Spatial network morphology and social integration of the elderly: The socio-spatial 'embeddedness' of community-based elderly care facilities

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Abstract

Moving from the outskirts of cities into urban neighbourhoods, so called community-based elderly care facilities are regarded as a shift from a traditional medical model of care to a social model of care, with an aim of fostering social interactions between facility inhabitants and local residents. This strategy of achieving social integration through spatial integration involves spaces at multiple scales, including not only the interior environment of facilities, but also the exterior urban fabric surrounding facilities. However, most existing research focuses on the building interior of facilities. Local authorities tacitly assume that allocating facilities within an urban community means the realisation of spatial integration, hardly addressing the spatial complexity of urban communities from a morphological perspective, which results in contradictory findings with respect to the social outcomes of implementing such policies.

Urban morphology can be a structural factor affording or eliminating opportunities of social interaction among inhabitants, which is particularly applicable to the ageing population, for whom social connections are largely realised via physical environments. Taking over 140 care facilities in the Chinese city of Nanjing as cases, this study develops a spatial network model to quantitatively identify the morphological patterns of urban communities in which facilities are located, thus considering the urban environment as an opportunity structure. It also disentangles to what extent facilities are connected or isolated from surrounding urban fabrics at various scales. Results show that being located within communities does not necessarily imply spatial embeddedness. Spatial network morphology may constrain social connection opportunities of facility inhabitants at global or local scales. Findings indicate that urban communities should not be regarded as spatially homogeneous entities when allocating care facilities. Differentiated morphological factors should be considered to optimise opportunities for social connection via spatial embeddedness.

Keyword: *spatial network morphology, social integration, elderly people, community-based elderly care facility*

Introduction

Social integration of older people is a field attracting more and more attention in the study of population ageing. Community-based elderly care facilities are regarded an important spatial and social strategy to tackle the threat of social isolation in older adults who need care, by facilitating their social connection with a local community. Although the idea of community care has been widely accepted worldwide, its actual social outcomes, as well as spatial forms, have always been controversial in the realm of ageing studies. From a spatial or morphological perspective, an evident drawback of existing literatures on this topic is that their description of the spatial relation between facility and urban community is mostly qualitative (Rowles et al., 1996, Corden and Wright, 1993, Wang et al., 2017), using semantic description rather than numeric measurements, which might be due to the non-spatial background of most researchers. This paper will introduce morphology study methods into the realm of elderly care facilities, using a network model and related spatial properties to quantitatively describe the spatial relation between care facilities and urban communities, as well as discussing social implications.

The paper starts with a brief introduction of the research background, including the social and spatial concepts of a community-based care facility, the contradictory findings in existing literature, and the necessity to employ morphological methods in this field. In the methodology section, details about spatial network model construction, network property selection and morpho-prototype detection methods will be explained. The following section will demonstrate the result of classification of all facility cases and use typical cases to exemplify their characteristic morphological traits in urban settings. Prototypes of social interactions will also be proposed to discuss potential mechanisms of how morpho-prototypes influence older people's social integration.

Background

Population ageing is continuously challenging the sustainability of existing forms of urban built environment from multiple aspects. An emerging debate regarding urban form and ageing populations is how the urban environment can better facilitate older people's social life, since social isolation and loneliness have been identified as a severe but often neglected threat to the physical and mental health of older adults. In addressing this issue, social integration becomes one of the eight major criteria in establishing age-friendly cities by the World Health Organization (World Health Organization, 2007).

Community-based elderly care facility is a scheme in response to the socio-spatial challenge facing an ageing population. By locating facilities within urban communities, it aims to facilitate older people's social connection with their familiar living environment and people. It is thus regarded as a social model of care, in contrast with the traditional medical model of care, represented by large 'professional' care facilities located in the outskirts of cities, separating older people from 'normal' social life. Community-based elderly care has been widely accepted around the world since the 1970s. Recently in China, many municipal governments have begun planning to allocate these facilities in all urban communities.

Previous empirical studies demonstrated community located care facilities can promote social integration by supporting their inhabitants continuing participating in local social activities, as well as using local services (Van Steenwinkel et al., 2017). For those more vulnerable residents being incapable of going out, these care homes can facilitate the frequency of being visited by friends and relatives (Corden and Wright, 1993, Reed et al., 1998), thus helping them maintain social connections. However, academic discussions on care facility location and older people's social integration are generally rare and mainly qualitative. The definition of 'good' location and 'close' connection to local community lacks precise and quantitative measurements, resulting in difficulties to make comparisons across different context and cases. This is also the case in the realm of practice. Policy makers and local authorities merely address the location of a care facility inside urban communities, neglecting the fact that, from a morphological perspective, urban communities can be endogenously heterogeneous and complex.

