CROSS-BORDER INTEGRATION AND GEO-VISUALIZATION: FROM TRIP CHAINS TO PROFILES OF CROSS-BORDER WORKERS

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ABSTRACT

The number of cross-border workers in Luxembourg has steadily increased for over twenty years. Cross-border workers have transnationals living spaces. Everyday, they cross the border between France, Germany and Belgium to perform their daily activities. However, in the collective imagination the cross-border workers come to the Grand Duchy just to work... The purpose of this article is to discuss this received wisdom with respect to the issue of the integration of cross-border workers in Luxembourg. By means of the concepts of social geography and Time Geography, it is possible to develop and analyse their living spaces according to the spatial and temporal organisation of their daily activities. The study of trip chains, synonymous with the organisation and sequence of the activities and their spatial distribution on both sides of the border, form the essential methodological and analytical support for this paper. The juxtaposition of these trip chains with the living spaces allows to identify and characterise the degree of integration of cross-border workers in Luxembourg. This paper suggests a new way of looking at the living spaces of cross-border workers.

Keywords: cross-border workers, living space, trip chains, geovisualization, cross-border integration

CONTEXT AND RESEARCH QUESTION

The Greater Region a transborder territory

The main specificity of the Greater Region is its cross-border character. The Greater Region is located at the meeting of four countries: the Grand Duchy of Luxembourg, France, Belgium and Germany. The presence of the border plays a vital role in economic and spatial dynamics. It is important to remember that borders are erected by man through his discourse and practices (LEFEBRE, 2007). Particularly in relation to its function as territorial limit between states. The border marks the limit of territorial jurisdiction and sovereignty of the countries that border it (ANDERSON, 1996). It also marks a boundary between the culture and the economy, and structures the identity of the social groups it separates (COHEN, 2000). However, the border does not only have the function of a barrier or separating element. The border can be crossed (REITEL, 2011). From an open border to a closed one, there is a gradient of permeability. This gradient depends on the political context, the will towards interstate cooperation and the degree of control that regulates the intensity of the interactions (O'DOWD, 2003). The border is an exchange interface that allows the entry and exit of flows, whether of goods, people or information. There is an artificial mechanism at the origin of these interactions: by erecting boundaries between states, man creates a differential. This differential is reflected at different levels: fiscal, legal or economic. However, in the context of the devaluation of borders (FOUCHER, 1991) at the European level, they are more permeable and allow free movement of goods and people. In the case of the Greater Region the open border of the European Union is at its peak. The border between the Grand Duchy of Luxembourg and its neighbouring states generates a significant economic differential both in the case of the labour market with more attractive salaries (BERGER, 2005), as well as with respect to the land market (DIOP, 2012). The Grand Duchy polarises labour flows due to its attractiveness as a result of its position as a regional economic engine (GERBER et al., 2012). This transborder territory constitutes a metropolitan catchment area extending well beyond the borders of the Grand Duchy (SOHN, WALTER, 2009; PIGERON-PIROTH, SCHNEIDER, 2009). This situation, both geographic and economic, is at the origin of cross-border work in Luxembourg. Daily, nearly 160,000 cross-border workers (STATEC, 2013) living in France, Germany and Belgium travel to Luxembourg to work. It is the largest cross-border flow in Western Europe (MKW, 2009). It is in this laboratory of the border, travel and spatial mobility that we position our study.

Cross-border workers integration by living space and daily activities

The representation of a cross-border worker as someone who only travels daily to work in Luxembourg and to supply with petrol and cigarettes (ZANARDELLI, 2005) persist in the collective imagination. This paper aims to debate this representation by studying the potential integration of cross-border workers in Luxembourg. There is still a lack in both theoretical positioning and in the study of the question of the integration of cross-border workers in the country where they work. There are many definitions of the integration concept. Integration can be defined as a "*Complex incorporation of one reality in another. Progressive incorporation of foreigners in a host society*" (LEVY, LUSSAULT, 2003). This definition highlights the notion of incorporation, i.e. the entry of a first element into another, either a reality or a population. Integration is also defined as "*Gatherings of elements in a new unity, or incorporation of an element in an existing body. The integration of people, immigrants, in a social body, is marked by their inclusion in the production system as well as in the laws and*

customs of the location, while each retains its, possibly unique, identity, unlike assimilation, which involves submission to, and a complete identification with, the dominant body" (BRUNET, FERRAS, 1992). The second definition introduces the creation of a new body by the integration of a foreign body. It also introduces the idea of a pre-existing body A in which a body B is incorporated. Definitions are both references to the integration of immigrants into a host society. The second definition is more precise and informs us about the integration vectors: insertion in the production system, compliance with the laws and customs of the location. For this paper, one must remember that integration is the incorporation of foreign individuals into a territorial entity by the vectors of employment, consumption and compliance with laws and customs. As a result, the first assumption is that the main vector of integration is insertion in the production system non only by work but also by the activities of consumption and leisure. The spatial dimension must also be considered: one needs to speak first of all of the spatial integration of the cross-border workers in Luxembourg. The latter can be measured by the application of the concept of living space (COURGEAU, 1975; FREMONT, 1976; DI MEO, 1991) which also takes into account work, leisure and consumption activities as well as the location where they are practised. Finally, the idea of integration through activities will use the trip chains within the meaning of Dekker (1995), the concepts of Time Geography and the structuring of activities in the short term as developed by Hägerstrand (1970). To summarise: the living spaces will be studied simultaneously on the basis of their spatial extent, the nature of the activities that are performed and their temporal organisation. Thus, first of all, the focus is mainly on the living spaces of the cross-border worker. Many authors, geographers, demographers and sociologists have worked on the concept of living space. According to Fremont, the living space represents "*all the locations frequented by an individual*" (FREMONT, 1976). Di Meo adds that it is "*the physical space of everyday life*", by including the concept of social space which corresponds to all the spatialised social interactions (DI MEO, 1991). Brunet proposes a definition of living space that takes into account housing, the economic relations of leisure, work and other social relations (BRUNET, 1975). To summarise the definition used in this paper, the living space is first of all a spatial extent in which individuals carry on their daily activities of residing, working, consuming, and practicing leisures involving social relations. The living spaces of cross-border workers are transnational as they practice their activities on both sides of the border. But in order to have a more precise analysis of these activities, especially in their everyday life, it is necessary to call on other concepts. The analysis of trip chains, little studied by researchers (PRIMERANO et al. 2008), nevertheless offers essential information for consideration of the integration of cross-border workers in Luxembourg. Instead of the term *activity chain* or *activity planning*, we prefer the notion of the trip chain "[...] *A trip chain is travel involving multiple purposes to single or multiple destinations and begins and ends at home or a similar origin*" (DUEKER, 1995 SHIFTMAN, 1998). To better characterise living spaces and the sequence of activities on both sides of the border, the trip chains will be studied to better understand the sequence of activities and locations during a typical workday. The focus is on activities that take place mainly outside home (in one of the three neighbouring countries involved) and which are mainly structured around home and workplace. The main premise is the fact that the characterisation of these activities: work, consumption and leisure, may be an indicator of potential integration. The activities of individuals also involve a time element at different scales. According to Hägerstrand, an isolated action has a position in both space and time (HÄGERSTRAND, 1970). In this case, the *Time Geography* considers the time of the individual as a variable describing his successive locations (CHARDONNEL, 2001). The organisation and sequence of activities in time and space thus produce specific chains of activities, according to time slots that need to be understood in the analysis of spatial integration. These chains determine the planning of daily activities of individuals.

