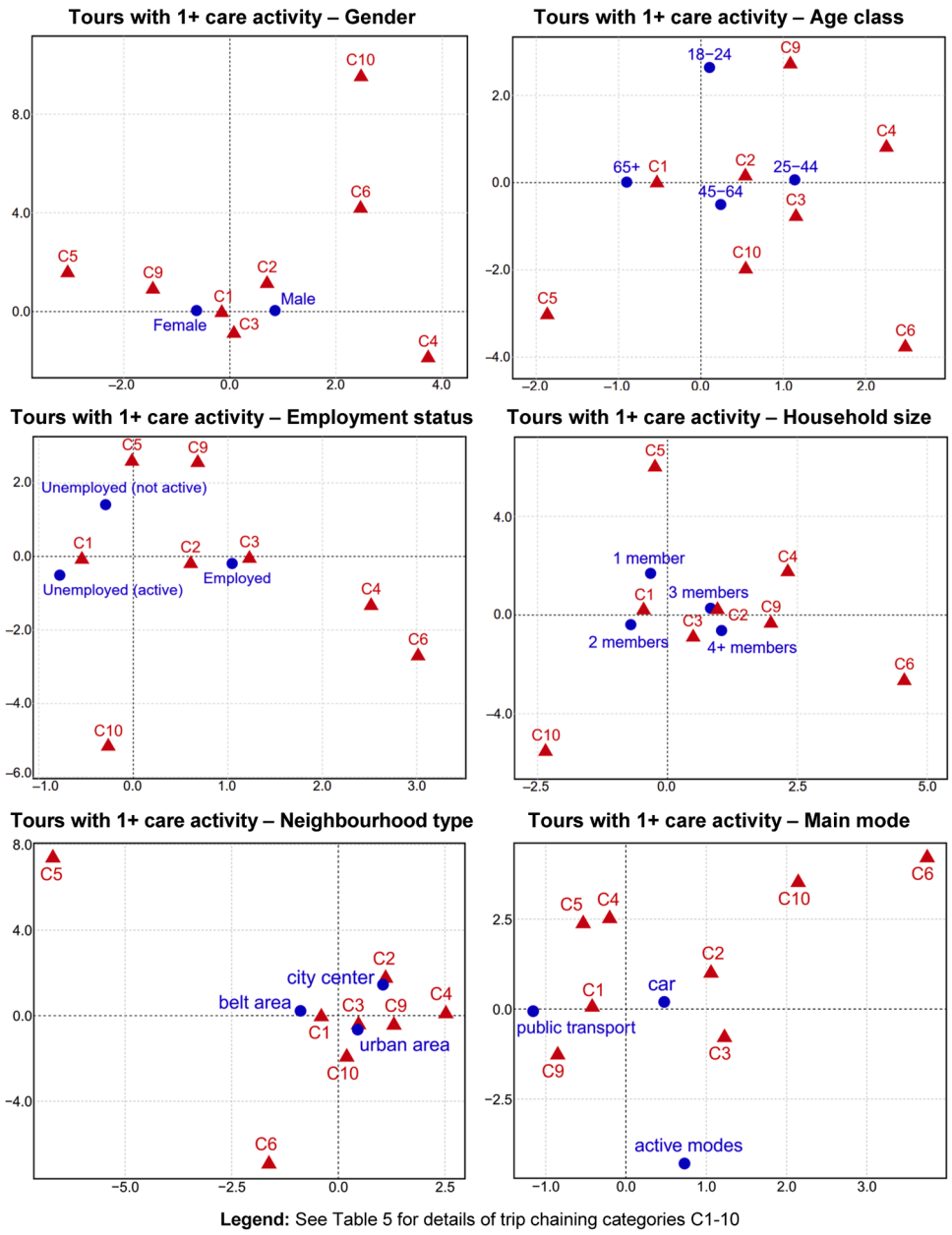

Fig. 12. Correspondence plots of tours with at least one care activity (triangles) and sociodemographic, geographic and travel traits (dots).

studies is still possible. In particular, we focus on four key aspects.