The ambiguity in the spatial relation between care facilities and urban communities results in controversial findings with respect to their social outcomes. For example, some proposed that small-size community-based care facilities can enhance social isolation. Without available nearby urban spaces for social activity, small-sized group settings generate negative social outcomes for their inadequate spatial provision to ensure residents' privacy and choice (De Syllas, 1999). Others documented that many care homes were situated 'inappropriately' within communities, such as inside gated communities, which not only constrained inhabitants' access to wider urban environment, but also reduced local people's usage and awareness (Wright, 1995, Wang et al., 2017).

Older people's social life is more dependent on the built environment than is the case for younger generations (Lawton and Simon, 1968). Urban form plays a crucial role in facilitating or impeding older people's access to resources, chance of encounters and interactions (Alidoust et al., 2018, van Melik and Pijpers, 2017), as well as feelings of integration and isolation (Schorr et al., 2017). As Wenger (1990) described, elderly people's neighbourhood relation is highly space dependent. It is thus necessary to introduce urban morphology methods into the realm of care facility research, to disentangle the extent to which facilities are embedded or isolated from their surrounding urban fabric and their influence on older people's social integration.

Methodology

Study area, context and data

The study area in this paper is comprised of four districts in the main city of Nanjing, China (**Figure 1**). Nanjing is the capital city of Jiangsu Province in Eastern China. It is the most developed, as well as 'oldest' areas in the country, with 23% of people aged 60 and over in 2017, ranking first among all provinces (Jiangsu Provincial Government, 2018). In 2014, Nanjing was made a pilot city for the exploration of establishing a comprehensive elderly care system by China's Ministry of Civil Affairs. Within the study area, there are a total of 147 community-based elderly care facilities. Their basic information and locational data are acquired from the website of Nanjing Municipal Government (2019). The road network data is from OpenStreetMap, an open-source geo-database.

Methodology framework

A methodology framework is proposed to quantitatively identify the morphological pattern of care facilities with regard to their spatial relation to surrounding urban communities at various scales (see **Figure 2**). The framework includes network model construction and spatial variable generation, principal variable extraction, clustering and morpho-prototype detection. At the end socio-prototypes of care facility users are proposed to discuss potential social implication of various morpho-prototypes.