Thus, it is through all these theoretical positions that the concept of integration in a cross-border context will be approached, combining the concepts of living space and trip chains. In the circumstances, two research questions emerge: i) Does a cross-border worker perform more of his main daily activities in his country of residence or in the country where he works? ii) Do the trip chains and the nature of activities on both sides of the border enable one to measure the degree of integration of a cross-border worker in Luxembourg?

Three thematic hypotheses and one methodological hypothesis try to answer these questions:

Hp1: Characterisation of the living spaces based on the daily typical activities of of a cross-border worker enables one to measure a more or less strong spatial integration of cross-border workers in Luxembourg.

Hp2: There is a relationship between the sequence of activities and the living spaces: the more the trip chain includes complex and diverse activities, the more the extent of living spaces increases.

Hp3: The socio-demographic profile of the cross-border workers influence the spatial characteristics of the living spaces: the more the income, socio-professional status and educational level are high, the more the extent of the living spaces increases.

From a methodological point of view, we propose a fourth hypothesis:

Hp4: Creating synergies from techniques usually developed separately, such as geovisualization, spatial analysis and multivariate analysis, allows to better understand how living spaces and trip chains mutually influence one another.

METHODOLOGY AND DATA

Regarding the need to build spatio-temporal data

In the context of this analysis, it is possible to use the data from the "Enquête Mobilité des Frontaliers" [*Cross-border Worker Mobility Survey*] (EMF) (SCHMITZ, DREVON, GERBER, 2012). The purpose of this survey is to provide a knowledge base of the mobility practices and energy representations of the cross-border workers. This survey focuses on the cross-border workers in an area permitting a round trip between the place of residence and place of work in a day. This survey is based on the social and spatial criteria of 146,000 cross-border workers working in Luxembourg in 2010. Thus, the scope of the survey was divided into 25 sectors drawn from spatial strata in which the population of cross-border workers was divided into social strata according to sex, age and place of residence and work. These strata were obtained from administrative records of the Administration of Direct Taxation and the General Inspectorate of Social Security in Luxembourg. These administrative records represent a complete census of cross-border workers in Luxembourg and are the survey base from which the sample was drawn. The survey was carried out in two phases according to a self-administered process. This type of process assumes certain problems in the quality of the answers of the respondent. Especially with respect to the data information concerning departure and arrival times of the trips. The first phase concerns the classic thematic investigation of a trip survey like the EMD (Enquête Ménage Déplacement [*Household Trip Survey*]) (GASCON, 2008) in France or BELDAM (Belgium Daily Mobility) in Belgium. The questionnaire of the first phase concerning trips was sent to 40,000 individuals. 7,235 cross-border workers sent back the questionnaire, i.e. a return rate of 18%. The second phase involved energy and modal representations. This second questionnaire was sent to those who responded to the first phase and the rate of return was 51%. The merger of these two databases simultaneously provided information on both the behaviour and mobility practices of cross-border workers, their energy representations and their opinions about the modes of transport.

Construction of the trip chains

It was possible to reconstitute the trip chains from the EMF data base. Theoretically, for each trip, the time and place of departure, the time and place of arrival, the duration as well as the purpose of the trip are provided. From these characteristics, using the variables mentioned above, it is possible to chain the daily activities and trips. The construction of trip chains was made from the concatenation of the variables related to trips. These variables represent the time, the space and the purpose of each trip (Figure 1). First of all, this concatenation enabled the reconstitution of the sequence of activities and trips in the form of a coding chain. Figure 1 shows an example of a trip chain of a cross-border worker who lived in Germany (home) and drop off his children to school near his home (school) and then went on to his workplace in Luxembourg (work). After work, he returned directly to his home in Germany (home).

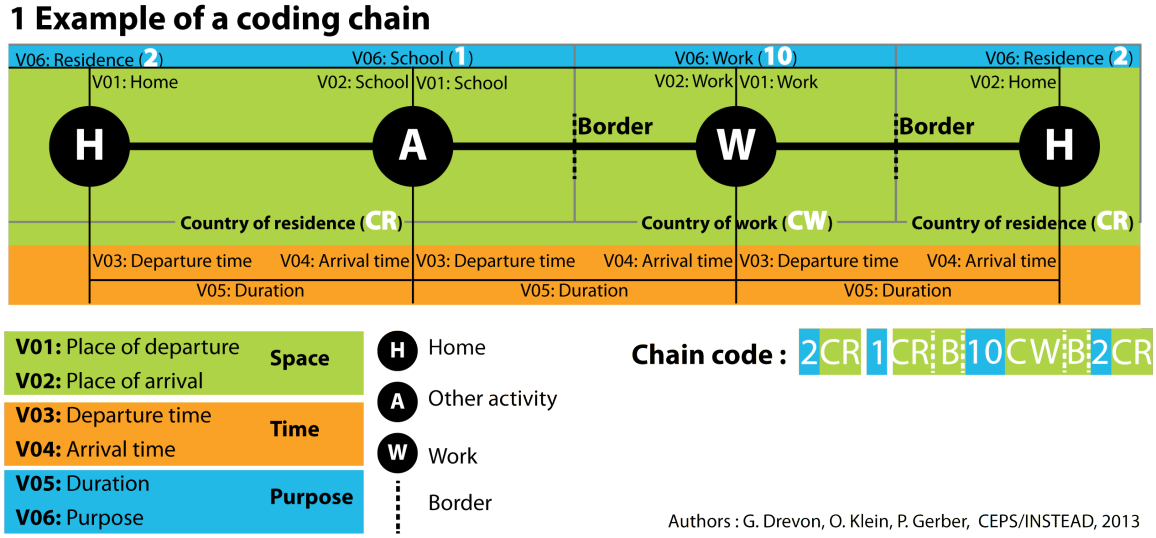


Figure 1 – Trip chain components

Taking the example of Figure 1, the trip chain is reconstructed by concatenation of the variables V01, V06, V02 (Figure 1). The border is located between two activities, when these are carried out on other sides of the border. For example, in Figure 1, we know that the German cross-border worker drop off his children to school in his country of residence. We also know that he works in Luxembourg, so he crosses the border during his trip between the school and his place of work, so the border is included in this trip. It should be noted that the purpose at the origin of the trip is the home in assuming that, on a typical day of the week, all the cross-border workers leave home in the morning. Temporal variables could not be included in the construction of the trip chains, given the lack of important information with respect to the times of departure and arrival of the trips. This lack of temporal data is related to the self-administered survey method. In the example in Figure 1, the chain is coded: 2CR 1CR B 10CW B 2CR. 2CR is the home activity (2) in the country of residence (CR). Then 1CR indicates the activity of leaving the children at school (1) in the country of residence (CR); B indicates the border crossing (B) on the way to work. 10CW corresponds to the work activity (10) in the country of work (CW). B represents crossing the border on the return home (B). Finally 2CR indicates the activity of returning home (2) in the country of residence (CR). This approach is applied to all cross-border workers to reconstitute their trip chains and to then incorporate them into the characteristics of the living spaces.

