Spatial Concerns in Logistical Networks with Special Reference to Proximity

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Abstract

In this mainly conceptual study, some aspects of space in logistical networks are discussed; especially distance as a reflection of spatiality is scrutinised. The theoretical contemplation is complemented with preliminary empirical analysis in transportation industry and networks. Because networks as metaphorical conceptualisations have very strong geographical aspects, it is necessary to link the question of spatiality - e.g. interorganisational proximity - to network analysis. Spatio-temporal aspects constitute even some ontological features in network analysis as they give valuable conceptualised tools for comprehending the diversity and complexity of networks. The significance of embeddedness in network studies means also that the spatiality should be deliberated, as embeddedness can also be interpreted as involvement in local or close dyadic and network relationships. Distance equals to interorganisational friction as presumed in literature, though often implicitly expressed (e.g. impedance, inconvience) and it can be an expression for studying the proximity between the actors. Conventionally, the Newtonian-based interpretation of interaction has dominated the logistical analysis with strong focus on gravitation, aggregate type of modelling and analysis of adequate distance measures (time and cost distance). With the help of extensions for assessing and measuring interorganisational interaction and its frequency, new types of correlations and interpretations can be formulated to describe the proximity and closeness-remoteness- axis between the participants of logistical networks. It can be suggested that the social distance measure (influencing how time and cost distance measures are perceived and interpreted by the actors) seems to be more important when interorganisational proximity is discussed and analysed.

Keywords: Spatiality, Proximity, Distance, Logistical Networks, Relationships

Introduction

Space or spatiality have been suggested to be among the most remarkable - even ontological - dimensions in network studies, although not enough attention has been paid to them (Törnroos et al. 1995; Oinas 1998; Halinen and Törnroos 1998). Theoretically, it is very difficult - if not even impossible - to discuss network-related issues without spatial considerations, especially when infrastructural networks are scrutinised. As Frybourg and Nijkamp (1998, p.16) point out '*network has a geographic meaning and covers a given area*'. Furthermore, this implies that there is '*no network without territory and no territory without network'*. It is thus necessary to pay proper attention to the closeness-remoteness aspects in networks, reflecting the different views of analysing organisational proximity.

When analysing how a single actor is embedded in its surroundings, the question of *s*patial embeddedness should be viewed as well (Halinen and Törnroos 1998; Oinas 1998). Spatial embeddedness can refer to the role of space and geography in networks in a general manner without an explicit content. Generally speaking, there are actually two different perspectives for discussing particularly this element: spatial issues as an outcome of related theory-making and testing (e.g. using the location theory as a presumption) and spatio-mental perspective, which encapsulates human actors' different understanding of space with the help of personal mental maps (Halinen and Törnroos 1998).

The role of space and geographical dimensions in general is inherently associated with logistical thinking, though *per se* not a major item of interest in related studies. In this study logistics as a concept refers to the operational side of conventional supply chain management (SCM), such as transportation systems, which constitute network-like structures. Unlike in traditional SCM, in this study logistical networks consist of multiple actors tied up with various links and (business) relationships. From the theoretical point of view, there is actually a remarkable difference between those interpretations which rely on the use of SCM-based network theory and those explanations, which discuss networks with the help of the interaction-based approach (for more discussion see Nikkanen 2003 or Nikkanen 2004).

In infrastructural logistics networks (with diverse hubs, nodes and connecting links enabling efficient transportation of goods and respective information flows), spatiality is often understood, but implicitly expressed in the models; some researchers even claim that space is nearly ignored in advanced research work (Törnroos et al. 1995). In order to grasp the spatial issues more accurately, the following illustration depicts the interconnected elements of the logistics theory (Törnroos et al. 1995):