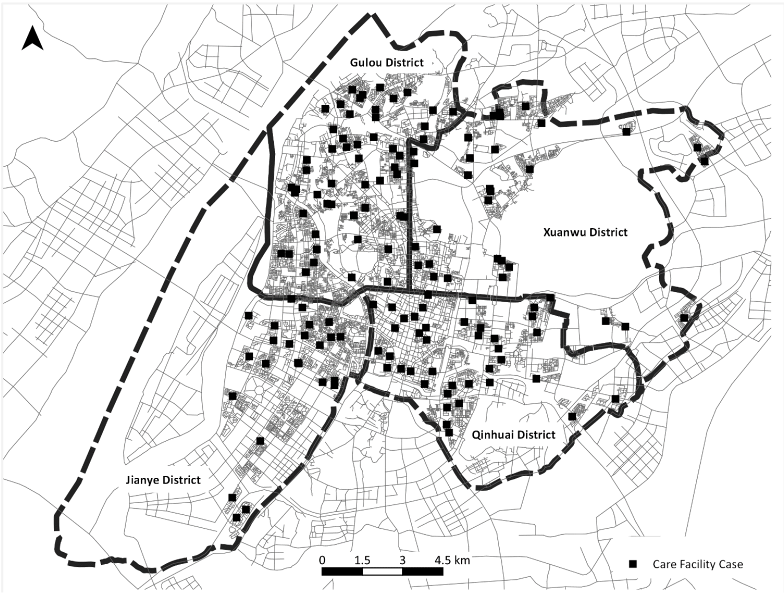

Figure 1. *Overview of the study area and facility cases in Nanjing*

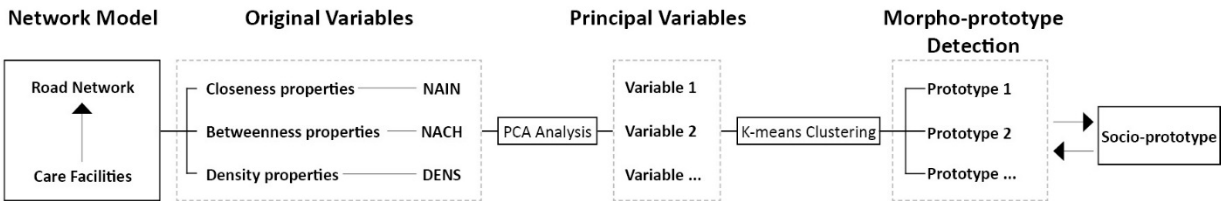

***Figure 2**. Methodology framework*

Network model and variables

Spatial Network modelling is a prevailing approach in studying urban morphology. Its distinctive advantage lies in transforming morphological elements into a network based on their spatial relations, and looking into morpho-patterns, as well as socio-behavioural impact through a relational perspective (Marshall et al., 2018, Porta et al., 2006). Various global and local morphologic patterns revealed by spatial network models have been proved to be significant in influencing people's social life. This matches well with the purpose of this paper, as well as the ethos of community-based elderly care facilities.

The spatial network model in this paper is formulated based on the street segment model widely used in Space Syntax research and other spatial network studies (Turner, 2007). In the model, each street segment (divided by intersections) is transformed into a node, while edges between two nodes are defined as two street segments sharing the same intersection. Care facilities are linked to street segments on which their main entrance is located. In this way network properties of the street segments are assigned to their linked care facilities.

Three types of network properties—closeness centrality, betweenness centrality and density, are employed to describe how care facilities connect with the community urban fabric. Closeness centrality measures the accumulated 'distance' from a street segment to all other segments within given radius. It captures how accessible a facility is to all potential destinations, being regarded as an indicator of 'to-movement' in urban studies (Hillier, 1996, Porta et al., 2008). Betweenness centrality measures the number of times a segment is to be passed on all shortest routes between all other segments within a given radius. It captures how a segment is to be passed through by local people, known as an indicator of 'through-movement'. Density describes the number of roads surrounding a facility available to move through. In this paper, closeness and betweenness centrality are calculated following the algorithm developed by Hillier et al. (2012), Normalised Angular Integration (NAIN) and Normalised Angular Choice (NACH), which use angular rather than metric distance to calculate spatial impedance between segments. As for street density (DENS), following the idea of street network modelling, here we use the total number of segments within a given radius (also known as 'Node Count') to measure street network density.

All network properties are calculated under certain distance thresholds (or radii). In spatial network analysis, different radii correspond to different movement patterns, from short to long distances. In this study, a range of distance thresholds from local (250 m) to global (5000 m) scales are specified, to represent walking and traveling distances of both frail and healthier elderly people, as well as long-distance visitors.

Morpho-prototype detection

To detect morpho-prototypes of care facilities based on their network properties, Principal Component Analysis (PCA) and a K-means clustering algorithm are used. Since all three types of network properties, NAIN, NACH and DENS are calculated at various radii, a total number of 18 spatial variables will be generated. Given that results of K-means algorithm are likely to be distorted by high dimension dataset, PCA is used to detect correlated variables and extract principal variables from original ones (dimension reduction) before clustering. To determine the optimal number of K-means, the sum of squared distances within clusters (distortion) are calculated and a knee-point detection algorithm is used to pick a validate cluster number (Brun et al., 2007, Satopaa et al., 2011).

Results and Discussions

All original spatial variables (NAIN, NACH and DENS) of each street segment are computed in Depthmap platform with a network model of the whole city. The result was then exported to QGIS platform, to align spatial properties from street segments to care facilities according to their location. Thus, each facility possesses its own spatial variables.

Principal variable extraction: results of PCA

PCA was conducted within each group of spatial variables (NAIN, NACH and DENS). Table 1 shows the result. For each group, two principal variables are extracted. Factor loadings indicate the degree to which extracted principal variables are related to original variables. It is clearly demonstrated that in each of the three groups, Factor 1 is highly related to global scale variables, while Factor 2 is highly related to very local scale variables. Therefore, the extracted six principal variables are named as Global and Local NAIN, Global and Local NACH, Global and Local DENS, respectively. They will be employed to conduct the following K-means clustering analysis.