Previous studies generally found significant shares of care activities embedded within trip chains (e.g. De Madariaga & Zucchini, 2019; Porath & Galilea, 2025; Ravensbergen et al., 2023). Ravensbergen et al. (2023) point out that about 60 % of care trips retrieved in Montreal are part of a trip chain. Li and Widener (2025) declare that less than 50 % of people living in four Canadian metropolitan areas reported trips for grocery shopping made within chains. Porath and Galilea (2025) shows that ca 35 % of reported trips are chained. Our results align with this last study but show a lower prevalence of chained care trips: 30 % of tours with at least one care activity are complex (i.e. include one chain), while 70 % are simple. However, partial divergences from some previous studies must be interpreted considering differences in addressed samples. Our analysis considers adults aged 18–65 and seniors aged 65+; while many previous studies focus on adults only, who are typically more associated with chained trips (as in our case study).

Several case studies from EU, US and South America showed that women tend to make more complex chains including the MoC, while men typically perform simple home-work-home tours (Abdelhalim et al., 2024; Hernández & de los Santos, 2020; Porath & Galilea, 2025). Moreover, Li and Widener (2025) found out that women are more likely to make work-based subtorus for grocery shopping. Our results partially confirm these trends. On the one hand, also in our case study females are more associated than males with some kinds of complex primary tours and subtorus including care activities (e.g. C3 and C5). On the other hand, some kinds of complex primary tour (e.g. C2, home-care-work-home) result more associated with men. This additional detail provided by our results might mirror different gender in MoC trip chaining: e.g. with men more typically dropping kids at school on the way to the workplace (C2), and women more typically engaged in care activities chained on the way back home after work (C3).

Regarding employment condition and household composition, Scheiner and Holz-Rau (2017) show that employed people in Germany make more complex tours than unemployed people regardless of gender; while data collected in Santiago by Porath and Galilea (2025) stress that tour complexity increases with children in the household. Our results are

Table 11
Synthetic results of the performed sensitivity analysis.

	Case-study analysis[a]		Scenario A[a]		Scenario B[a]	
	11: 67 % care; 33 % leisure 12: 33 % care; 67 % leisure 13: 33 % care; 67 % leisure		11: 0 % care; 100 % leisure 12: 0 % care; 100 % leisure 13: 0 % care; 100 % leisure		11: 100 % care; 0 % leisure 12: 100 % care; 0 % leisure 13: 100 % care; 0 % leisure	
	Count	Share[b]	Count	Share[b]	Count	Share[b]
Care activities (all)	1458	15 %	780	8 %	2003	21 %
Care trips (all)	2824	41 %	1551	23 %	3822	56 %
Tours with at least one care activity (all)	1349	44 %	754	25 %	1779	58 %
Tours with at least one care activity (Primary simple: C1)	837	62.0 %	458	60.7 %	1098	61.7 %
Tours with at least one care activity (Primary complex: C2–8)	358	26.5 %	200	26.6 %	446	25.1 %
Tours with at least one care activity (Secondary simple: C9)	136	10.1 %	87	11.6 %	209	11.8 %
Tours with at least one care activity (Secondary complex: C10)	18	1.3 %	9	1.2 %	26	1.4 %

Notes:
[a] 11 in Table 7 - Shopping activities, 12 in Table 7 - Visiting activities, 13 in Table 7 - Other activities;
[b] For the first three rows, this column reports the share of care activities, care trips, and tours with at least one care activity over the total; For the last four rows, this column reports the share of tours with at least one care activity by category over the total number of such tours.

in line with both considerations, as visible in our MCAs. Employed individuals are sharply more associated than unemployed people with complex primary tours C2 (home-care-work-home) and C3 (home--work-care-home), which are the most diffused ones including at least one care activity. The same applies to people belonging to households with 3+ members, clearly more associated with complex primary tours (C2-3-4), as well as with secondary tours (C9).