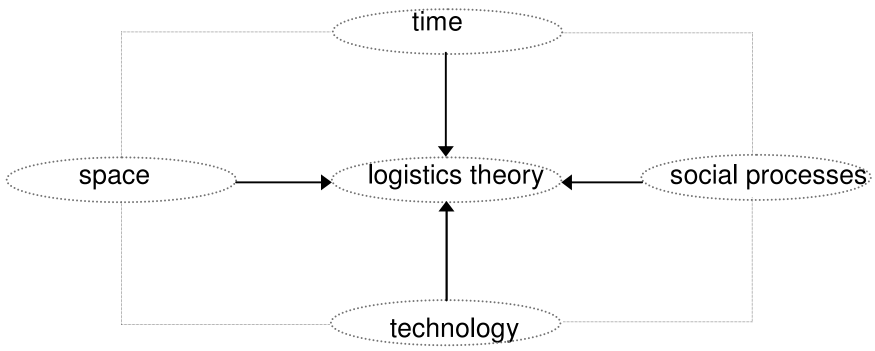

Figure 1. Core Concepts of Logistics Theory for Analysing Networks

Besides the ontological concepts space and time, also *social processes* have an influence on how actors observe the outer reality and thus perceive proximity. When operationalising the space element, three items can be particularly derived: location, spatial interaction and the distance factor in the interfirm context, and the firm-environment interface (Törnroos et al.1995). With respect to the infrastructural networks, it is a necessity to make the present system work more efficiently in space, changing the space through new infrastructural investments to serve the needs of logistics better, and co-operating with other firms to manage and organise the geography of logistics more efficiently (Törnroos *et al*. 1995, 21). As regards technology, state-of-the-art solutions in sending and dealing with information flows (e.g. for tracing and tracking single consignments) can compress the in-transit time in supply chains, shrinking the scope of networks and creating more compact visions of their extent for the observing actors.

Castells (1996, p.376) hypothesises that actually space organises time in a network society; this statement assumes the domination of space by time. Castells is obviously interested in the social meaning of time, analysed with adequate social theories rather than geographical and/or logistical models. For Castells (1996, p.410) space is the expression, not a reflection of a networked society, as spatial forms and processes are formed by the dynamics of the overall social structure or social processes. Furthermore, 's*pace is crystallised time'* (ibid. 411).

Scope and objectives

The major objective of this study is to discuss and analyse different perspectives of spatial issues particularly in logistical networks; especially distance as a reflection of proximity is scrutinised. The analysis relies on the use of related theories, beginning from conventional interaction models, and subsequently enhancing the scope from the traditional approach to other types of distance measure (mental maps often as an outcome). Some preliminary empirical testing is also provided (intermodal freight transportation networks with the Finnish railway system as a testing ground). As transportation networks include a multitude of actors engaged (not just carriers and transportation companies but also e.g. logistical service providers, shippers, and consignees), the concept logistical network is preferred to transportation; on the other hand the operational side is addressed. In this study the distance measure covers not only physical proximity, but also organisational proximity based on the actors' perceptions of obstacles and friction. The actors - alone or collegially - perceive and interpret the common space in a different manner based on their own mental maps; interorganisational friction can thus be an expression of perceived distance.

When analysing connectedness in infrastructural networks it is important to evaluate the interaction between the nodes broadly and deeply (e.g. perceiving actors or hubs, as often in transportation nets) by utilising appropriate interaction models. Unlike in logistics, spatio-temporal dimensions are widely contemplated e.g. in the modern geography of enterprises (see e.g. Oinas 1998). Furthermore, the growing significance of embeddedness *inter alia* as a conceptualisation in network studies means also that the spatiality should considered; embeddedness can be interpreted as the involvement of the actors in local or close dyadic and network relationships.

Conventional Approach for Distance in Explaining Spatial Interaction

As mentioned above, distance can be defined as friction - impedance indicating spatial separation or segregation - between two points. This friction is an obstacle or hinder for interaction in space, thus reducing the amount and frequency of desired interaction. The major interest for considering geographical aspects in conventional logistics research is to find a *correlation between interaction and distance by using adequate variables*. The correlation between distance and interaction can be depicted graphically with a distance-decay curve: a downward loping curve expresses a simple trade-off, in which spatial interaction tends to diminish with distance. Distance *per se* is an expression and a measurement tool for studying the proximity between the actors in logistical networks. Conventionally, the Newtonian-based interpretation of interaction has dominated the analysis with strong focus on 'gravitation', aggregate type of modelling and adequate distance measures. Thus two distinct levels can be distinguished: either individuals as actors (disaggregate level) or groups of people (aggregate level) are under consideration. Distance is typically measured with concrete distance (close to

Euclidean distance), which means a straight connecting line between two points or a physical distance between two points. In addition, concepts like time distance and cost distance can be relevant. These models are still more predictive than explanatory - actually these models do not tell much about the motives and reasons beyond the interaction. Particularly aggregate correlations predominantly express statistical probabilities and random distributions for behaviour. Due to the limitations typical for traditional analysis, there is lot of interest to wider the discussion with new initiatives.