Table 1. Results and factor loadings of Principal Component Analysis

Original variables	**Extracted variables**		**Original Variables**	**Extracted variables**		**Original Variables**	**Extracted variables**	
	Global NAIN	Local NAIN		Global NACH	Local NACH		Global DENS	Local DENS
NAIN_R5000	0.932	0.067	NACH_R5000	0.944	0.306	DENS_R5000	0.966	0.006
NAIN_R3000	0.942	0.192	NACH_R3000	0.938	0.330	DENS_R3000	0.963	0.115
NAIN_R1000	0.788	0.500	NACH_R1000	0.894	0.440	DENS_R1000	0.244	0.873
NAIN_R800	0.714	0.612	NACH_R800	0.857	0.503	DENS_R800	0.133	0.941
NAIN_R500	0.429	0.835	NACH_R500	0.735	0.650	DENS_R500	-0.020	0.965
NAIN_R250	0.029	0.898	NACH_R250	0.322	0.940	DENS_R250	-0.070	0.757
Total Variance Explained	87.370%		**Total Variance Explained**	98.407%		**Total Variance Explained**	85.160%	

Results of K-means clustering and morpho-prototype detection

Six global and local spatial variables extracted by PCA are employed to classify care facilities by K-means algorithm. The sum of squared distances within clusters (distortion) are calculated and plotted (see **Figure 3**). The knee-point detection algorithm suggests 5 as the optimal number to compute cluster results. Table 2 shows the result of clustering, network properties of five cluster centres, as well as the number of facility cases within each cluster. **Figure 4** visualises network properties of five cluster centres with radar maps and detailed morphology patterns of typical cases within each cluster, from which we can clearly tell the differentiated patterns of network properties of care facilities.

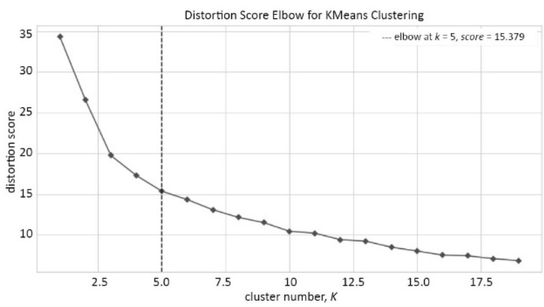

***Figure 3**. Validation of K-means cluster number*

Table 2. Cluster results and cluster centres measured by local and global network properties.

Clusters	**Network properties of cluster centres**						**Count**	**Perct**
	Global DENS	Local DENS	Global NACH	Local NACH	Global NAIN	Local NAIN		

1	0.422	0.483	0.690	0.638	0.697	0.351	22	15.0%
2	0.333	0.311	0.532	0.651	0.393	0.250	31	21.1%
3	0.181	0.187	0.833	0.162	0.641	0.275	10	6.8%
4	0.195	0.573	0.491	0.812	0.314	0.363	56	38.1%
5	0.193	0.336	0.134	0.428	0.256	0.204	28	19.0%

