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Walking, trip purpose, and exposure to multiple environments: A case study of older adults in Luxembourg

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1 **Title:** Walking, trip purpose, and exposure to multiple environments: A case study of older
2 adults in Luxembourg

3

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18

19

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29

30 **Abstract (200–300 words)**

31 **Purpose:** Understanding the geographical and environmental triggers for active transport
32 among older adults is crucial to promote healthy and independent lifestyles. While
33 transportation research has long considered trip purpose as a major determinant of transport
34 mode choices, “place and health” research has paid little attention to it, and even less in
35 connection with environmental determinants. To avoid an oversimplification of how
36 neighborhood built environments influence utilitarian walking, it is critical to account
37 simultaneously for trip purposes, the locations of visited places, and the related exposure to
38 surrounding environments.

39 **Methods:** Based on a cohort of 471 older adults in Luxembourg, this study examines the
40 influence of trip purposes on utilitarian walking, and the potential interaction effects with
41 characteristics of multiple geographic environments and distance to the place of residence.
42 Information related to demographics, health status, and regularly visited destinations was
43 collected in 2015 and 2016. Associations between trip purpose, environment, distance, and
44 walking were analyzed using multilevel logistic regressions, accounting for demographics,
45 neighborhood self-selection, and health status.

46 **Results:** After accounting for environmental attributes, distance, and confounding factors, trip
47 purpose remained a strong correlate of walking among older adults. Associations between
48 distance and walking strongly differed by trip purpose (Wald Chi² test $p < .001$). Access to
49 amenities, public transport stops, and street connectivity were associated with walking,
50 although no interaction with trip purpose was observed.

51 **Conclusion:** Trip purposes based on free-time activities—including visits to family and friends,
52 and restaurants and cafés—seem to be less influenced by the barrier effect of distance on
53 walking. While place and health studies increasingly address both the “where” and “when” of

54 travel behaviors, the current study additionally stresses the importance of the trip purpose to
55 emphasize “why” and “for what” people walk.

56

57 **Keywords:** utilitarian walking, multi-place exposure, trip purpose, older adults, distance
58 traveled

59 **Highlights**

- 60 • Trip purpose is a key correlate of utilitarian walking among older adults
- 61 • Connectivity, access to public transport and amenities are associated with walking
- 62 • Environmental influence on walking does not vary by trip purpose
- 63 • Trip purpose modifies the association between distance and walking

64 **1. Introduction**

65 “There are many ways to walk”(Gatrell, 2011), depending on speed, intensity, or distance; each
66 being potentially explained by the purpose of the trip, in addition to the characteristics of the
67 person (physical capability, mood, etc.) and the walkability of her or his geographic life
68 environments. Recent literature on the effect of trip purpose on walking separates recreational
69 from utilitarian walking, (Lee and Moudon, 2006; Owen et al., 2004; Saelens and Handy, 2008;
70 Spinney et al., 2012) and shows that utilitarian bouts are shorter, faster, and occur in denser
71 environments (Kang et al., 2017). With regard to utilitarian walking, other research separates
72 commuting from multipurpose non-work trips (Carse et al., 2013; Cervero and Radisch, 1996;
73 Feuillet et al., 2016; Menai et al., 2015), which are more flexible in time and space (Krizek,
74 2003). The current study goes further, and investigates in greater depth the role played by trip
75 purpose in non-work utilitarian walking. The research is based on the specific population
76 segment of older adults. Due to the recent demographic shift, this group is gaining in
77 importance, which triggers changes in the built environment to enhance and maintain daily
78 mobility and independent lifestyles as people age (Dumbaugh, 2008). In addition to maintaining
79 physical functioning and independent mobility, active travel (i.e. walking or cycling) in old age
80 is further associated with reduced mortality rates (Cerin et al., 2017), as well as lower risks of
81 cognitive impairment, depression, dementia, cardiovascular diseases, and some cancers.
82 Shifting to a more active travel mode seems to provide greater overall health benefits to older
83 adults than to younger individuals (Cerin et al., 2017; Mueller et al., 2015).

84 As stressed by Sugiyama and colleagues (Sugiyama et al., 2018), “aging in place” is a crucial
85 component of the well-being of older adults, and—beyond the general idea of staying in a
86 familiar neighborhood—it relies on older adults’ ability to move outdoors and accomplish day-
87 to-day activities as shopping, recreational activities, or engaging in social interactions with
88 family and friends. The distance from home to engage in such types of activities typically

89 decreases with age, which underlines the importance of the residential neighborhood
90 environment in predicting short-distance, utilitarian walking trips (Cerin et al., 2017).
91 Identifying the environmental attributes that facilitate utilitarian walking could contribute to
92 inform urban planning interventions. Additionally, accounting for the purpose of walked trips
93 (i.e. different types of errands or recreational activities), which may be influenced by different
94 environmental attributes, would allow urban planners to target neighborhoods with specific
95 characteristics.

96 It is well known that utilitarian walking is determined by trip characteristics such as the origin
97 and destination, distance, and walkability of the environment (Lee and Moudon, 2006; Moudon
98 et al., 2007; Owen et al., 2004). However, the nature of the trip purpose itself may impose
99 additional physical or time-space constraints on walking that need to be accounted for (specific
100 clothing, goods to carry, opening hours, etc.). Transport research has long recognized the effect
101 of trip purpose on the choice of travel mode (Hatamzadeh et al., 2014; Krizek, 2003; Mackett,
102 2003), but there is little understanding of how trip purpose interacts with the other
103 environmental or spatial determinants of utilitarian walking to shape active transportation
104 patterns. Scheepers and colleagues (Scheepers et al., 2013) reported an effect of the interaction
105 between trip purpose and the level of urbanity on non-motorized travel. However, they
106 considered an aggregate environmental typology and solely focused on the residential
107 environment, thus providing only an incomplete picture of the linkage between exposure to
108 environments during a trip, its purpose, and the mode of transport. There is also seldom any
109 evidence of heterogeneity in the relationship between distance and utilitarian walking
110 depending on trip purpose (Dijst and Vidakovic, 2000; Hatamzadeh et al., 2014; Susilo and
111 Dijst, 2009; Yang and Diez-Roux, 2012), and no study has systematically examined the
112 variations by trip purpose on the determinants of walking while accounting for both residence
113 and destination environments.