Living spaces analysis by the standard deviational ellipse method

During their daily trips, cross-border workers may perform several activities defining their living spaces. To analyse these living spaces, the standard deviational ellipse appears to be the most appropriate method. The standard deviational ellipse enable the characterisation and synthesisation of the spatial dimension of the trip and of the distribution of the activity locations in space (CAUVIN et al., 2008). The activities are represented graphically in the form of a set of points. Spatial indicators such as the median center of the ellipse, the X and Y length and the surface of the ellipse encapsulate the dispersion and distribution of the activities in space (PUMAIN, SAINT-JULIEN, 1997). First of all, the activity locations are

geolocated on the basis of variables related to activities that correspond to the places of departure and arrival of the trips given in the survey. However, with only one location in the locality, corresponding to a living place generally represented by the steeple of a church (GERBER KLEIN, 2009), the activities have been geolocated randomly here. Given the size of the localities, the margin of error of this positioning is relatively low. Thus, from the set of points corresponding to the activities, ellipses are constructed for each individual. This process enables continuous spatial variables to be constituted: the X and Y axis length, the surface of the ellipse and the location of the median center. Consideration of the border is essential in the cross-border context of this study. By adding four additional variables, one can create: the surface of the ellipse respectively inside and outside Luxembourg, the number of activities inside and outside Luxembourg. It is possible to compare this variables by a ratio as: X axis length divided by Y axis length, or ellipse surface inside Luxembourg divided by surface outiside. All these variables are shown in Figure 2.

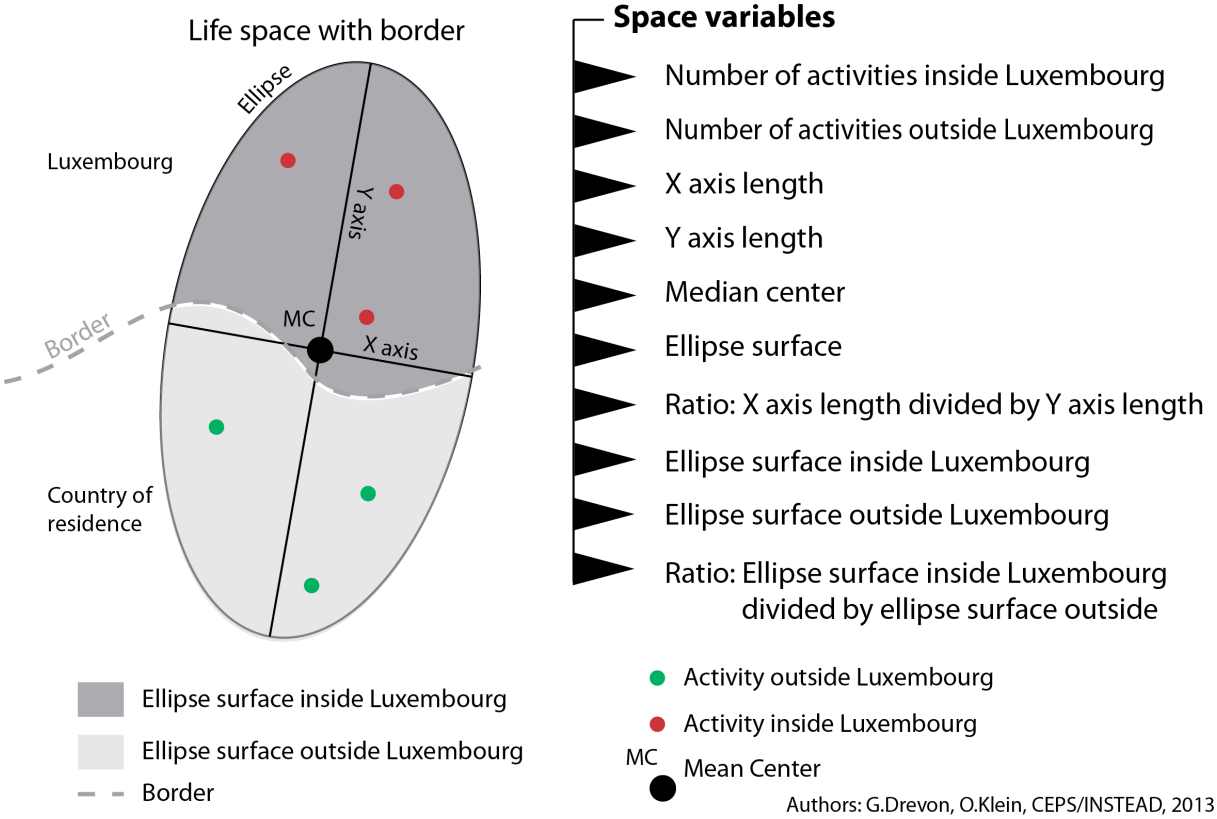


Figure 2 –Standard deviational ellipse and space variables

Principal Component Analysis and Clustering Analysis

The standard deviational ellipse method presented above, therefore, allows consideration of ten continuous variables. This mass of information must be reduced in order to facilitate its consideration and interpretation. The most suitable type of analysis for this is Principal Component Analysis (PCA). This allows the summarisation and prioritisation of all the information (its dispersion in the statistical sense). In our case, it is more a question of determining the correlations between the spatial variables resulting from the standard deviational ellipses in order to identify the principle components characterising the dispersion and distribution of the activities in the living space of the cross-border workers. After

determining these components, a Clustering Analysis (CA) is used to create groups of characteristic profiles of the living space of the cross-border workers.

Multiple Correspondence Analysis

Multiple Correspondence Analysis (MCA) enables the combination of several types of nominal variables: spatial, temporal and socio-demographic. This type of analysis enables the description of the relationships between these variables. The MCA appears to be the most appropriate method to understand how activity chains and socio-demographic profiles influence the living spaces. From a methodological point of view, the MCA enables the linking of discontinuous variables. In our case, the variables resulting from the standard deviational ellipses are continuous while the temporal variables related to trip chains are discontinuous. It is possible to convert the continuous variables resulting from the standard deviational ellipses into discontinuous variables. However one cannot convert discontinuous variables into continuous variables. The MCA can then be used to link the discretized continuous variables of the standard deviational ellipses, the discontinuous variables of the trip chains and the socio-demographic variables.