Concerning geographic and travel-related factors, Scheiner and Holz-Rau (2017) show that German people living in urban cores tend to make more complex tours than those living in peripheral/rural areas. Instead, analyses done in Madrid (De Madariaga & Zucchini, 2019), Montreal (Ravensbergen et al., 2023), and Mexico City (Soto-Villagrán, 2024) indicate that care trips in general are more often made by active modes and public transport than other trips (e.g. work ones). However, they are more likely carried out by car and less likely by walking when performed in chains. Our results in Turin are aligned with these trends. First, trip segments having care as origin and/or destination register a higher modal share for public transport than work trips. Second, car is most clearly associated with care-related complex primary tours C2 and C3. Third, people living in the belt area are more associated with simple primary tours C1 than those living close to the city center.

5.1.2. *Interpretation of findings in light of the theoretical debate on MoC-related issues*

The findings discussed above in relation to other case studies can also be linked to the broader theoretical debate on MoC-related issues. In the text below, we focus on two aspects.

Feminist literature clearly stresses that women's daily lives are more complex than men (Daly & León, 2022; Scheiner & Holz-Rau, 2017), and their higher involvement in care activities beside employment is one of the main reasons for that (MacDonald, 1999; Nobis & Lenz, 2005). Consequently, women more often deploy trip-chaining strategies to cope with their mobility burden (McGuckin & Nakamoto, 2005; Scheiner & Holz-Rau, 2017; Strathman & Dueker, 1995). As already showed above in comparison with other case studies, our results tend to confirm this gendered macro trend. However, they provide also further details: (a) care activities done by females are often chained on the way back home; (b) they are also performed within secondary tours typically occurring after the primary one; and (c) they are almost never performed within work-based subtours. These patterns might be linked to behavioural explanations, although not supported by demonstrated causal relations in our study. For instance, the role of women as main household caregivers has proved effects on their employment: e.g. more common part-time work among women (e.g. Nobis & Lenz, 2005). This might explain why subtours are less common in our study, as they typically imply a work-based small tour during the lunch break in a full-time working day. Yet, it may explain the relevance of secondary tours, which are typically compatible with a part-time work.

Several social and gender sciences underline how care labour plays a key role for the wellbeing of care recipients, but it may have mixed effects on the wellbeing of caregivers (Offer & Schneider, 2011). For instance, the MoC is positively associated with wellbeing when adults interpret it as part of being a good parent (McLaren, 2018), or when seniors see it as a chance for social interaction (Chizzali et al., 2025). In contrast, the MoC may deteriorate wellbeing when it increases time and logistic pressure (Fong & Atiyya Shaw, 2024), makes work-life balance harder (Gilow, 2020), or decreases personal time available for leisure (Zhang & Song, 2024). Although our empirical results do not cover the topic of wellbeing, they still provide nuances that can be linked to this topic. For instance, our MCAs show that unemployed older people undertake most care activities in simple primary tours (home-care-home). This logically relates to their age and employment condition, but it may suggest something on the meaning attached to care activities, being the major and single scope of a tour and not a minor stop within a chain. Opposite reflections might apply to employed people in large households, consistently with literature. For them, chaining care activities within multipurpose tours is common, and complex tours including care activities often do not include leisure activities. This pattern may be indicative of the time and logistic pressure they experience, which reduce opportunities for leisure and may negatively affect personal wellbeing.

5.2. *Policy implications*

5.2.1. *Main target groups and their needs*

Findings above stimulate a discussion also around implications for policies, which could help making the MoC less burdensome and car dependent. To discuss such policies, it may be useful to first identify target groups reflecting different MoC trip-chaining patterns (implying different policy needs).

(1) *People performing most care activities in simple primary tours*: Association analyses show that especially unemployed older adults in small households are observed to perform care activities as their primary activity within a simple primary tour (i.e. home-care-home). However, this applies also to females in general, since they are (i) more associated than males with care as P

activities, (ii) sharply more connected than males to care-home and home-care trips, and (iii) clearly more linked than males to C1 tours including care activities (home-care-home). This group may especially need e.g. care facilities within active-travel distance from residential locations, in line with an idea of accessibility by proximity given by e.g. the 15-minute city concept (e.g. Moreno et al., 2021).