114 Various classifications of trip purpose have been used in travel studies (Engstrom, 2014;
115 Krizek, 2003). These range from using three or four classes (i.e. work, study, or shopping)
116 (Hatamzadeh et al., 2014; Larranaga and Cybis, 2014; Scheepers et al., 2013; Yang and Diez-
117 Roux, 2012), to more-refined categorizations (i.e. shopping, appointments, personal, college,
118 free time, visiting, work, or school) (Krizek, 2003; Mackett, 2003; Manaugh and El-Geneidy,
119 2012; Millward et al., 2013; Susilo and Dijst, 2009). Some authors contrast activity types
120 between major anchor points (e.g. home, work) and minor locations (e.g. restaurants, banks,
121 shops, etc.) (Flamn and Kaufmann, 2004), while others distinguish between mandatory and
122 discretionary activities, between fixed and flexible activities (Hägerstraand, 1970), or between
123 habitual, planned and spontaneous in space and time (Gärling et al., 1998). Building on time-
124 geography (Dijst, 2009), transport (Flamn and Kaufmann, 2004; Hägerstraand, 1970; Mackett,
125 2003), activity-based approaches (Krizek, 2003), and epidemiology (Hatamzadeh et al., 2014;
126 Larranaga and Cybis, 2014; Millward et al., 2013; Scheepers et al., 2014, 2013; Yang and Diez-
127 Roux, 2012) research lines, we opted for a categorization of non-work trip purposes that could
128 constrain or enhance walking among older adults (Table 1).

129 In this study, we explore three hypotheses, based on precise geographical information about
130 participants' regular destinations, the corresponding transportation mode, and the trip purpose:
131 First, *ceteris paribus*, trip purpose is an independent correlate of utilitarian walking (H1).
132 Second, the associations between environmental attributes surrounding participants'
133 destinations and walking vary by trip purpose (H2): depending on the purpose, individuals
134 might be more or less sensitive to the walking-friendly attributes of neighborhood
135 environments. Third, the association between the distance travelled and walking varies
136 depending on the trip purpose (H3), as the barrier effect of distance on walking may vary
137 according to the type of activity realized at the destination.

138

139 **2. Methods**

140 2.1. Population

141 Our data is taken from a cross-sectional study in Luxembourg, initiated within the CURHA
142 project (Contrasted Urban contexts and Healthy Ageing) (Kestens et al., 2016a). In total, 471
143 participants aged 65 years and above were sampled between April 2015 and January 2016. The
144 sample was assembled randomly from Social Security files and stratified by age and gender,
145 and along spatially contrasted strata representing different degrees of urbanity (Figure 1). Each
146 participant completed two face-to-face questionnaires: the LuxCohort questionnaire focusing
147 on self-reported socio-demographic data, health, well-being, perception of residential
148 neighborhood, and overall physical activity habits; and the VERITAS questionnaire
149 (Visualization and Evaluation of Route Itineraries, Travel destinations, and Activity Spaces)
150 (Chaix et al., 2012b), allowing identification and geolocation of the participants' regularly
151 visited destinations and associated transport modes. The actual routes traveled between
152 residence and destinations were not reported.

153 2.2. Measurements

154 *Utilitarian walking.* In the VERITAS survey, participants reported their usual mode of transport
155 to reach each regular destination.

156 *Regularly visited destinations and trip purposes.* The term “destination” refers to a non-
157 residential location visited by a participant to perform an activity, and “trip purpose” refers to
158 the main activity performed at the given location. During the VERITAS survey, participants
159 were invited to report and geolocate regular destinations visited for 19 different purposes. We
160 subsequently re-ordered these into eight categories based on the classification detailed in Table
161 1. Details of the number of items per category and the walking probability are presented in

162 Table 2. Due to the small number of reported locations, work as trip purpose was not analyzed,
163 and free-time sports and non-sports activities were merged.

164 *Environmental measurements.* Exposure to multiple environments was assessed within
165 buffered line-based network buffers (Oliver et al., 2007), computed around the residence of the
166 participants, their regular destinations, and the shortest route between locations. The buffer size
167 was set at 30 meters from the street segments reachable within a 10-minute walk. Walking
168 speeds were adjusted for uphill and downhill directions: with final values from 4.4 km/h for a
169 slope of 0–2 percent, to 2.0 km/h for a slope greater than 10 percent (Carre and Julien, 2000)
170 (Appendix 1). The 30 meter threshold was chosen in order to include adjacent plots and
171 buildings, while avoiding inaccessible ones. We merged exposure areas (buffers) around the
172 place of residence, around each regular destination, and around the shortest route between the
173 residence and each destination; overlaps between buffers were removed. Five environmental
174 variables were computed based on past evidence concerning the main components of the built
175 environment influencing travel behaviors, as suggested by Ewing and Cervero (Ewing and
176 Cervero, 2010) and based on the increasing interest in research about the effect of greenness on
177 walking (Sarkar et al., 2015): number of amenities, diversity of amenities, street connectivity,
178 number of public transport stops, and an index of greenness (see Table 3). All the environmental
179 variables were estimated using ArcMap 10.5 and PyScripiter 3.2 software programs.

180 *Distance to activity places.* The street network distance from the place of residence to each
181 destination was calculated using the shortest route. Distance was computed as a continuous
182 time-distance variable based on walking speed.

183 *Individual covariates.* Several socio-demographic factors were considered: age (continuous),
184 sex, education (none, primary, secondary, or post-secondary), marital status (living alone or
185 living as a couple), and having a valid driving license. A composite score of physical health
186 was computed based on the Medical Outcome of the 36-Item Short Form Health Survey (SF-

187 36).(Health et al., 2016) Mental health was evaluated using the geriatric depression score and
188 categorized as either “no depression,” or “suggestive, to indicative of depression.”
189 Neighborhood self-selection (Handy et al., 2006; McCormack and Shiell, 2011; Van Dyck et
190 al., 2011) was evaluated using three variables. Participants reported whether when they moved
191 to their current residence they considered it important to live in a neighborhood that was i)
192 pleasant to walk in, ii) well served by public transport, and iii) convenient for driving (ease of
193 parking, not too much traffic, good accessibility by car).

194 2.3. Statistical analyses

195 *Analytical sample.* From the initial sample of 471 participants and 5,080 geolocated activity
196 places, we excluded 94 participants who reported physical limitations to walking more than 100
197 meters, 6 participants who reported no residence or destinations, and 21 participants for missing
198 values. Of the 4,179 remaining destinations, 53 were located outside Luxembourg and were
199 ignored. As we focus on utilitarian walking, we only considered regular destinations within a
200 60-minute walking distance from of each participant’s residence. The final sample includes 342
201 participants and 2,433 destinations.