RESULTS

Trip chain analysis gives a first indicator of integration through activities

The trip chain analysis yielded several results. First of all, a typology of trip chains according to the sequence of the activities of cross-border workers (Figure 3). The second result represents all of the trip chains of the 140,000 cross-border workers as well as the location of the border in their trip chains (Figure 4). Thus, Figure 3 presents the ten main trip chains. The home-work-home chain represents the vast majority of cross-border workers at 54%. This concerns cross-border workers making just a round trip between their place of residence and their place of work in the day. These cross-border workers do not practice any other activity during the day. Then, 14% of the cross-border workers perform an activity after work, 7% before and after and 5% between two periods of work, which corresponds to the lunch break between noon and two o'clock.

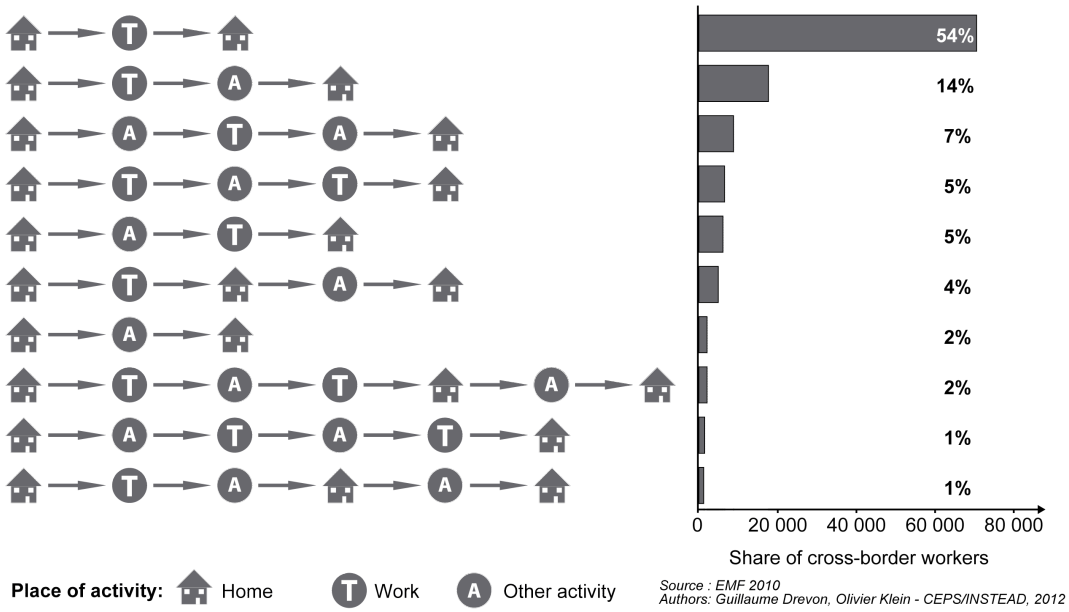


Figure 3 – Typology of the trip chains

The positioning of the border in the activity chains (Figure 4) enables one to determine how cross-border workers allocate their activities on both sides of the border. These chains differ in their varying lengths, from two to ten trips a day, to effect daily activities, both in the professional and personal sphere. Thus, the activities of going to work and returning home largely structure the trip chains. So, to simplify the mapping, only three periods are shown in the figure: the period before work, the time between two periods of work and the period after work. The home-work-home axis represents the majority of cross-border workers. Secondary activities are distributed on both sides of the border and the home-work-home axis. The period before work usually corresponds to the morning. 108,000 cross-border workers (83%) go directly from home to their place of work. Approximately 15% of cross-border workers perform an activity in their country of residence before going to work. A small proportion of cross-border workers (1.6%) practiced their first activity in Luxembourg. Between two periods of work, corresponding to the lunch break, nearly 10% of cross-border workers practice an activity in Luxembourg, compared to 0.2% in the country of residence. This can be easily explained because of the distance separating the two places. The third period, after work is noteworthy for a majority of cross-border workers (73%) who return directly to their homes. However, 14% of cross-border workers practice a secondary activity in Luxembourg after work compared with 11% in their country of residence. There is symmetry in the distribution of activities over this period between the number of secondary activities performed in the country of residence and those practiced in Luxembourg. This shows the interest of cross-border workers in doing some activities in Luxembourg. A limited number of cross-border workers (2,300) practice activities of both sides of the border before returning home. After cross-border workers get home, they rarely return to Luxembourg (less than 1%).This descriptive analysis of activities apart from working and returning home enables one to characterise more precisely the timelines: before work, between two periods of work and after work, as well as the distribution of activities on both sides of the border.