Besides physical distance (between nodes such like terminals in intermodal transportation), particularly in logistical networks with diverse hubs and nodes, cost distance and time distance can be even more relevant than physical distance, especially when a shipper assess the closeness or remoteness. Cost distance is the sum of the total costs (often evaluated with the help of the total cost of ownership- approach) during the transportation legs; the time distance denotes the total travelling time between two points. Regarding the time distance, it is often an urge for the operators in supply chains to reduce the transportation time by eliminating the non-value added time (NVAT). It has been estimated that the NVAT can be as high as 95 % of the total time (as interpreted by Burgess 1998, p.18).

When the total spatial interaction in logistical network studies is assessed, gravity models are the most frequently applied. These models are analogies to the common Newtonian theory of interaction, which aims at finding correlation between interaction, mass components (implying attraction) and distance. The analysis is typical on the aggregate level with strong descriptive expression. Some attempts have been made to increase the explanation power of these models, but they are still more predictive than explanatory - actually these models do not tell much about the motives and reasons beyond the interaction (Marjanen 1997). One of the obstacles in the aggregate correlations is that they express predominantly statistical probabilities and random distributions for behaviour.

As regards interaction, scholars mostly define total interaction as the flow between two points that are scrutinised - between i and j (e.g. Fotheringham and O'Kelly 1989). In the gravity models the distance measure should be quantifiable - that is measurable in some unitary, mainly physical units such like geographical units (see Appendix 1 for details). For this reason the use of more cognitive, attitudinal, and social distance measures are often criticized, because they are based on qualitative evaluations among actors - they are ordinal in nature (Sen and Smith 1995); moreover the classical gravity type of expression as a functional relation '*cannot possibly hold for all ordinal transformations of such distances,* (e.g. social distance) *between population centres i and* j, (which can be in more general relation more context-specified, and flexible: in general the mass component) *this model would fail to have any empirical content whatsoever*' (op.cit.,p. 20; the comments in parenthesis by the present author).

Despite of the dominance of the traditional approach, also in logistics research scholars have recently paid more attention to disaggregate cognitive spatial choices with detailed description of the decision-making of individuals. Hence, distance equals to interorganisational friction, as presumed in network-oriented literature, though often implicitly expressed (e.g. impedance, inconvience, lack of intimacy). Williamson claims (1986, p.176) that basically even transaction costs *'are the economic equivalent of friction in a physical system'.* Accordingly, friction is parallel to impedance, which means that the term is close to the distance attribute. The Transaction Cost Approach (TCA) contributes to the theoretical discussion on spatial issues as well, as this particular theory attributes to determining the optimal type of relationship a firm should develop in the network; at the extreme, a (business) relationship is either a close one (as in smaller nets) or distant (as often in the entire network).

Enhancing the Content of Distance

In contrast to geographical distance, which locates facilities and assesses the amount of interaction, cognitive distance can be classified as *subjective distance.* In this sense Piaget's developmental theory (Piaget's fundamentals: perception and conception of single items like space, or physical causality among individuals) can be integrated to spatial analysis. Every individual goes through different stages in his/her life - from infancy to adulthood - creating mental or cognitive maps from the surrounding reality. Information is filtered and it is a subjective perception of reality and real-life circumstances. Thus, an individual continuously assesses the alternatives, and with the help of cumulating knowledge, re-locates points in his/her mind, and consequently evaluates the distance e.g.

with the help of mental maps (e.g. Novak 2002, p. 58-63 discusses the basic elements of Piaget's theory). In the constructive paradigm of behavioural sciences each individual creates new solutions and knowledge to a solid basis, which is (re)constructed over time. The cognitive distance is a result of personal experiences with attitudes, values, norms, and preferences as critical forces and drivers. In the spatial theory of interaction the distance hypothesis is common: the location of more attractive centres tends to be underestimated in terms of distance. Individuals may have adopted new models when visiting this relatively more attractive place or they have gathered more information of the place through media or personal contacts.

In the network-based approach, where networks are defined as sets of relationships, four types of distance variables are generally listed: besides geographical and time distance, social and technological distances are considered (Ford 1997, p. 44). The geographical distance has undeniably a powerful cultural connotation, and thus dispersed interpretations are typical for the term. Table 1 is compilation of various ways to discuss the different dimensions and their measurement criteria (compiled from presentations by Turnbull and Topcu 1994, p.20; Ford 1997; Castells 1996; Ford et al. 1998). Some preliminary findings of distance measure in intermodal freight transportation industry, which represents transportation systems as logistical networks, have been added as well (see also Nikkanen 2003, p.98-105).