202 *Regression models.* Considering each destination of participants with the corresponding mode
203 of transport as the unit of analysis, we modeled the probability of reporting walking as the usual
204 way to reach a destination. To evaluate associations between environment, trip purpose,
205 distance, and walking, we estimated several multilevel logistic models, using Laplace
206 approximation from the Glimmix procedure in SAS 9.4.

207 Since individuals reported multiple destinations, random effects account for the within-
208 individual correlation in travel mode choice. Individual covariates were tested separately as
209 potential confounders and excluded when not significant (p-value >0.05), except for age and
210 sex, which were retained in all models. Each variable was first examined separately in a

211 bivariate regression with the Loess procedure (SAS 9.4) to visualize the shape of the
212 relationship between each effect and walking, and to identify potential nonlinearities. Different
213 continuous modeling approaches were tested, including linear, quadratic, and linear spline with
214 two or three knots (Lamb and White, 2015). Models were compared using the Akaike
215 Information Criteria (AIC). We then tested the association between trip purpose and walking
216 (H1), accounting for distance, environmental variables, and confounding factors in the same
217 model (see Model A). Lastly, we tested one by one the potential multiplicative interactions
218 between trip purpose and i) each environmental variable (H2), and ii) distance to the residence
219 (H3). Only statistically significant interaction terms were retained after a type III test of fixed
220 effects (Wald Chi² p-value <0.01) comparing the models with and without interactions (see
221 Model B). A parsimonious modeling approach was chosen, thus environmental quadratic
222 transformations or spline knots were removed from the full model when not significant (p-value
223 <0.05), either as an independent effect on walking or as an interaction effect with trip purpose.

224 **3. Results**

225 The regular destinations, study population, and environmental characteristics are presented in
226 Table 2, Table 4, and Table 5 respectively. Some 47 percent of the participants were female, 52
227 percent reported having a secondary education level, and 34 percent were living alone.
228 Participants reported a mean number of 7.11 (SD: 3.94) destinations. Among the 2,446
229 destinations, 41 percent were reached by walking. “Personal” trip purpose was the most
230 prevalent category (24 percent), followed by “daily shopping” (16 percent), and “health
231 appointment” (16 percent). “Visit to family and friends” and “daily shopping” were the most
232 walked activities (52 and 46 percent, respectively). Out of all the destinations, 53 percent were
233 located within a 20-minute walk of the place of residence. The mean time-distance from the
234 residence to all destinations reached by walking was 11 minutes (SD=9.52). The mean time-
235 distance walked varied from 13 minutes (SD=10.90) for the “health appointment” trip purpose,

236 to 9 minutes (SD=5.86) for “heavy goods shopping.” These results are in line with the 10-
237 minute buffer size defined around each residence and destination.

238 Among the confounding factors tested, education level, marital status, geriatric depression
239 score, having a valid driving license, and neighborhood self-selection related to public transport
240 services and car use, were kept in full model.

241 3.1. Distance, environment, and walking

242 Table 6 presents the associations between distance, environment, and walking, after adjusting
243 for confounding factors. Looking at the environment, the odds of walking were positively
244 associated with the number of amenities ($\beta=0.006$; $SE=0.002$) and negatively associated with
245 the number of public transport stops ($\beta=-0.030$; $SE=0.013$) (Model A). Street connectivity
246 ranging from 0 to 8 intersections was positively associated with the odds of walking ($\beta=0.176$;
247 $SE=0.059$) while above 8 intersections, we observe a negative correlation coefficient $\beta=-0.015$
248 ($\beta=0.176-0.191$; with 0.176 indicating the slope before the knot and 0.191 indicating the
249 difference in slopes before and after the knot). An increase of 5-minutes in the walking distance
250 from the place of residence is strongly negatively associated with walking ($\beta=-0.189$;
251 $SE=0.010$) (Model A).

252 3.2. Trip purpose and walking

253 The probability of walking was found to vary according to the trip purpose, with the highest
254 value for “visit activity” (52 percent) and the lowest for “heavy goods shopping” (17 percent)
255 (Table 2). Even after accounting for confounding factors, environment and distance, a strong
256 association remained between trip purpose and walking ($p < 0.001$) (Model A). The odds of
257 walking to “visit to family and friends” were higher ($\beta=0.966$; $SE=0.338$) than the odds of
258 walking to conduct “personal activities.” The odds of walking to a “heavy goods shopping”
259 destination were much lower ($\beta=-1.826$; $SE=0.324$).

260 Interactions between trip purpose and environmental attributes are non-significant. However, a
261 strong heterogeneity is observed for the association between distance and walking depending
262 on the trip purpose (Wald Chi² test $p < .001$) (Model B). Figure 2 presents the odds ratios of
263 walking to a destination located 15 minutes from the place of residence compared with 10
264 minutes, by trip purpose. The odds ratio of walking to “restaurant” destinations was 0.513 (95%
265 CI: 0.428; 0.615), while for a “heavy goods shopping” destination it was 0.174 (95% CI: 0.097;
266 0.311). Overall, the odds of walking were low for “heavy goods shopping” and “daily
267 shopping,” and high for “restaurant,” “visit to family and friends,” “free time,” and
268 “appointment” (health related or not).

269

270 4. Discussion

271 4.1 The decision to walk depends on the trip purpose, irrespective of the distance and
272 environment

273 The trip purpose remains a major correlate of walking, after controlling for environment,
274 distance, and confounders. “Heavy goods shopping” was negatively associated with walking
275 compared with “personal” activities, which is highly understandable as the former implies
276 carrying heavy bags, thus favoring car use. Also in line with our first hypothesis, “visit” to
277 family and friends was positively associated with walking; it does not imply specific time-space
278 or physical constraints that affect the travel mode. Our results contribute to existing knowledge
279 by analyzing a more detailed trip purpose typology, which offers opportunities for future
280 generalizations by replication (Davis et al., 2011; Yang and Diez-Roux, 2012).

281 4.2. Walking is associated with multi-place environmental exposure

282 Three reviews have recently examined the role of different aspects of the built environment on
283 active travel among older people (Barnett et al., 2017; Carlin et al., 2017; Cerin et al., 2017).

284 Our results are consistent with numerous studies on walking among the elderly (Borst et al.,
285 2009; Cerin et al., 2017; Li et al., 2005; Maisel, 2016; Siu et al., 2012; Tamura et al., 2014; Van
286 Cauwenberg et al., 2012, 2011), and show a positive relationship between street connectivity
287 and utilitarian walking among those with a low street connectivity (up to eight intersections
288 within buffered line-based network buffers around the place of residence, the destination, and
289 the shortest route). The rationale is that greater street connectivity promotes walking (Chaix et
290 al., 2014; Rosso et al., 2011; Saelens and Handy, 2008) by providing more routes within a
291 neighborhood, more direct paths, and shorter walking distances to destinations. However, some
292 studies have obtained mixed results (Barnett et al., 2017; Nagel et al., 2008; Satariano et al.,
293 2010; Wang and Lee, 2010), which could explain the slightly negative correlation observed
294 with street connectivity above eight intersections.