(2) *People performing several care activities in complex primary tours*: Association analyses show that especially employed (younger and male) adults in larger households often undertake care activities as secondary activity within complex primary tours, where care activities are chained before or after their primary activity (e.g. home-care-work-home; home-work-care-home). This group might more typically need to find care facilities in the surrounding of their commuting destinations, or in the nearby of main transit nodes, so as to ease trip chaining and reduce detour (e.g. Cervero et al., 2002). Moreover, Ravensbergen et al. (2023) highlight that such caregivers often need to travel while transporting people and/or items (such as grocery bags or prams carrying children).

(3) *People performing some care activities in simple secondary tours*: Association analyses show that diverse users perform their care activities in simple secondary tours, which precede or follow the primary tour (e.g. home-work-home-care-home). In particular, females are more associated with such secondary tours for care. For this target group, the issue of e.g. temporality gains high relevance, as secondary tours are often more time-constrained as performed before or after other primary tours with typically rigid schedule (e.g. home-work-home). In this case, e.g. the time availability of care amenities (like opening hours of grocery stores) might be very influent and condition the ability of people to access care facilities (e.g. Delafontaine et al., 2011).

5.2.2. Sample MoC-related policies

To address the needs of these target groups, several policies affecting e.g. the land-use system, transport system, the times of the city, and even the digitalisation of services could be implemented (also based on the results from previous MoC works). Below we provide some examples.

First, specific data about the MoC should be systematically gathered to properly identify mobility patterns and needs of both caregivers and care recipients (Kim, 2025; Ravensbergen et al., 2023). In this way, transport planning and modelling can effectively understand, consider and prioritise the MoC (Smith et al., 2025). To this end, also the typical activity and trip purposes defined in mobility surveys should be rearranged to better reflect the MoC concept. As mentioned in Section 4.1.2, this is not a straightforward task, especially if one wants to intercept even less evident self-care activities, as well as care activities conducted at home (Orjuela & Schwanen, 2023).

Second, as regards public transport, a regular scheduled public transport service to reach care-related destinations (e.g., schools, grocery stores, healthcare facilities, bank and pharmacies) should be planned (Smith et al., 2025). Moreover, public transport lines should be designed so that accessibility to these locations is ensured (Ravensbergen et al., 2023). If the travel demand for such a service is limited from a spatial and temporal dimension, Demand-Responsive Transport should be provided, in particular for ensuring access to healthcare facilities (Wolfe & McDonald, 2020). As an alternative, grouping multiple healthcare facilities in the same location could justify the introduction of dedicated transit lines serving these facilities (Villamizar Duarte et al., 2025). Furthermore, as chained care trips typically exhibit a higher complexity than those performed for other purposes, travel-time-based fares should be avoided resulting in more cost-effective transit trips (Ravensbergen et al., 2023). In addition, fare capping could provide a high flexibility when travellers have to take multiple stops (Smith et al., 2025). Lastly, taxi and ride-hailing vouchers could be introduced to ensure MoC for low-income users (Kim, 2025).

Third, public transport vehicles should be equipped with dedicated space for dependents, groceries or strollers, with clear benefits for care travel requiring these items (Smith et al., 2025). Well-maintained sidewalks, convenient access to building entrances and transit vehicles with wheelchair spaces could improve the quality of MoC travels (Kim, 2025). Beside such measures fostering car-free MoC for most of the users, car-related measures may be needed to support very specific target groups. For instance, accessible parking spaces close to care facilities should be reserved to people who must rely on car to fulfil their care duties, such as adults escorting disabled seniors to healthcare facilities (Kim, 2025). Apart from transport-specific measures, even land-use strategies may support car-free MoC. For instance, care facilities might be located in proximity of residences, and/or close to big employment hubs. The former strategy eases independent mobility of care recipients like children and seniors and fosters simple secondary tours performed before or after simple primary tours for employed caregivers. The second strategy makes complex primary tours with chains less burdensome for caregivers, as chains are simpler and detours are minimised (Villamizar Duarte et al., 2025). It is important to notice that these two strategies might be contradictory, especially in areas with a strong zooning (i.e. separation of functions like living and working in monofunctional locations). However, they can also be complementary. For instance, small care amenities like primary schools and general practitioners could be located close to residents, while large care facilities such as hospitals might be close to employment hubs. At the same time, these strategies might differently respond to the temporal and spatial constraints of caregivers. For example, caregivers who work full time and have long commutes may find it more convenient to access care services near their workplace right after work, since those services might be closed by the time they get home in the evening. The same might apply to people living in rural areas and working in urban centres, who might prefer to access urban care amenities (e.g. big grocery stores with broad product variety), given a potential lack of the same amenities in the nearby of their rural homeplace.