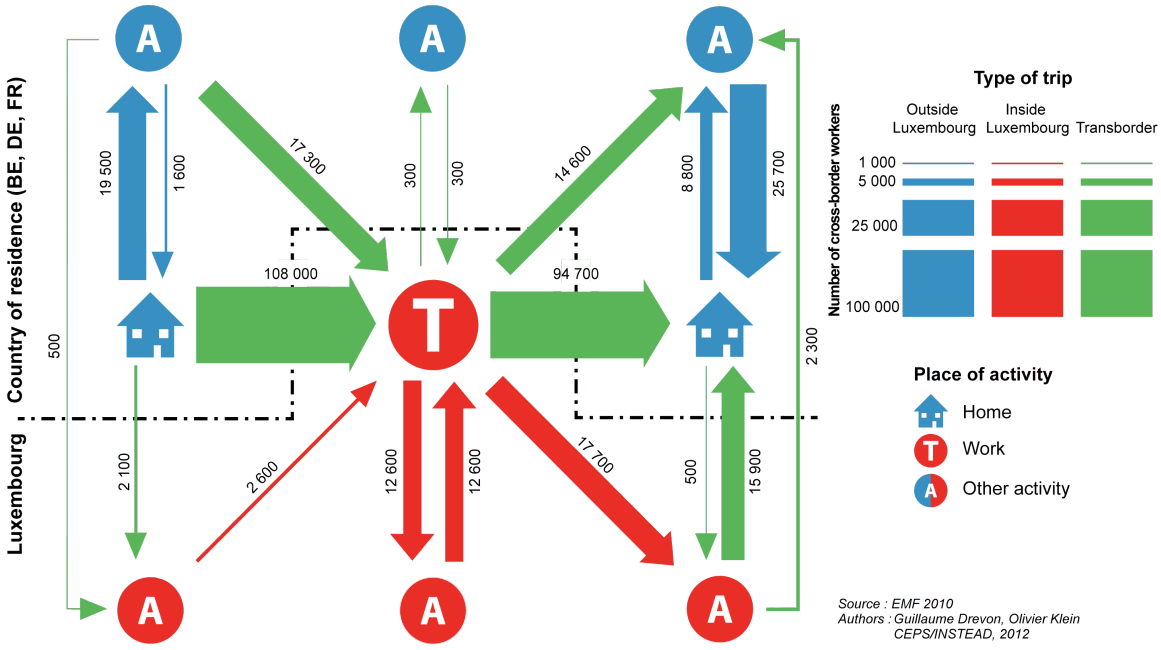


Figure 4 – Sequence of activities during a typical day

Based on the three periods considered in the activity chains, one needs to clarify the nature of these activities (secondary activities) apart from home and work. In the period before work, 85% (Figure 5) of the secondary activities are effected in the country of residence compared to 15% in Luxembourg. The main secondary activity practiced in the country of residence and Luxembourg is the dropping off of people, i.e. respectively 84% and 54% of the activities before work. However, although the number of activities on the territory of Luxembourg is lower, they are more diverse: 17% shopping, 7% services and 13% devoted to other activities. Secondary activities in the country of residence are rather monofunctional but we note that 4% of activities are dedicated to travel as part of work and shopping. The secondary activities carried out between two periods of work (lunch time) are mainly carried out in Luxembourg at 97% of the secondary activities. Only 3% of cross-border workers return to their country of residence during this short period. Dining is the main secondary activity performed in Luxembourg (63%), followed by shopping (15%) and travel related to work 13%. The low proportion of cross-border workers who return to their country of residence go mainly for lunch (9%) or drop off or pick up someone (8%). The third period, which covers the time after work is much more balanced, with a nearly symmetrical distribution of secondary activities in the country of residence and in Luxembourg. 57% of after-work secondary activities are carried out in Luxembourg, compared with 43% in the country of residence. The activities related to work trips in Luxembourg (46%) and to dropping off or picking up someone in the home country (48%) represent a strong majority on both sides of the border. Shopping activity represents 13% and 19% respectively in Luxembourg and the country of residence. Secondary activities related to leisure, services and visiting family and friends are around 7% in the country of residence compared with 2%, 5% and 1% in Luxembourg. It should be noted that the activity of eating out in Luxembourg is strongly represented at 26%.

Details of the activities referred to as secondary has enabled us to understand how cross-border workers divide their activities on both sides of the border during a typical day. It was found that during the first period, the cross-border workers effect their activities in their country of residence mainly in dropping off or picking up someone. During lunch time, cross-border workers travel mainly in Luxembourg for lunch. The third part of the day is characterised by a greater balance in the distribution of activities on both sides of the border. For example, 26% of the activities carried out in Luxembourg after work involve eating out.

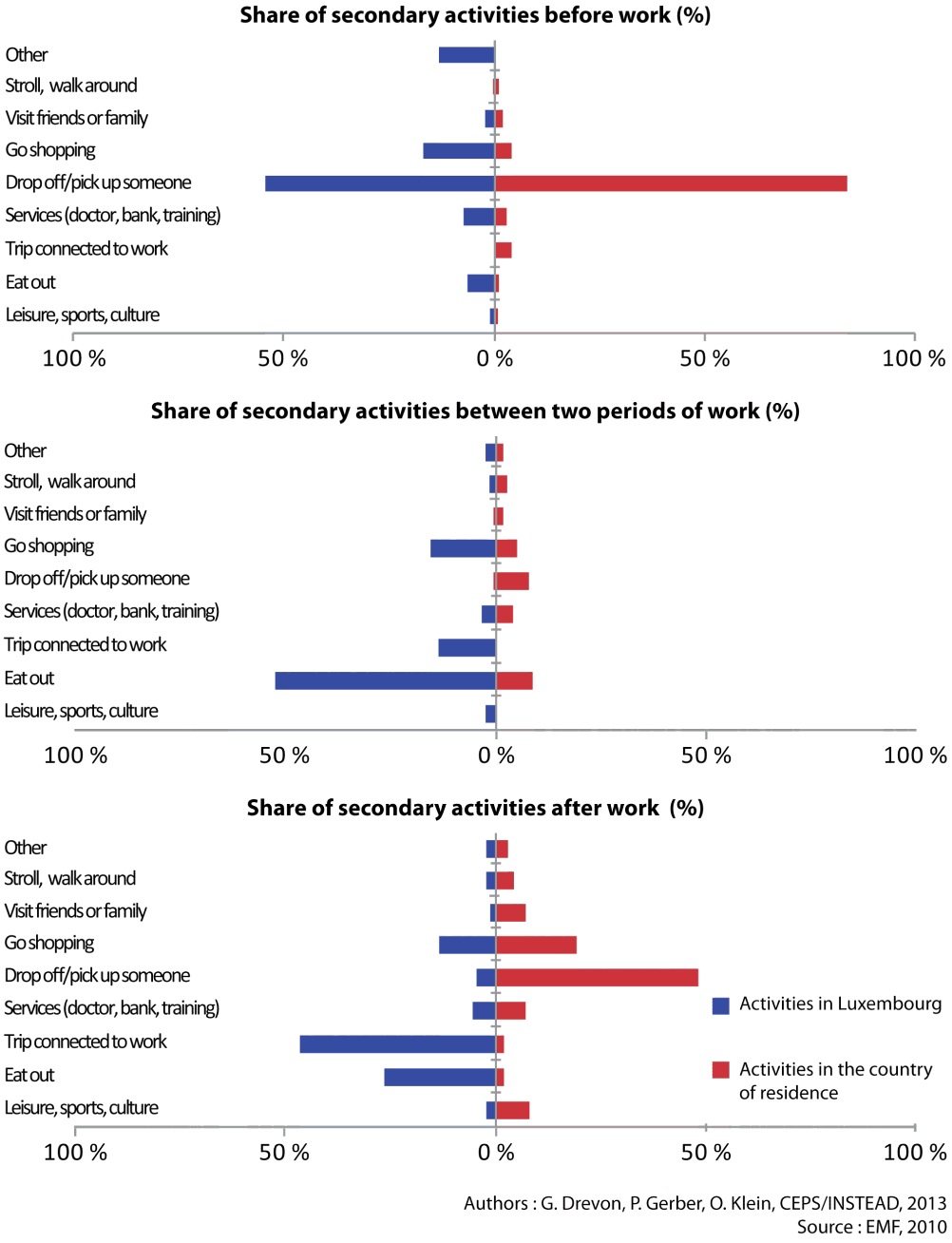


Figure 5 – Share of secondary activities in the country of residence and in Luxembourg

Living spaces and spatial integration

The analysis of trip chains showed that there are several types of trip chains. The majority of cross-border workers (54%) just a round trip between their place of residence and their place of work in the day. The remaining 46% effect at least one secondary activity outside of their home-work trip. From these trip chains, three periods have been identified for carrying out these activities: before work, between two periods of work and after work. The data used to determine how the activities are distributed over time and how they are distributed between Luxembourg and the country of residence are now clarified due to the trip chains. It is now necessary to consider the spatial dimension of the living spaces of the cross-border workers. The analysis focuses on a subset of cross-border workers, 46%, who effect at least one secondary activity apart from home and work. To identify and characterise the living spaces, the standard deviational ellipse provides an ellipses for each individual, i.e. 2248 (unadjusted raw sample), corresponding to cross-border workers who effect at least three trips during their working day.