295 We observed a slightly positive association between the number of amenities and walking,
296 while no relationship was observed with the diversity of amenities (Cerin et al., 2013; Chudyk
297 et al., 2015; Rosso et al., 2013). Other studies among older adults have reported positive
298 associations between walking and the perceived access to amenities (Cerin et al., 2014, 2013;
299 Salvador et al., 2010), or objective measurements of density or the number of amenities
300 (Chudyk et al., 2015; Etman et al., 2014; Hirsch et al., 2016), or with the use of
301 walking scores.(Frank et al., 2010; King et al., 2011; Wasfi et al., 2017). However, only a few
302 researchers have examined these associations within both residential and non-residential
303 neighborhoods (Chaix et al., 2017, 2016; Hirsch et al., 2016; Howell et al., 2017; Karusisi et
304 al., 2014; Perchoux et al., 2015; Tribby et al., 2015), and have reported differing results from
305 the varying methods used. Hirsh and colleagues found no association among older adults
306 between physical activity and the density of destinations measured within both “all-modes” and
307 “pedestrian and bicycling” GPS-defined activity spaces (Hirsch et al., 2016). By contrast, using

308 trip-level data, Chaix and colleagues observed a positive association between walking and the
309 density of services at the trip origin and the trip destination separately (Chaix et al., 2016).

310 The negative association between the number of public transport stops and utilitarian walking
311 was unexpected. In their meta-analysis, Barnett and colleagues observed significant evidence
312 among older adults of a positive association between access to public transport and total
313 walking (Barnett et al., 2017). Access to public transport stops provides an opportunity for less
314 car use, and tends to increase the overall level of physical activity by fostering active mobility
315 to and from public transport stops. However, since the survey only allowed participants to report
316 one unimodal transport mode, we were unable to evaluate a potential fine-grained increase in
317 walking, measured as walking time or walking frequency.

318 Further, no interaction between environment and trip purpose was observed, which invalidates
319 our second hypothesis: the associations between walking and the number of amenities, public
320 transport stops, or street connectivity do not depend on the trip purpose. This contrasts with the
321 results obtained by Manaugh and colleagues who found that the variance of walking explained
322 by residential-based walkability measurements changed in accordance with the trip purpose
323 (i.e. shopping vs. school) (Manaugh and El-Geneidy, 2011). Scheepers and colleagues observed
324 that shopping trips realized within urban centers were the most likely to lead to active transport,
325 compared with other trip purposes and other urbanity types (Scheepers et al., 2013). While their
326 study classified residential neighborhoods by the degree of urbanity, we examined multiple
327 environmental factors measured around both residence and regularly visited destinations. Our
328 results suggest that among older adults in Luxembourg, the influence of micro-scale
329 environments on walking does not vary by purpose.

330 4.3. Distance remains the key factor for walking and varies with the trip purpose

331 In the vast body of literature on transport mode determinants, distance is the key determinant
332 of walking, and our study is no exception. Nevertheless, there is much less research explicitly
333 devoted to interaction effects. Our results confirm our third hypothesis that there is a
334 multiplicative interaction between trip purpose, distance, and walking. We observed similar
335 results using trip-level analyses categorized by purpose; with shorter distances and durations
336 for meals and shopping (Yang and Diez-Roux, 2012). Our sorting by trip purpose suggests that
337 the likelihood of walking for mandatory activities such as “daily shopping,” “heavy goods
338 shopping,” or “personal” decreases as the distance increases. The underlying mechanism could
339 be that the physical constraint of carrying goods is reinforced with distance, favoring car use
340 even for short journeys. This is consistent with studies on the modifying effect of distance,
341 showing that distance tends to reinforce associations with some walking inhibitors (Panter et
342 al., 2010; Perchoux et al., 2017). More discretionary activities such as “free time,” “restaurant,”
343 and “visit to family and friends” are more likely to involve walking with increasing distance.
344 These activities are usually characterized by low physical constraints and high flexibility in
345 terms of space and time, which may give older adults the opportunity to engage in such activities
346 in optimal conditions (e.g. good weather, good mood, feeling physically well, having time, etc.)
347 and thus diminish the barrier effect of distance on walking. The relatively high probability to
348 walk to health appointment locations seems notably peculiar with regard to our hypothesis that
349 feeling unwell or being ill would be associated with a low probability to walk, and even more
350 so with increasing distance.

351 Overall, individuals seem to have a different sense of an “acceptable distance” (Rahul and
352 Verma, 2014) for walking, depending on the trip purpose (Hatamzadeh et al., 2014). The
353 acceptable distance by trip purpose was also investigated in relation to travel time and activity
354 duration. Travel time (and thus transport modes) was found to be positively related to
355 activity duration (Kitamura et al., 1998), but the travel time/activity duration relationship varied

356 by trip purpose (Susilo and Dijst, 2009). Mandatory activities showed a more unfavorable
357 balance between travel time and activity duration than discretionary activities (Dijst and
358 Vidakovic, 2000).

359 4.2. Strengths and Limitations

360 The relationship between trip purpose and transport modes has been little investigated in place
361 and health research, while it is well known within transport research. Using a multi-places
362 exposure approach, we investigated the environmental attributes around the place of residence
363 and the shortest route to regularly visited destinations among older adults. Systematically
364 testing the interactions between utilitarian walking and distance, environment, and trip purpose
365 constitutes one of the very few attempts to disentangle how space-time and physical constraints
366 imposed by trip purposes may modify the influence of well-known walking correlates
367 (Scheepers et al., 2013; Yang and Diez-Roux, 2012). Limitations include the fact that both
368 visited locations and the usual mode of transport were self-reported. In addition, environmental
369 conditions at the trip origin were disregarded, as we did not have data about the activity chaining
370 and the actual path between locations. We also ignored the potential confounding effect of the
371 transport mode used during the previous or next trip in the chain (Chaix et al., 2016), or of the
372 activity undertaken at the origin (Scheepers et al., 2014). Further, the time spent in each
373 destination and the frequency of visits were not considered, although they could weight the
374 environmental exposure of a trip. We did not distinguish between residential and non-
375 residential environments, since 52 percent of destinations were located within a 20-minute walk
376 of the residence and this would have resulted in overlaps of the exposure areas (i.e. buffers).
377 However, this might have led to a misestimation of the associations between environment and
378 walking, as associations between the residential/trip-origin environment and non-
379 residential/trip-destination environments may differ (Chaix et al., 2017; Lee et al., 2011).
380 Lastly, although we attempted to reduce self-selection in the transport modes available to a

381 person by including environmental preferences at the time of moving to a residential
382 neighborhood, selective daily mobility bias (Chaix et al., 2013; Perchoux et al., 2016) cannot
383 be ruled out.