Finally, even digital solutions (Dianin & Ceccato, 2026) and temporal policies may make the MoC less burdensome. For instance, home delivery of products like grocery bags and pharmaceuticals may relieve travellers of the need to chain care activities, although they may have other side effects (e.g. Jamal et al., 2025). The same applies to digital banking, healthcare and postal services that reduce the need for care trips (e.g. Le et al., 2022). Temporal policies and so-called "city time plans" may also contribute, improving temporal compatibility between e.g. work, care and leisure in the daily life of people, especially parents with children (TUI, 2025). In this regard, the city of Turin developed its own "Plan of City Times and Schedules" decades ago (Belloni, 1984; Comune di Torino, 2001). Moreover, in 2024 the City adopted the so-called "Plan for Families" (Piano per le Famiglie; TorinoClick, 2024) to support households of one or more adults taking care for minor(s).

5.3. Limitations of the study

The results of our analyses must be interpreted considering also some limitations. The most relevant ones are listed and discussed below.

(1) ***Identification of care activities in our dataset*:** Our travel diary survey was not designed with the MoC concept in mind. Therefore, we had to transform our original activity classification also by means of some hypotheses for the activity purposes 11, 12 and

13 in Table 7 (transformations based on previous relevant literature like De Madariaga, 2013; and De Madariaga & Zucchini, 2019). This last assumption has been addressed in the sensitivity analysis reported in Section 4.3. The related results show that our MoC trip-chaining findings remain generally stable, although the prevalence of care activities, care trips, and tours with at least one care activity over the total registers relevant variability. To address this limitation, future travel diary surveys should be structured considering the MoC, so as to enable a more straightforward distinction between care, leisure and work even in the most ambiguous cases (like shopping for pleasure vs shopping for household upkeep).

(2) ***Alternatives to descriptive analyses and MCA*:** In this work we used descriptive analyses and MCAs since our purpose was explorative. We aimed to describe how the MoC is embedded in daily trip chains by going beyond the simplistic distinctions of previous MoC studies thanks to the establishment of more articulated trip-chaining categories, based on relevant literature. However, this descriptive and explorative approach represents only a first step that can serve as basis for e.g. future modelling works. As example, tour-based and day activity schedule models (e.g. Ben-Akiva & Bowman, 1998; Dong et al., 2006) may better capture the sequential and decision-dependent structure of daily travel and model travel behaviour accordingly. Therefore, they may be used in future works to understand e.g. how the MoC influences the daily modal choices of individuals based on its role within daily trip chains and tours.

(3) ***Impossibility to infer causalities through MCAs*:** The MCAs used in our work report associations between variables, but they do not allow causal inferences (Diana, 2014; Greenacre, 2007). We decided to use the MCA due to its capacity to study statistical interdependencies between non-continuous variables, like those addressed in this study. Indeed, we applied it to observe correlations between types of trip-chaining patterns (categorical variable) and selected sociodemographic, geographic, and transport variables (also categorical). Starting from this preliminary step, future studies can attempt to verify causal relations potentially relevant for the MoC, like the potential influence of a given employment condition on a specific trip-chaining pattern.

(4) ***Influent factors overlooked in this work*:** Our MCAs focus on selected sociodemographic, geographic and travel factors. These variables have been selected based on previous MoC literature, by choosing those that have been most frequently mentioned as relevant in shaping the routine of caregivers (e.g. De Madariaga & Zucchini, 2019; Porath & Galilea, 2025; Ravensbergen et al., 2023). However, further variables would be relevant. They include individual-level factors such as car ownership rate, income, migrant background; as well as context-level factors like availability of childcare facilities, density of grocery stores, and other proxies of the degree of accessibility to care amenities. Future works may try to address these factors, so as to investigate e.g. how the availability and spatial distribution of care services in the land-use system may influence the way the MoC is integrated into daily trip chaining.