Table 1. Variations of Distance Measure in Interorganisational Studies

Dimension	*Criteria for Measuring the Attribute*
• social distance	level of friendship extent of exchange of special information frequency of contacts level of knowledge about each other
• cultural distance	cultural differences with a non-local partner
• geographical distance	location of point of interest (hubs and nodes)
• technological distance	differences in technologies differences in production technologies and features number/event of technical adaptation required
• time distance	lead time (between acts, or actions, or episodes)

The interorganisational distance varies between zero (high, intense interaction, no preventing factors, high frequency) and infinite (no connections, no transactions, no interaction; Castells 1996). If the preventing factors totally block interaction, the perceived distance between the partners is infinite. In network studies it can be hypothesised that objective distance might be a poor predictor of interorganisational performance, since the social nets compress the distance by shrinking the space. In all, effective communication does not necessarily require geographical proximity, because the use of communication applications enables close contacts also in distant locations. Consequently, distance as a concept can be interpreted as accessibility or interorganisational location, thus having tangents with the position concept. Moreover, the technological distance measure is essential for assessing the degree of structural bonding. It is hypothesised that stronger adaptation of advanced technology (e.g. EDI or similar information delivery systems) significantly reduces this distance measure. Distance as a hinder in interaction is specially an important attribute in the so called co-existence phase of network formation; this stage is one of the stages in the relationship evolution, leading subsequently to deeper co-operation among the actors in the net (Easton and Araujo 1992, p.71-81).

In general, the adoption of new behavioural features seems to have an impact on the perception of distance. Adoption is a process among individuals, having such aspects as full uncertainty and no knowledge before deeper awareness and even action regarding many options. This means that individuals' preferences go through effects on cognitive, affective, and conative (behavioural, experimental) levels (CAC-expression; see e.g. Novak 2002).

As regards the intermodal choice, the CAC- expression is quite valuable in evaluating the perception of distance. If a decision-maker (e.g. a shipper, or more generallly an actor in a net) is at a cognitive stage, he or she has the basic information regarding the route. The knowledge is neutral and still quite a long distance is assessed in terms of cognitive distance. The affective level means more positive attitudes and preferences against a specific route or a counterpart. The conative stage refers to testing and experiencing the service promise provided by the operator. In addition, the successful co-operative activities as results of practical issues drive the individual's attitudes towards the conative level. The cognitive distance can be decreased by practical testing and gradual adjustments. In general, adoption as a process is more linked to situations in which an actor more unconditionally accepts the external pressures and their impact on his/her own activities.

Consequently, cognitive distance can be utilised to measure and evaluate the sum of factors hampering the interaction between the actors. Moreover, the position as a conceptualisation includes the notion that each actor subconsciously examines his/her own mental space, which means that there is both a constellation of locations for the actors and a bundle of dimensions impeding the interaction between the actors in their positions.

The personal interpretation of the distance measure is an important notion, as individual interpretations do influence on how organisations handle and conceptualise proximity: interorganisational relationships often tend to be as much inter*personal* as truly inter*organisational*. The power of social nets is remarkable in understanding the nature of relationships (and subsequently nets/networks as well). Earlier studies clearly indicate that besides cost and time distance, also social distance seems to be more important when distance as a conceptualisation is discussed and analysed (Nikkanen 2003).

Distance analysis includes several imperatives for the empirical working procedure. It is essential to analyse the possible pitfalls and obstacles for deepening the collaborative actions among all the actors in a network. The perceptions are undoubtedly affected by non–subjective, concrete distance measures evident in the infrastructural network. With the help of appropriate methodology, cognitive distance measure can be applied in those situations where the main target is to assess the organisational proximity between the partners. The distance measure is significant for the roles of the operators, as well. The roles are often reinforced by closeness, because of the diverse actor bonds (and other links) between the operators (actors) force them for certain adaptations. It can be hypothesised that the more bonds there exist between the actors, the less perceived remoteness there is, and the stronger are the identifiable roles. Regarding the position of an actor in a network, it can be claimed that it is not possible to locate a single actor without considering the organisational distance, as actors define their position as a relation to others. This is especially true when nets as subentities of networks are considered; the social distance either enables being a catalyst or hampers collaborative interaction.

Concluding Discussion

In this study the distance measure captures not only the physical proximity, but more the organisational proximity based on actors' perceptions of the obstacles and friction. The spatio-temporal dimensions, in general, are fundaments in the common interaction theory, though it has to be admitted that they are not fully explained especially in the field of logistics. The role of space and spatiality is vital in network studies. Instead of considering the concrete location of firms or operators (e.g. hubs, nodes, or facilities) as presumed in Supply Chain Management-based (SCM) thinking, it is worth analysing how a single firm is embedded in its surroundings, embracing also the analysis of the aspects of spatial embeddedness. Actors - whether alone or collegially - perceive and interpret the common space in a different manner, based on their own mental maps. Perceived distance – as presumed in the network view – can be an expression of interorganisational friction.