384 4.3. The importance of walking purpose in place and health studies

385 Recent work has pushed the boundaries of place and health research by accounting for
386 individuals' daily mobility while evaluating neighborhood effects on health (Perchoux et al.,
387 2013; Shareck et al., 2014). This breakthrough has been supported by the increased use of
388 Global Positioning System (GPS) data, and has opened up new possibilities to refine the
389 assessment of daily exposure, visited locations, and transport mode (Brondeel et al., 2015;
390 Chaix et al., 2013; Kerr et al., 2012; Kestens et al., 2016b). While the current study does not
391 question the potential benefits of such types of data, our results stress the importance of taking
392 into account the purpose of conducted activities (Kestens et al., 2017). GPS data allows us to
393 answer the “where and when” (Kestens et al., 2017, 2016b), but it gives few meaningful insights
394 into the “why” and “what for,” or more specifically, the type of activities performed. The
395 physical and space-time constraints that apply to the realization of an activity at a specific
396 location may have an impact on the transport mode choice, and modify the influence of
397 transport-related correlates. Some authors have further recognized the role played by “social
398 relations” and “social networks” in the spatial distribution of activity places, travel behavior,
399 and transport modes (Axhausen, 2007, 2008; Carrasco et al., 2008; Kestens et al., 2017;
400 Perchoux et al., 2013). Accounting for the actual nature of the activity performed at a given
401 location—and why, and with whom—would allow examination of the transport mode choice as
402 part of a behavioral continuum in space and time, and not only as an isolated activity. In this
403 sense, our study puts into perspective the importance of “walking purpose,” which can be
404 assessed with GPS combined with body-worn cameras (Carlson et al., 2014) prompted
405 recall interviews (Chaix et al., 2012a), travel surveys (Kestens et al., 2010; Setton et al., 2011),

406 map-based questionnaires (Chaix et al., 2012b; Shareck et al., 2013), or travel or activity diaries
407 (Chudyk et al., 2015).

408 From a policy perspective, understanding the distribution of walking by purpose could be
409 translated into public health initiatives. For instance, strategies for designing walkable
410 neighborhoods could account for the type of activities that are found in each area. This is all
411 the more important with regard to increasing the cost-effectiveness of public health and land
412 use planning interventions, as budgets are limited and interventions are rarely implemented
413 homogeneously over space. Another implication would be to design interventions among older
414 adults aimed at increasing walking for specific trip purposes only, such as free-time and
415 recreational activities, or visits to relatives and friends. Further studies into the spatial
416 dependency of these walking-friendly trip purposes, and how destinations cluster over space
417 (or not), would thus geographically inform such interventions. This would constitute a “low-
418 hanging fruit” strategy compared with targeting other destinations, such as supermarkets, which
419 are less walkable destinations independent of the surrounding environment (Yang and Diez-
420 Roux, 2012), and more likely to be reached by motorized transport, even over short distances.

421

422 **5. Conclusion**

423 The current study contributes to the overall understanding of utilitarian walking among older
424 adults. By bridging concepts from time-geography, transport, and epidemiology, we examined
425 the role played by trip purposes on utilitarian walking, and the potential interactions with well-
426 known walking correlates—including environment and distance—in shaping active transportation
427 patterns. We have shed light on the differential barrier effects of distance on utilitarian walking
428 by trip purposes. Trip purposes characterized by low physical constraints and high flexibility in
429 space and time seem to be less influenced by the barrier effect of distance on walking. While
430 place and health studies increasingly address both the “where” and “when” of travel behaviors,

431 this study additionally stresses the importance of the trip purpose to address “why” and “for
432 what” people walk.

433

434

435 **References**

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Table 1. Trip purposes and their potential time-space and physical constraints

Trip purpose	Comments on the potential space-time and physical constraints
<p>Personal (e.g. banking, filling station, dry cleaning, etc.) (Krizek, 2003)</p>	<p>Personal activities have been defined as “getting a service done or completing a transaction”(Krizek, 2003). This category can encompass various activities, with low to medium physical constraints that inhibit utilitarian walking. While mandatory, these activities are relatively flexible in space, but limited in time by the opening hours of facilities.</p>
<p>Free-time activity (e.g. entertainment, theater, sport, church, library, exercise) (Krizek, 2003)</p>	<p>Free-time activities have been defined as “non-task-oriented activities”(Krizek, 2003). With regard to distance and duration, recreational activities (both “go to gym/exercise/play sports” and “rest or relaxation/vacation”) were the trip purposes with the highest probability to walk compared with other trip purposes (work, study, shopping, social event, and meals) (Yang and Diez-Roux, 2012). Walking distance and duration were also higher for recreation purposes than for other categories. We believe that an additional distinction between sports and non-sports activities is meaningful. Non-sports activities during free time are likely to be flexible in space and time. Sports activities may require specific clothing and equipment that could inhibit utilitarian walking (Scheepers et al., 2014). Looking at physical constraints related to energy expenditure, walking to or from a sports facility may be considered as either a warm-up/stretching exercise, or an excess expenditure of energy that is in competition with the sports activity itself, and should thus be avoided.</p>

Shop

Locations at which to “buy concrete things”(Krizek, 2003). Shopping is a mandatory activity that responds to specific physical needs. Different types of shopping places might, however, relate to different degrees of physical and spatial constraints.

Daily shopping: Shopping for small goods or the provision of daily requirements does not imply specific physical or temporal constraints. The flexibility in space and time of this activity, as well as the numerous shops in high accessibility neighborhoods, should facilitate utilitarian walking.

Heavy goods shopping: heavy goods shopping is usually realized in large stores, new commercial areas, and malls. Walking would require carrying heavy bags on the way back home (Mackett, 2003; Perchoux et al., 2015; Scheepers et al., 2014), and carrying heavy goods has been identified as the most common reason for car use on short trips (Mackett, 2003). Moreover, these activity locations are absent from high neighborhood accessibility areas due to the need for large parking areas and ease of car accessibility (Krizek, 2003).