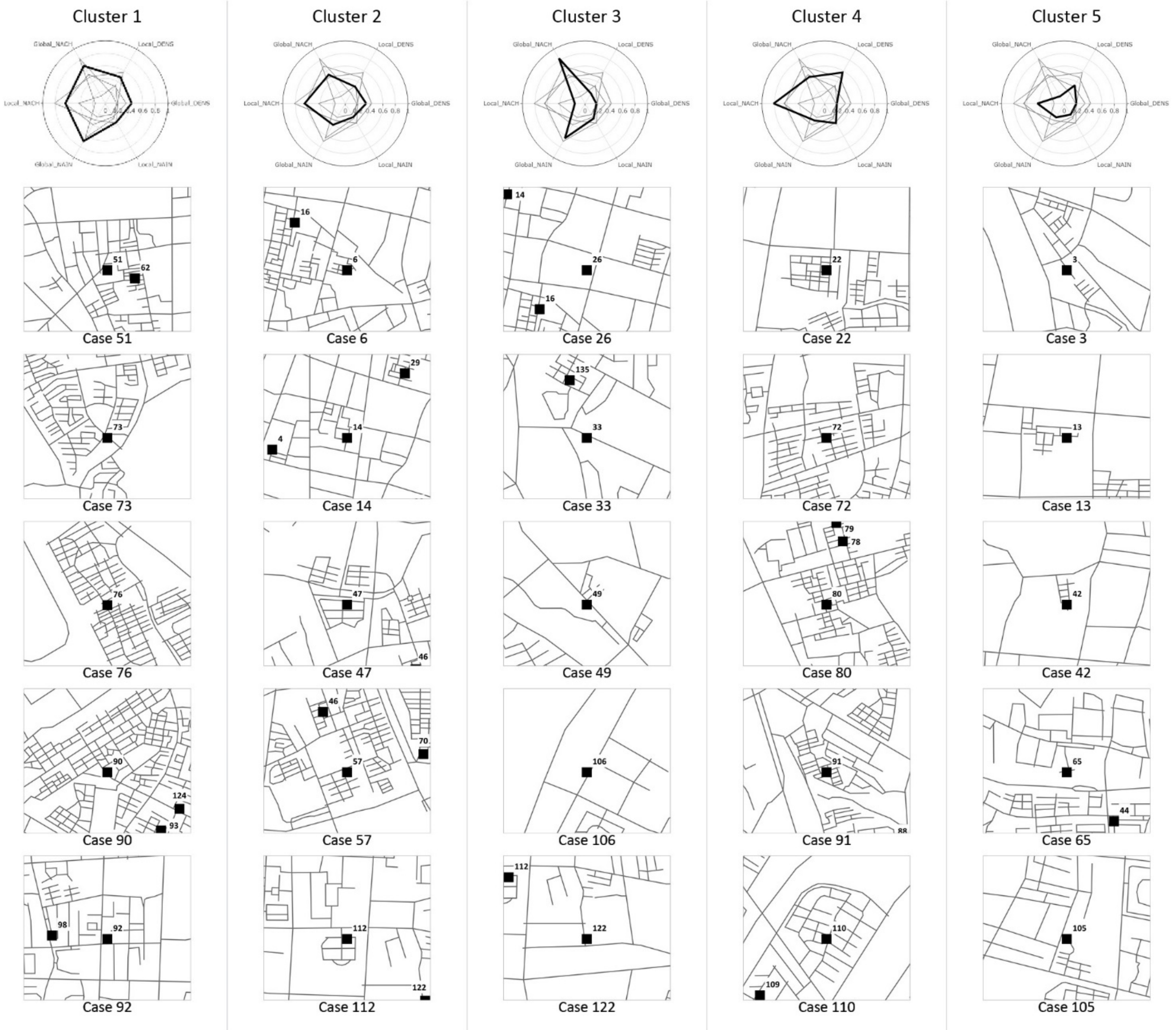

Figure 4. *Radar map of cluster centres and typical cases within five clusters*

Cluster One – Spatially Integrated Facilities have almost the highest values regarding all morphological properties compared to other clusters. Most of the cases in this cluster are located on streets which not only connect closely with large areas of residential communities (high NAIN and DENS value), but also bridge the connection between individual communities (high NACH value), such as Case 73, 76 and 90. Another type of cases in this group are those located at the intersections of main roads, with dense nearby urban grids such as Case 51 and Case 92. **Cluster Two – Globally Isolated Facilities** are mostly located in small gated residential communities, and on those roads directly connected with community entrances (low local DENS and high local NACH values). **Cluster Three – Globally Integrated Facilities** are featured by high values at global scale network properties, while values at local scales are low. Urban blocks in these areas are notably large and street network density is low. Extremely high global choice values of roads with care facilities imply a large volume of long-distance traffic flow. **Cluster Four – Locally Integrated Facilities** accounts for the largest proportion of facility cases among the five clusters. Values at local scale are high, whereas their global scale performance is relatively limited. Compared with Cluster Two, high local density values are attributed to the large scale of gated communities within which they are located. Besides, they are also located on main streets within communities. **Cluster Five – Spatially Isolated Facilities** have the most disadvantaged spatial network properties of all clusters. As shown in the radar chart, every aspect of their morphological values is relatively low. Their most recognisable morphological pattern is being locating at the 'end' of roads, which are either dead ends within gated communities (Case 13, 42, 105), or cul-de-sacs in urban environments (Case 3, 65).

Based on the clustering results and morphological properties of cases within each cluster, we propose six morpho-prototypes of care facility locations regarding their patterns of connection with the urban fabric (see **Figure 5**). Type 1 to 5 correspond to Cluster One to Five as described above.