Result of the Principal Component Analysis

The PCA enabled the identification of three principal components. The first (explaining 33% of the variance) is a measure of cross-border integration. Four variables contribute significantly to this (Figure 6, Table I): the distance to the border, the number of places of activity in the country of residence compared with the number of places of activity in Luxembourg and the ratio between the surface of the ellipse in Luxembourg and the total surface of the ellipse. The juxtaposition of these variables represents a cross-border integration gradient. At one end of the gradient are individuals who effect their secondary activities in their country of residence and who live relatively far from the border. At the other end of the gradient are the cross-border workers who tend to perform their activities in Luxembourg and thus the ratio between the surface of their ellipse in Luxembourg and the total surface that reflects living spaces largely anchored in Luxembourg.

Table I- Space variables

	Variables
V01	Distance to the border
V02	Number of activities in the country of residence
V03	Ratio X and Y length axis
V04	Y axis length
V05	X axis length
V06	Surface of the ellipse
V07	Number of activities in the Luxembourg
V08	Ratio: Luxembourg and ellipse surface

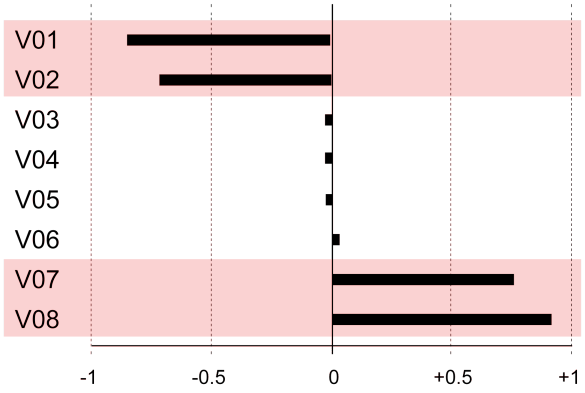


Figure 6 – Component 1 of the PCA

The second component, with an explained variance of 28% (Figure 7), characterise a dispersion of activities. Variables related to the X and Y axis length, as well as the surface of the ellipse, mainly contribute to this component without opposition. This factor shows the correlation between the length of X axis, Y axis and the surface of the ellipse, and therefore a greater or lesser dispersion of activities in the living spaces. Typically, individuals whose activities are dispersed possess ellipses with a more significant surface, length of the X axis and Y axis.

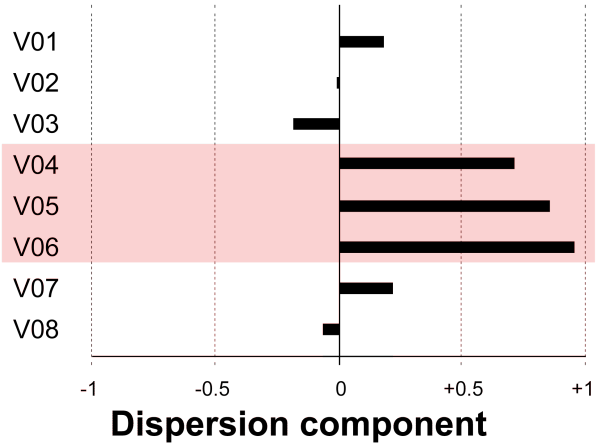


Figure 7 – Component 2 of the PCA

The third component (Figure 8), (explaining 17% of the variance) relates to the stretching of the ellipse with two characteristic variables: the ratio between the Y axis and the X axis and the length of the Y axis. These variables concern individuals whose ellipses are elongated, which also explains the correlation with the Y axis.

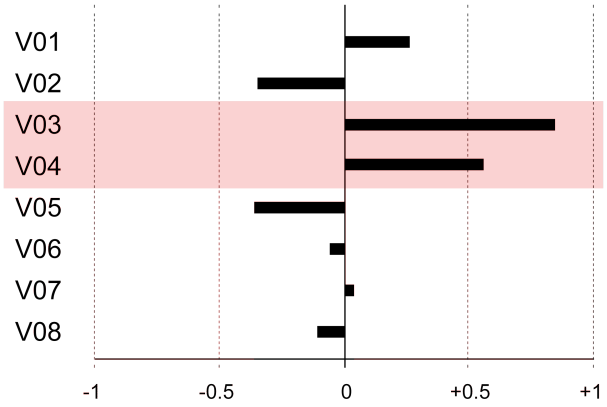
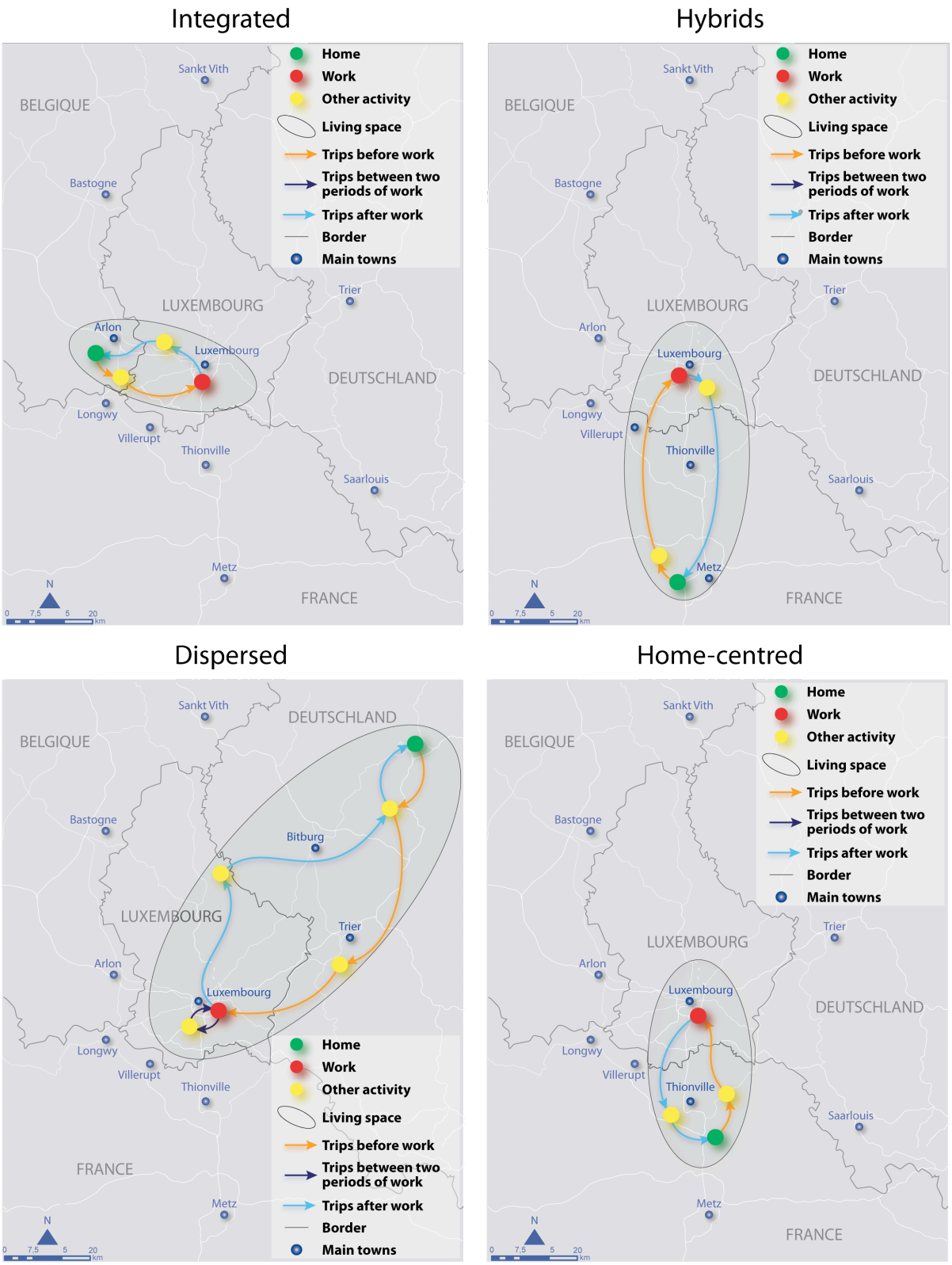