Health appointments

Visiting a medical doctor is mandatory and usually associated with being, or perceiving oneself as being sick, which might negatively influence the ability to walk. “Feeling unwell” has been reported as an importance motive for car use (Mackett, 2003).

Other appointments

Appointments are usually fixed in space and time, and being “short of time” has been rated as the third main reason for using a car (Mackett,

(hairdresser, meeting, etc.) 2003). However, it is unlikely that non-medical appointments require a large amount of energy expenditure or physical constraints. Therefore, if there is reasonable time to travel to or from the appointment location, utilitarian walking should be possible.

Visiting family and friends Visiting relatives and friends, per se, is a discretionary activity, flexible in space and time, and should not require specific space-time or physical constraints. However, Mackett and colleagues observed that carrying “heavy goods” was the first reason to use a car for social trip purposes (Mackett, 2003).

Restaurant (e.g. café, restaurant, bar, etc.) Eating or drinking activities are discretionary, flexible in space and time, and should not imply specific space-time or physical constraints that limit utilitarian walking to or from a location. Some evidence shows that visiting “restaurants or bar” ranks as the fourth destination most likely to be reached by walking (single episode trip only) (Millward et al., 2013). However, Yang and Diez-Roux observed that 36 percent of walking trips were more than 10 minutes in duration and 5 percent more than 30 minutes (Yang and Diez-Roux, 2012), which represent the shortest durations and distances walked compared with other purposes (recreation, work, and shopping).

763 Note: This classification of type of activities is adapted from Krizek K. “Neighborhood
764 services, trip purpose, and tour-based travel”, *Transportation* 30:387-410, 2003.

Table 2. Characteristics of destinations reported in the VERITAS survey

Label	Trip purpose	Minimum frequency of visit	Maximum number of items to be geolocated	N	% Walked	% located within 20-min walk of the residence	Mean (SD) time-distance walked in minutes
Personal	ATM	at least once per month	1 item	582	44	58	10 (7.59)
	Bank	sometimes	1 item				
	Pharmacy	sometimes	3 items				
Free time	Cultural activity	over the last three months	3 items	310	44	53	12 (11.76)
	Sports activity	over the last three months	3 items				
	Spiritual, religious, or associative activity	over the last three months	3 items				
	Cemetery	over the last three months	3 items				
Daily shopping	Open market	at least once per month	1 item	401	46	60	10 (7.37)
	Bakery	at least once per month	1 item				
	Fruit store	at least once per month	1 item				
	Specialty food store	at least once per month	1 item				
	Small grocery shop	at least once per month	1 item				
Heavy goods shopping	Large supermarket	at least once per month	1 item	241	17	35	9 (5.86)
	Discount supermarket	at least once per month	1 item				
Health appointment	General practitioner	sometimes	1 item	382	41	49	13 (10.90)
	Medical specialist	sometimes	3 items				
	Other health professional not authorized to prescribe drugs	over the last six months	3 items				

Other appointments	Hairdresser or barber shop	sometimes	1 item	169	46	55	11 (8.18)
Visit	Visit to a person	at least once per month	3 items	134	52	59	10 (10.87)
Restaurant	Restaurant, bar, or café	over the last three months	3 items	227	33	43	13 (12.80)
Total	All	-	38 items	2446	40.60	52,46	11 (9.52)

Table 3. Description of environmental variables, treatment, and data sources

Variable	Geographic treatment	Source
Number of amenities	Number of amenities within the street network buffers. The categories of amenities include: open markets, supermarkets, garages, restaurants and cafés, bakeries, butchers, tobacco shops, newspaper kiosks, banks, ATMs, post offices, hairdressers, libraries, movie theaters, theaters, performance halls, swimming pools and gymnasiums, and parks and gardens	Luxembourg Institute of Socio-Economic Research (2013)
Diversity of amenities	Index ranking from 0 to 1, based on a formula from Youssoufi (Youssoufi, 2011), applied to Luxembourg by Glaesener et al. (Glaesener and Caruso, 2015), and representing the diversity of amenities within the street network buffer	Luxembourg Institute of Socio-Economic Research (2013)
Number of public transport stops	Count of public transport stops within the buffers	Luxembourg Institute of Socio-Economic Research (2014), Verkeiersverbond
Street connectivity	Count of intersections (three-way or more) within the street network buffers	Base de données topographique de l'Administration du Cadastre et de la Topographie (2008), and Open street map (2014)
Greenness index	Index ranking from 0 to 1, based on a formula from Klein et al., 2015. The Soil Adjusted Vegetation Index (SAVI) was derived from radiometric data from Red and Near Infrared bands. The SAVI values were classified in four greenness categories according to Jenks natural breaks. The different categories were weighted and used to calculate a green score	Landsat 8 reflectance data from June 2014, provided by the U.S. Geological Survey. The imagery is free of clouds

Table 4. Socio-demographic characteristics of the participants (N=342)

Variables	Categories	%
Age	65–71	29.24
	72–76	26.61
	77–81	23.98
	>81	20.18
Sex	Woman	47.37
	Men	
Education	Post-secondary	19.01
	Secondary	52.05
	None or primary	28.95
Marital status	Living alone	33.63
	Living as a couple	
SF-36 Physical Functioning	Score >80	72.81
Geriatric depression score	No depression	90.06
	Suggestive, to indicative of depression	9.94
Valid driving license		80.12
Importance of public transport services when moving to the residential neighborhood	Important	45.03
	Not important	54.97
Importance of the ease of using a car (parking spaces, not too much traffic, good accessibility by car) when moving to the residential neighborhood	Important	50.88
	Not important	49.12

Table 5. Environmental characteristics measured around the place of residence, each regularly visited destination, and the shortest route (N=2446)

Variables	Mean	(SD)	1st Quartile	2nd Quartile	3rd Quartile
Number of amenities	78.92	(86.68)	17	37	100
Diversity of amenities	0.77	(0.16)	0.78	0.82	0.84
Number of public transport stops	23.83	(14.90)	13	22	30
Street connectivity	19.12	(17.46)	5	13	30
Greenness index	0.17	(0.19)	0.10	0.15	0.23

Table 6. Associations between environmental characteristics, trip purpose, and utilitarian walking (N=2446)