(5) ***Categorisation of trip-chaining patterns*:** Our analyses rely on a trip-chaining categorisation defined based on previous literature. Therefore, our results intrinsically depend on our categorisation and other approaches could lead to other results. Moreover, our trip-chaining categorisation clearly reduces the wide array of real-world chaining patterns to 10 categories. This implies a partial loss of the complexity of real-world mobility patterns, which must be considered. However, similar simplifications are applied in several other studies on trip chaining that we used as basis also for our approach (see especially Ortúzar & Willumsen, 2024; Primerano et al., 2008; Schneider et al., 2021). Moreover, the approach used in this study is significantly more articulated than the ones used in previous MoC works, which mostly distinguish only between chained and non-chained trips, or between simple and complex chains (e.g. Abdelhalim et al. 2024; Li & Widener, 2025; Ravensbergen et al. 2023; Shuman et al. 2023).

(6) ***Dataset regarding diaries from 2016–2017*:** Our dataset is nearly ten years old. As a consequence, our results cannot reflect mobility trends emerged in the last years, especially after the Covid-19 pandemic. This may include e.g. the widespread of teleworking or the development of cycling infrastructures and public-transport services boosted especially by the EU Recovery Fund (NextGenerationEU). Despite these developments, the overall need to perform care activities in daily routine and the tendency to chain them with other purposes is highlighted by several studies based on datasets from diverse periods (like De Madariaga, 2013; Hernández & de los Santos, 2020; Porath & Galilea, 2025). Therefore, our results may still be interesting to consider. To address this limitation, future MoC studies may use our approach to e.g. compare trip-chaining patterns before and after the Covid-19 pandemic, by taking travel diaries surveys performed in different moments but in the same area.

6. Conclusions

Despite the increasing research on the MoC characteristics and needs, analytical evidence about the role of the MoC in daily trip chaining is still limited. This study addressed this gap by: (a) defining an own categorisation of activities, trip segments, trip chains and tours inspired from literature; and (b) applying it to the MoC to explore its role. Following this approach, this work aimed to offer a deeper understanding of the role of the MoC in daily trip chaining, which is an important starting point to estimate its potential influence on daily mobility as a whole.

Empirical results align with previous research, although they offer a higher granularity regarding *how* the MoC is chained in daily routines. These results have implications especially for policymaking, as well as they raise new questions. For instance, they stress the importance of developing policies that make it easier to chain care activities on the way back home after work by collective means of transport. This may imply the development of e.g. optimised locations of care facilities in the nearby of employment hubs or transit nodes, transport fares that ease trip-chaining strategies, or working arrangements that promote temporal flexibility. Another point is the role of secondary tours headed to care activities undertaken before or after primary tours. In that case, increasing the temporal flexibility of opening hours of care facilities, and providing alternative forms of digital access may be strategic. Finally, the association between residential location in the belt area and simple tours without chains raises questions like: to what extent does the spatial density of care opportunities foster trip chaining? Why do sample members living in the belt area chain care activity less even if this would help them cope with longer daily commutes? Is there a connection

between centrality/peripherality and distribution of caregiving responsibilities (and trips) across household members?

Starting from these considerations, future research might develop in multiple directions. First of all, in order to address the assumptions discussed in the limitations, travel diary surveys could be developed by bearing the MoC in mind. This means that potentially ambiguous purposes like "shopping" or "visiting relatives" should be specified more clearly to indicate whether they are undertaken to enjoy free time (flexible activities), or to take care for others (mandatory and maintenance activities). Moreover, the explorative approach used in this study could be extended to a broader area (e.g. an entire country) to verify the generalisability of our findings and even examine broader geographic variability of MoC trip chaining (e.g. between urban and rural settings). Yet, trip-chaining strategies could be qualitatively discussed with a smaller sample of individuals, to understand the main determinants that lie behind certain choices (e.g. complex primary tours vs simple secondary tours). Finally, modelling approaches could be deployed to e.g. estimate the influence of the MoC on diverse daily mobility choices (e.g. mode, destination, route).