Figure 8 – Component 3 of the PCA

Thus, the CPA includes a first component of cross-border integration, the second being a component of the dispersion of the activities, while the third shows the stretching of the variability ellipse. From these results, it is necessary to determine, with the help of a Clustering Analysis (CA), groups of individuals presenting similarities in order to characterise the degree of spatial integration of the cross-border workers in Luxembourg.

The Clustering Analysis, effected on the basis of three components, identified four types of cross-border worker profiles in addition to the 54% of cross-border workers who effect only two trips during the day to get to their workplace and then back home: the integrated, the hybrids, the dispersed and the home-centred. The integrated cross-border workers represent 35% of the workforce. This cross-border worker profile presents different characteristics in its ellipse (Figure 9). The first concerns the median center of the ellipse that is in most cases located inside the Luxembourg. The second characteristic relates to the number of activities effected on both sides of the border. In the case of the integrated cross-border workers, they effect a greater number of secondary activities in Luxembourg and generally reside near the border. Their living spaces are largely included in Luxembourg, with a significant surface ratio between the ellipse surface in the Luxembourg and in the country of residence. The hybrid cross-border workers, at 13%, reside relatively far from the border. The average median center is generally located outside Luxembourg and their activities are not far from each other. The dispersed cross-border workers represent 5% of the cross-border workers. They are characterised by long distances between home and work. This type of cross-border workers perform many activities and have dispersed living spaces. Finally, the home-centred cross-border workers represent the majority of the cross-border workers (47%). This cross-border worker profile has a living space that is more concentrated in his home country. For them, secondary activities are mainly effected around his home. This profile is the least integrated from a spatial perspective.



Authors : G.Drevon, O.Klein, CEPS/INSTEAD, 2013
Sources : EMF CABAC, 2010

Figure 9 – Living spaces according to the profile of spatial integration

The influence of trip chains and socio-demographic profiles on living spaces

The standard deviational ellipse analysis has highlighted the existence of several types of spatial integration of cross-border workers in Luxembourg. In fact, four different degrees of integration of cross-border workers are highlighted according to the spatial patterns under consideration: the integrated, the hybrids, the dispersed and the home-centred. To go deeper into the integration features, the three types of spatio-temporal results coming from i) the standard deviational ellipse ii) the chain analysis and (temporal variables) iii) the spatial distribution of activities can be integrated and juxtaposed in a new analysis by also adding iv) the main socio-demographic variables: age, sex, socio-professional categories, income, marital status, housing tenure status and type of housing occupied by the cross-border workers.It is now necessary to determine the influence of trip chains and socio-demographic variables on living spaces. A quantile discretization of the continuous variables (more relevant discretization given the distributions of the spatial variables) enables one to integrate the spatial variables in the Multiple Correspondence Analysis (MCA). All these variables were included based on the three different MCAs, according to a logic of pairwise comparison. The first includes the discretized spatial variables and temporal variables (MCA1). The second takes into account the socio-demographic variables and temporal variables (MCA2). Finally, the last MCA includes the three types of variables: spatial, temporal and socio-demographic (MCA3).The results of the MCA1 show no link between the spatial variables and the temporal variables, no relationship of correlation or antagonism between the two types of variables. The variables that predominate in the analysis are spatial variables, while the temporal variables contribute little to the MCA1 factors. The results of MCA2 also show there is no relationship between the temporal variables and the socio-demographic variables: as in the case of the MCA1, no variable expresses a relationship of positive or negative correlation. In addition, the temporal variables also contribute very little to the factors of MCA2. Finally, MCA3 links all types of variables. It confirms the trend previously described. Firstly, spatial and socio-demographic variables strongly structure the three factors of MCA3. The spatial variables contribute significantly (Figure 10, Table II) to the factors 1 and 2; the socio-demographic variables contribute mainly to factor 3. It should be noted that the temporal variables make a very low contribution of the three factors. Moreover, there is no relationship between the temporal and spatial variables, and between the temporal and socio-demographic variables. Similarly, there is no relationship between the spatial variables and the socio-demographic variables. No clear relationship emerges between the spatial, temporal and socio-demographic variables.These analyses showed the absence of relationships between the spatial, temporal and socio-demographic variables. Thus the trip chains and socio-demographic characteristics of cross-border workers exercise no influence on their living spaces.