It can be assumed that the frequency of interaction between two points (e.g. actors often as nodes or hubs) is an attraction measure divided by some distance measure, as presumed in location theories. The attraction is a perception reflecting many determinants, forces and features and respective variables, and can be linked with bonding as well. The distance can be cognitive by nature, as often explained by often by network scholars, and have many variations, such as social, technological, and transaction based time distance; occasionally the term psychic distance is parallel to cognitive distance in IMP-related studies.

The enhanced distance analysis includes several aspects for the practical working procedure. It is essential to analyse the possible pitfalls and obstacles for deepening the collaborative actions among all the actors in a network, that is studied Perceptions are undoubtedly affected by non–subjective, concrete distance measures evident in the infrastructural network. With the help of appropriate methodology cognitive distance measure can be applied in those situations where the main target is to assess the organisational proximity between the partners. The distance measure is significant for the roles, as well. The roles are often reinforced by closeness, because of the diverse bonds between the actors. This implies that that the social distance measure (influencing how time and cost distance measures are perceived and interpreted by the actors) seems to be more important when interorganisational proximity is discussed and analysed.

However, the conventional SCM theory is poorly equipped to explain the true nature of social elements; for this reason there is still a dominance of concrete and measurable distance measures in analysis (e.g. time and cost distances). Among SCM practitioners there tends to be an illusion of totally managing the chains/systems/logistical networks. The network approach considers also social net(work)s addressing also the non-linear pattern of processes. The outcome is thus less deterministic, implying an impressionistic interpretation of the reality. Reality is a social construction, which means that every actor (whether a firm, a group of people, or a single human actor) or an observing researcher has a limited ability to comprehend the reality and its features clearly, including also the abundant dimensions of proximity.

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Appendix 1: Newtonian-based Interpretation of Distance and Interaction

A general correlation for spatial interaction is (Sen and Smith 1995; Fotheringham and O'Kelly 1989):

$$T_{ij} = G\ (w_i P_i)^{\theta}\ (w_j\ P_j)^{\phi}\ / d_{ij}^{\delta}, \quad \text{where} \qquad (1.1.)$$

Ti j= total spatial interaction between points i and j measured by means of flow from point i to j,
Pi = size (the population /the mass variable/the attractiveness /the attraction) of point i,
Pj = size of point j,
wi, wj = parameters reflecting the heterogeneity of masses (e.g. the population); similar to classical Newtonian hypothesis,
dij = distance between points i and j indicating spatial segregation
G = gravity coefficient (the gravitational constant – often e.g. demographic constant), and
θ , ϕ and δ are parameters - statistically estimated - for which θ, ϕ, and $\delta > 0$. In the classical Newtonian model for $\delta = 2$.

In a more reductionist view, it can be supposed that the distance decay function *per se* summarises all the effects of spatial interaction. The following correlation highlights the power deterrence function (Sen and Smith 1995, p. 4; also Martellato et al. 1998). The decay function can be expressed as follows:

$$F\ (d_{ij}) = (d_{ij})^{-\delta}, \quad \text{in which} \qquad (1.2.)$$

Fij = is the intensity of attraction and
dij = distance measure (e.g. time/cost)

The basic model can be modified with the following determinants:

- the size factor, typically measured in terms of mass in the gravity models is replaced with the attraction of a particular point defined in terms of personal beliefs, values, preferences, and other adequate determinants of behaviour; these variables are context-specified and elaborate the situational features at one temporal point, and
- the distance is defined with some appropriate distance measure.

When configuring the basic model, the following hypothetical relation can be written:

$$T_{ij} = \sum_{i=1}^{n} (w_i C_{ij}) / d_{ij}, \quad \text{where} \qquad (1.3.)$$

Tij = spatial interaction between points i and j,
wi = the proportional importance of factor in decision makers preferences at the point i,
Cij = the preference/ importance of factor i in point j, and
dij = distance between points i and j.

In short, the amount of interaction is directly proportional to the attraction of a certain point measured e.g. in terms of the decision maker's perception of that point and inversely proportional to the distance measure. The proposed correlation is consistent with the general model expressed by Sen and Smith (1995) as a compilation of many researchers' work; they claim that an extended, general class gravity model is Tij = A (i) B (j) F (dij), where A (i) and B(j) are unspecified origin weight functions and F(dij) is an unspecified deterrence function.