	Model A Coefficient (SE)	Model B Coefficient (SE)
Environmental variables		
Number of amenities		
<i>1 amenity increase</i>	0.006 (0.002) **	0.006 (0.002) **
Diversity of amenities		
<i>10% of diversity increase</i>	-0.636 (0.702)	-0.632 (0.717)
Number of public transport stations		
<i>1 stop increase</i>	-0.030 (0.013)*	-0.028 (0.013)*
Street connectivity		
<i>(spline with 2 knots – 1 intersection increase)</i>		
<i>1st segment, 0–8 intersections</i>	0.176 (0.059)**	0.160 (0.061)**
<i>2nd segment, 8–90 intersections</i>	-0.191 (0.062)**	-0.170 (0.064)**
Greenness		
<i>10% greenness increase</i>	-0.411 (1.689)	-0.280 (1.721)
Distance (in minutes' walk)		
<i>Five minutes' walk increase</i>	-0.189 (0.010)***	-0.229 (0.022)***
Trip purpose		
<i>Personal</i>	ref.	ref.
<i>Free time</i>	0.455 (0.253)	-0.348 (0.478)
<i>Daily shopping</i>	-0.034 (0.226)	0.156 (0.478)
<i>Heavy goods shopping</i>	-1.826 (0.324)***	-0.140 (0.888)
<i>Health appointment</i>	0.280 (0.230)	-0.582 (0.450)
<i>Other appointment</i>	0.232 (0.313)	-0.177 (0.650)
<i>Visit to family and friends</i>	0.966 (0.338)**	0.155 (0.588)
<i>Restaurant</i>	-0.196 (0.284)	-1.774 (0.650)***
Interaction terms		
Trip purpose * Distance		
Wald Chi ² p-value for interaction		<.001
<i>Personal * distance</i>		ref.
<i>Free time * distance</i>		0.052 (0.025)*
<i>Daily shopping * distance</i>		-0.012 (0.028)
<i>Heavy goods shopping * distance</i>		-0.122 (0.061)*
<i>Health appointment * distance</i>		0.055 (0.024)*
<i>Other appointment * distance</i>		0.029 (0.036)
<i>Visit to family and friends * distance</i>		0.051 (0.030)
<i>Restaurant * distance</i>		0.095 (0.026)***
AIC	1824.33	1805.73

Note: All models are adjusted for age, sex, marital status, education, geriatric depression score, having a valid driving license, and neighborhood self-selection regarding car use and public transport.

* p-value <0.05; ** p-value <0.01; *** p-value <0.001

Figure captions

Figure 1. CURHA LuxCohort study area

Figure 2. Total interaction effect on walking between trip purpose and distance to the place of residence (N=2,446)

Note 1: Odds ratios estimate of the odds of walking to a specific destination located 15 minutes from the place of residence compared with the odds of walking to the same destination located 10 minutes from the residence.

Note 2: Multilevel logistic regression adjusted for age at the mean, sex, marital status, education, geriatric depression score, having a valid driving license, neighborhood self-selection regarding car use and public transport, and street connectivity (Model B). Odds ratios were customized using the ODDSRATIO option to define the reference value of the distance variable (“AT” distance=10 min) and the unit of change (“UNIT” distance=5 min).

Figure 1. CURHA LuxCohorte study area

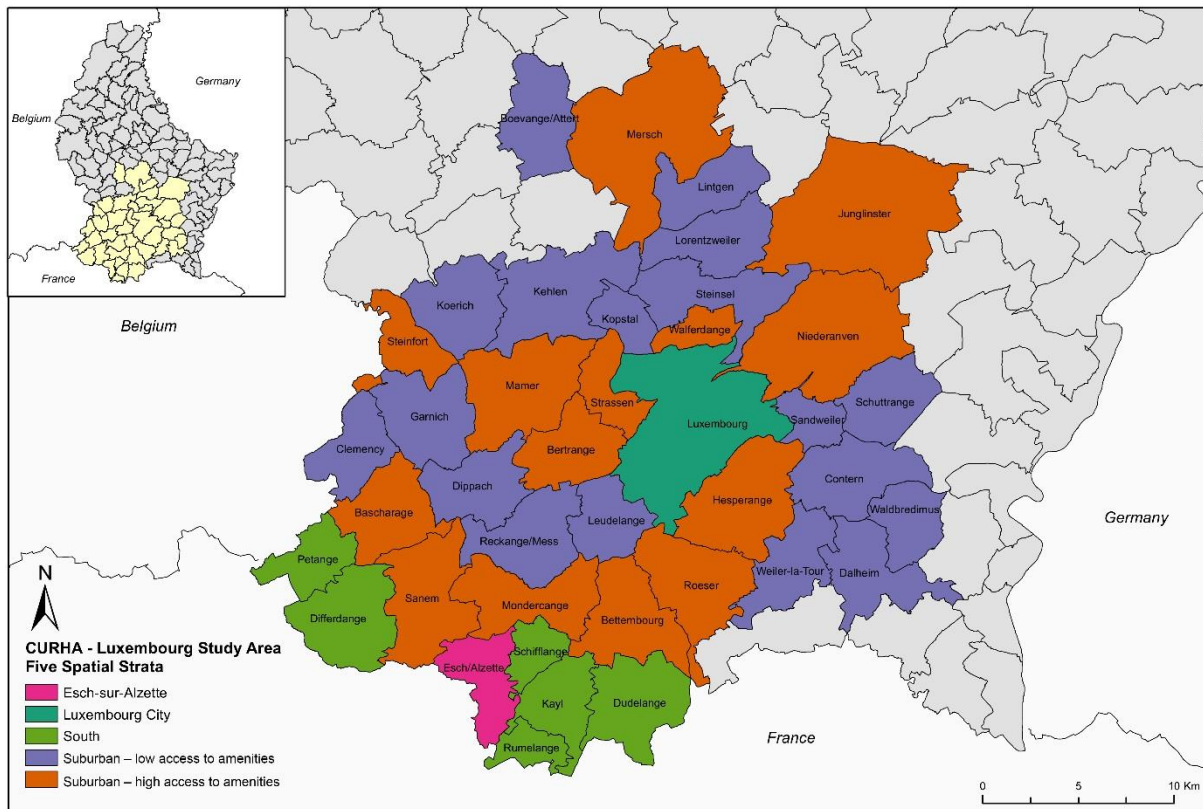
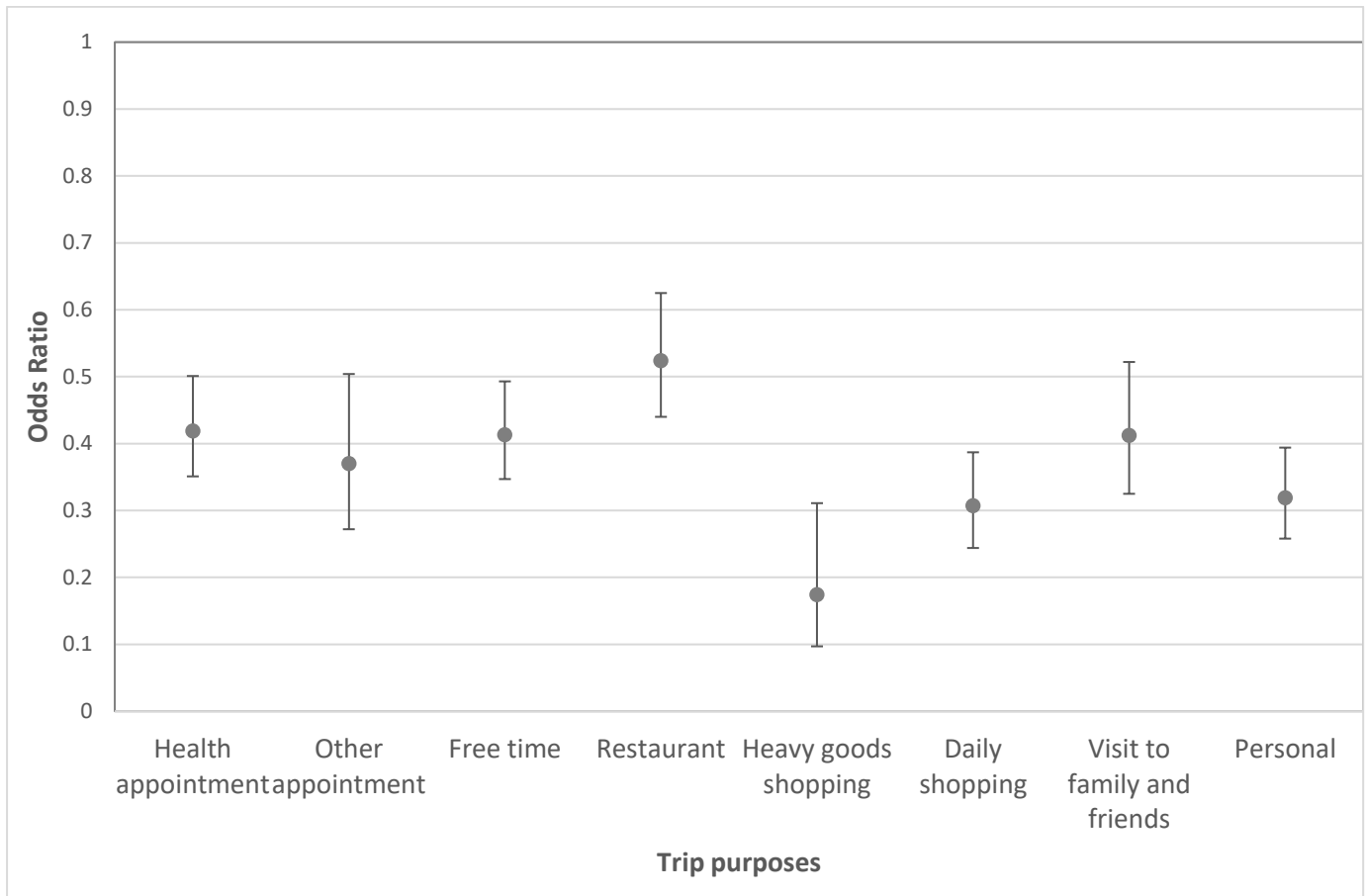