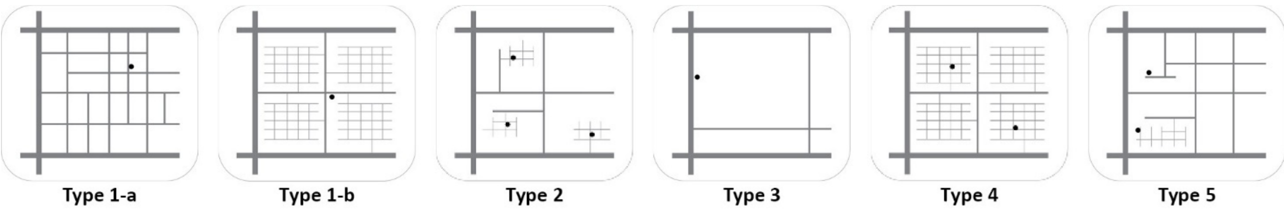

***Figure 5**. Morpho-prototypes of care facilities based on clustering results*

Morphological prototypes of care facilities and social implication

To discuss the social implication of the six morpho-prototypes, we firstly propose a mechanism of social interactions in community-based elderly care facilities (**Figure 6**). Four types of social interactions (A, B, C and D) happen among four types of people (healthy and vulnerable inhabitants, visitors and local residents) in spaces within both the urban community and facility interior. Except for type B (interactions between vulnerable and healthier inhabitants within facilities), the occurrence of all other types of interactions relate to the urban community environment. For type D, the community environment is supposed to support healthier inhabitants when they go out to socialise with local people. For type A and C, the facilities' spatial relation with the community influences the way visitors use the facility thus the opportunity for inhabitants to socialise with visitors.

Generally, maintaining vulnerable inhabitants' external social relations is more attributed to the facility location than for healthier inhabitants, because they cannot leave the facility freely, and being visited by neighbours, friends or relatives is the only way to keep in touch with others. Therefore, we assume vulnerable inhabitants living in facilities of type 2, 3 and 5 are more likely to lose weak social ties (friends and neighbours) for the reason that local pedestrian flows passing through the facility are likely to be low. Although healthier inhabitants are more independent and can overcome certain spatial impedance by walking out, living in facilities of type 3 can still be problematic, because the choice of walkable streets nearby is limited. As for type 2 and 5, healthier inhabitants might have to walk to places with more social opportunities at their will. The urban morphology of cases in type 1 and 4 can be more advantageous to facilitate older people's social interaction with the local community. Considering type 4, a location within gated communities is not necessarily an isolated situation, when the community is large, and the facility is on main roads.

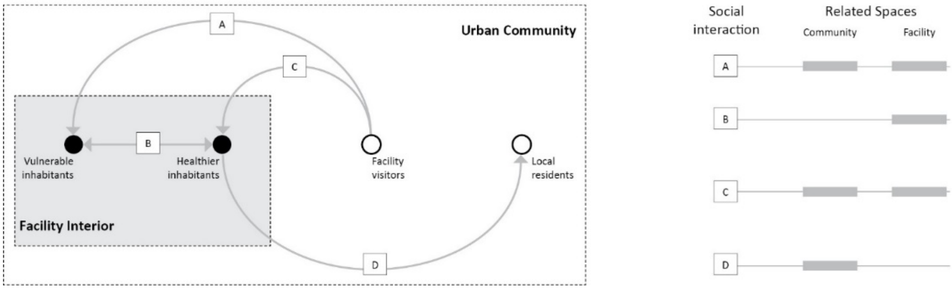

Figure 6*. Mechanism of social interactions in community-based elderly care facilities and their related spaces*

Conclusions

This study develops a network model and investigates morphological patterns of care facilities with regards to how they are connected with the urban fabric, using network closeness, betweenness and density properties at local and global scales. Taking over 140 care facilities as cases, we detect six distinctive morpho-prototypes. Our findings demonstrate the diversity and complexity of morphology in urban communities and reveal the fact that community-based care facilities are not always spatially 'integrated' into the urban fabric. Potential social outcomes of these morpho-prototypes are also discussed. The study provides a quantitative method disentangling the myth and contradictory findings regarding community embeddedness of care facilities. It also proposes a framework bridging socio- and morpho-prototypes, which can be used in future empirical study of older people's social networks and interaction behaviours.

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