Data availability

Data presented in this paper is available by the authors upon reasonable request.

CRediT authorship contribution statement

Alberto Dianin: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Riccardo Ceccato:** Writing – review & editing, Writing – original draft, Validation, Methodology, Data curation, Conceptualization. **Marco Diana:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Contingency table of trip segments by purpose (rows) and trip-chaining category (columns). See related Fig. 7 in Section 4.2

	Home-Primary (H-P)		Primary-Home (P-H)		Home-Secondary (H-S)		Secondary-Home (S-H)		Primary-Secondary (P-S)		Secondary-Primary (S-P)		Secondary-Secondary (S-S)		Total	
	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share
Care*-Home (cr-hm)	–	–	895	13 %	–	–	361	5 %	–	–	–	–	–	–	1256	18 %
Home-Care* (hm-cr)	930	14 %	–	–	231	3 %	–	–	–	–	–	–	–	–	1161	17 %
Home-Work (hm-wr)	955	14 %	–	–	17	0 %	–	–	–	–	–	–	–	–	972	14 %
Leisure-Home (ls-hm)	–	–	595	9 %	–	–	274	4 %	–	–	–	–	–	–	869	13 %
Work-Home (wr-hm)	–	–	841	12 %	–	–	11	0 %	–	–	–	–	–	–	852	12 %
Home-Leisure (hm-ls)	611	9 %	–	–	219	3 %	–	–	–	–	–	–	–	–	830	12 %
Work-Care* (wr-cr)	–	–	–	–	–	–	–	–	109	2 %	1	0 %	4	0 %	114	2 %
Home-School (hm-sc)	110	2 %	–	–	3	0 %	–	–	–	–	–	–	–	–	113	2 %
Leisure-Leisure (ls-ls)	–	–	–	–	–	–	–	–	46	1 %	40	1 %	19	0 %	105	2 %
School-Home (sc-hm)	–	–	98	1 %	–	–	1	0 %	–	–	–	–	–	–	99	1 %
Work-Leisure (wr-ls)	–	–	–	–	–	–	–	–	96	1 %	0	0 %	3	0 %	99	1 %
Care-Care* (cr-cr)	–	–	–	–	–	–	–	–	54	1 %	27	0 %	11	0 %	92	1 %
Leisure-Care* (ls-cr)	–	–	–	–	–	–	–	–	38	1 %	33	0 %	11	0 %	82	1 %
Care*-Leisure (cr-ls)	–	–	–	–	–	–	–	–	42	1 %	28	0 %	10	0 %	80	1 %
Leisure-Work (ls-wr)	–	–	–	–	–	–	–	–	0	0 %	59	1 %	2	0 %	61	1 %
Care*-Work (cr-wr)	–	–	–	–	–	–	–	–	0	0 %	29	0 %	1	0 %	30	0 %
Others[1]	–	–	–	–	–	–	–	–	19	0 %	10	0 %	0	0 %	29	0 %
Total care*[2]	930	14 %	895	13 %	231	3 %	361	5 %	252	4 %	118	2 %	37	1 %	2824	41 %
Total	2606	38 %	2429	35 %	470	7 %	647	9 %	404	6 %	227	3 %	61	1 %	6844	100 %

Notes: – Not possible by definition; *Relevant rows for the topic of the MoC;[1]This row sums up origin-destination couples with less than 10 occurrences each; [2]This row sums up origin-destination couples having care activities as origin and/or destination.