Table II – Factors of MCA3

Variables	Type	Variable	Factor 1	Factor 2	Factor 3
V01	Spatial variables	Distance to the border	0.57	0.12	0.01
V02		Number of activities outside Luxembourg	0.59	0.19	0.02
V03		Major axis and minor axis relationship	0.04	0.37	0.06
V04		Length of the major axis	0.12	0.12	0.01
V05		Length of the minor axis	0.15	0.75	0.06
V06		Area of the ellipse	0.22	0.68	0.03
V07		Area of the ellipse in Luxembourg	0.65	0.30	0.02
V08		Number of activities in Luxembourg	0.73	0.13	0.04
V09		Relationship between the ellipse area in Luxembourg and outside Luxembourg	0.60	0.11	0.01
V10	Temporal variables	Activities before work	0.15	0.05	0.03
V11		Activities between noon and two	0.18	0.05	0.04
V12		Activities after work	0.23	0.13	0.02
V13	Socio-demographic variables	Sex	0.06	0.05	0.03
V14		Age	0.02	0.03	0.20
V15		Marital status	0.01	0.07	0.43
V16		Income	0.02	0.02	0.61
V17		Housing type	0.01	0.09	0.36
V18		Housing tenure status	0.00	0.05	0.46
V19		Socio-professional categories	0.09	0.04	0.29
V20		Level of study	0.01	0.01	0.17
		Total	4.45	3.36	2.88

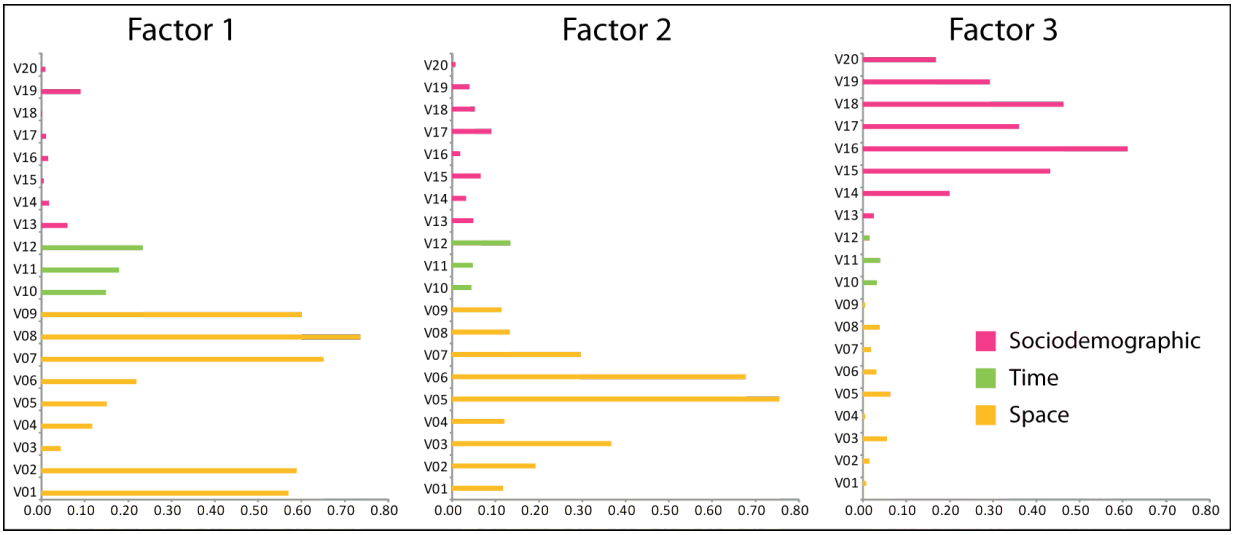


Figure 10 – Factorial diagram

CONCLUSION AND DISCUSSION

The standard deviational ellipses enable one to obtain spatial variables that are indicative of the extent of the living space and the spatial dispersion of constituent activities. From the point of view of visualization, ellipses of cross-border workers are more or less integrated spatially in Luxembourg. On integrating the spatial variables obtained from these ellipses, four types of cross-border worker profiles emerged: the integrated, the hybrids, the dispersed and the home-centred. One must also keep in mind that the majority of cross-border workers only make two home-work-home trips in a typical day. These profiles are characteristic of varying degrees of spatial integration. The first hypothesis is validated: there is indeed a spatial integration of cross-border workers in Luxembourg to varying degrees. The analysis of trip chains shows the complexity in the sequence of activities during a typical day. According to an analysis of the principal components, there is no relationship between the number of activities, which also corresponds to the length of the chain on either side of the border, and the surface of the ellipses as well as the dispersion of the activities which represent the living space. Therefore, the living space is not necessarily more extensive in the case where the number of activities is higher. Moreover, the last MCA performed shows that there is no relationship between the spatial variables, which represent the living spaces, and the temporal variables, which reflect both the distribution of activities in time and space as well as their structuring. Thus the second hypothesis cannot be validated: there is no relationship between the extent of the living space and the length or the diversity of the trip chains. The spatial and socio-demographic variables largely structure the results of the MCA, while the temporal variables contribute very little to the analysis. Moreover, there are not relationships between the spatial and socio-demographic variables on the three factors. Logically, the third hypothesis is not valid, and thus the socio-demographic profile do not affect the spatial characteristics of the living spaces. Several methods were used during the analysis to obtain the variables needed at the juxtaposition of the spatial and temporal dimensions. The combination of these methods was extremely beneficial in the understanding and characterisation of the living spaces, the trip chains and their relationships. Thus the methodological hypothesis is validated. Our assumption in the context of consideration of the integration of cross-border workers in Luxembourg was based on two ideas. The first idea concerned integration by way of activities while the second idea concerned the spatial integration of cross-border workers in Luxembourg. It was established that there was indeed a spatial integration of cross-border workers through their living spaces. Moreover several degrees of integration were identified from the typical profiles of the cross-border workers. The trip chains showed that cross-border workers did not come only to work in Luxembourg. They practiced other leisure and consumption activities. On the other hand, it is not possible to verify the existence or emergence of an integration of cross-border workers in Luxembourg by way of activities. The analyses were disrupted by several problems, firstly with respect to the data. First of all, the lack of an address database for the area studied. Therefore places of activity were randomly geolocated inside localities. The second difficulty with respect to the data concerned the lack of information about the duration of activities. There remained many empty fields in the database. Times of departure and arrival of the trips were often misinformed. This lack is probably due to the non-completion of question related to time by the respondents surveyed. Therefore, it is not possible to determine with certainty a time for each activity. Information on the duration of activities could have completed the Time Geography component of our approach and allowed more detailed analysis of the relationship between the duration of activities in Luxembourg and in the

country of residence. It would have been interesting to have been able to determine a time budget for the cross-border workers and to have juxtaposed this data with the spatial dimension of living spaces and the organisation of activities to verify the idea of integration by way of activities by introducing the duration of the activity. This lack of information undermines the method of data collection. The choice of a self-administered process raises a number of questions. Today it is clear that this method is effective for simple questions concerning demographic profiles for example. However, for more complex issues especially related to trip, respondents experienced more difficulties. It should be noted that the questionnaire is long (9 pages), and there may also have been a certain weariness on the part of the respondents as the answers to the first questions were answered better. In France in particular, the method of data collection for household trip surveys (EMD) is based on a face-to-face interview. This type of interview avoids fatigue or non-response on the part of the respondent. In any future studies concerning cross-border workers in Luxembourg, it would be advisable to borrow the face-to-face method from EMD in order to effect more detailed analyses especially with respect to the duration of activities as a support for the analysis of the integration of cross-border workers in Luxembourg.

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