Figure 2. Total interaction effect on walking between trip purpose and distance to the place of residence (N=2,446)



Note 1: Odds ratios estimate the odds of walking to a specific destination located at 15 minutes from the place of residence compared to the odds of walking to the same destination located at 10 minutes from the residence.

Note 2: Multilevel logistic regression adjusted for age at the mean, sex, marital status, education, geriatric depression score, having a valid driving license, neighborhood self-selection regarding car use, number and diversity of amenities, street connectivity, greenness, and public transport station (Model B). Odds ratios were customized using the ODDSRATIO option to define the reference value of the distance variable (“AT” distance = 10 min) and the unit of change (“UNIT” distance = 5 min).

Appendix 1. Detailed pedestrian network based on a walking time-distance metric and definition of potential walking areas

To compute the potential walking areas of elderly, it is important to take into account certain relevant characteristics of their environment that require additional effort when walking. Thus, topography has a direct impact on the pedestrian movement of elderly, who will get tired more quickly when facing a significant slope, whether on uphill or downhill. To integrate this type of constraints, a GIS is mandatory. In our case study, we have used ArcGIS Desktop 10.5 and proceeded as follows.

1. Construction of a pedestrian network.

The pedestrian network is built from trails and roads network taken from topo-cartographic database (BD-L-TC, provided by Luxembourgish Administration of Cadastre and Topography). This network has been complemented by the digitization of zebra crossing, footbridges, underground passageways. In addition, all open spaces such as places, squares and parking have been converted from polygonal to linear objects, which makes it possible to integrate them in the pedestrian network.

2. From Digital Elevation Model (DEM) to a network integrating slope

A DEM was generated based on the contours and height spots from topo-cartographic database. Then, altitudes are assigned to each vertices of the different arcs composing the pedestrian network. Each segment was cut beforehand at equidistant intervals of 60 meters maximum. In many cases these segments of the network have both downward and upward slope. In that case, an average slope on these segments is calculated using the following formula:

$$\tan\left(\frac{\bar{x}_{up} \times l_{up} + \bar{x}_{down} \times l_{down}}{L} \times \frac{\pi}{180}\right) 100$$

where \bar{x}_{up} : average slope uphill (in °)
 \bar{x}_{down} : average slope downhill (in °)
 l_{up} : slope length uphill on a section
 l_{down} : slope length downhill on a section
 L : total length of a section

3. Determination of the speed of the pedestrian

The walking speed through the network, and consequently the travel time is determined by the slope previously computed according to Julien and Carré (2003) and real-life experiments conducted by Nadja Victor (Victor, 2015) in her PhD thesis (table 1).

Table 1 - Slope and average speed of a pedestrian

Slope percentage	Average speed of a pedestrian (in km/h)	
	uphill	downhill
0-2 %	4.4	4.4
2-4 %	4	4.2
4-6 %	3	3.4
6-8 %	2,5	2.6
8-10 %	2.3	2.4
10% and more	2	2

4. Potential walking area

Finally, the potential walking areas are computed as an area that each surveyed participant would reach by walking from a starting point (i.e. place of residence or place of activity) within 10 minutes (20 minutes to go and return from an activity). Services areas are created by using ArcGIS network Analyst. The polygons which form the services areas will be the study unit areas.