Appendix B. Contingency table of tours by purpose (rows) and trip-chaining category (columns). See related Fig. 10 in Section 4.2

	Primary tour without subtour								Primary tours with subtour						Secondary tour				Total	
	Simple		Complex						Complex						Simple		Complex			
	C1: Chained P during H		C2: Chained S before P		C3: Chained S after P		C4: Chained S before & after P		C5: Chained P during H		C6: Chained S before P		C7: Chained S after P		C9: Chained S during H		C10: Chained S during H			
	H-P-H		H-{S}-P-H		H-P-{S}-H		H-{S}-P-{S}-H		H-[P]-H		H-{S}-[P]-H		H-[P]-{S}-H		H-S-H		H-{S-S}-H			
	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share
hm-cr*-hm	837	27 %	–	–	–	–	–	–	–	–	–	–	–	–	136	4 %	–	–	973	32 %
hm-wr-hm	771	25 %	–	–	–	–	–	–	–	–	–	–	–	–	7	0 %	–	–	778	25 %
hm-ls-hm	538	17 %	–	–	–	–	–	–	–	–	–	–	–	–	86	3 %	–	–	624	20 %
hm-sc-hm	95	3 %	–	–	–	–	–	–	–	–	–	–	–	–	1	0 %	–	–	96	3 %
hm-wr-cr*-hm	–	–	1	0 %	90	3 %	–	–	–	–	–	–	–	–	–	–	3	0 %	94	3 %
hm-cr-cr*-hm	–	–	25	1 %	53	2 %	–	–	–	–	–	–	–	–	–	–	7	0 %	85	3 %
hm-ls-ls-hm	–	–	31	1 %	41	1 %	–	–	–	–	–	–	–	–	–	–	4	0 %	76	2 %
hm-wr-ls-hm	–	–	0	0 %	72	2 %	–	–	–	–	–	–	–	–	–	–	1	0 %	73	2 %
hm-cr*-ls-hm	–	–	20	1 %	38	1 %	–	–	–	–	–	–	–	–	–	–	3	0 %	61	2 %
hm-ls-cr*-hm	–	–	26	1 %	30	1 %	–	–	–	–	–	–	–	–	–	–	4	0 %	60	2 %
hm-ls-wr-hm	–	–	43	1 %	0	0 %	–	–	–	–	–	–	–	–	–	–	0	0 %	43	1 %
hm-cr*-wr-hm	–	–	18	1 %	0	0 %	–	–	–	–	–	–	–	–	–	–	0	0 %	18	1 %
Others[1]	–	–	15	0 %	33	1 %	36	1 %	7	0 %	2	0 %	1	0 %	–	–	1	0 %	95	3 %
Total care*[2]	837	27 %	97	3 %	228	7 %	28	1 %	3	0 %	2	0 %	0	0 %	136	4 %	18	1 %	1349	44 %
Total 1[3]	2241	73 %	179	6 %	357	12 %	36	1 %	7	0 %	2	0 %	1	0 %	230	7 %	23	1 %	3076	100 %
Total 2[3]	2813 (91.4 % of all tours)								10 (0.3 % of all tours)						253 (8.2 % of all tours)					

Notes: – Not possible by definition; *Relevant rows for the topic of the MoC;[1]This row sums up tours with less than 10 occurrences each; [2]This row sums up tours comprising at least one care activity; [3]"Total 1" sums up tours for the 10 categories while "Total 2" sums up tours for the three aggregated macro categories; See Table 5 for details of trip-chaining categories C1–10.

Appendix C. Work, school, leisure activities (rows) belonging to tours with(out) care activities (columns). See related Fig. 11 in Section 4.2

	Activities belonging to a tour including at least one care activity												Activities belonging to a tour without any care activity	
	Primary tour without subtour						Primary tour with subtour				Secondary tour			
	Complex						Complex				Complex			
	C2: Chained S before P		C3: Chained S after P		C4: Chained S before & after P		C5: Chained P during H		C6: Chained S before P		C10: Chained S during H			
	H-{S}-P-H		H-P-{S}-H		H-{S}-P-{S}-H		H-[P]-H		H-{S}-[P]-H		H-{S-S}-H			
	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share	Count	Share
Work activ. (wr)	21	2 %	98	9 %	20	2 %	1	0 %	2	0 %	3	0 %	929	86 %
School activ. (sc)	0	0 %	9	8 %	2	2 %	0	0 %	0	0 %	0	0 %	105	91 %
Leisure activ. (ls)	55	5 %	75	7 %	27	2 %	4	0 %	1	0 %	8	1 %	950	85 %

Notes: Relevant cells for the topic of the MoC; See Table 5 for details of trip-chaining categories C1–10.

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