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Using Networks to Measure Properties of Mediterranean Liner Transport System

Summary

Ordinary geographical and transportation maps are networks where actor positioning reflects Euclidean distances between the actors. Distances between the actors on these maps reflect a structural data set: spatial distances. In principle, what this research is doing is a re-mapping of the spatial contects into an economic context using network structures.

The idea of the research is to implement the social network techniques in the field of transportation networks. The proposal of the authors is to accept the calculated measures that could be indicative for understanding possible economic advantages derived from geographical and transportation networks. Although this research is in its primary stage, the results calculated and presented in the paper show that this approach could be significant in showing new trends, when dealing with the network structure. In this paper, the research theory has been first reviewed and then the Mediterranean liner transportation model has been presented. Authors are aware that the real world models are different and that a model represents a momentary snapshot of the liner network and that there is also the tramp vessel network…

Notwithstanding this, the authors are convinced that the models and results shown in the research are sufficient to provide ulterior research.

Key words: transport networks, ports, social networks, the Mediterranean transport system

1. Introduction

The increasing use of container as standardized cargo unit in maritime transport, which has involved an important technological shift, is the most outstanding phenomenon that has taken place in this sector last thirty years. The pace of growth in the European and Mediterranean container port markets has been truly dynamic in recent years. This has been driven by the globalization of the world economy, the introduction of much larger vessels into the deep-sea trades – with associated rapid feeder demand growth – and also strong expansion in intra-regional trades.

The routes through the Suez Canal and the Mediterranean have historically been very important as they connect Asia and Europe. In the era of containerization the old Mediterranean ports have changed their traditional roles, the new ones have introduced relatively new concepts, such as transshipment and port networking, totally changing the commercial map. As landbridges are becoming more and more important in the logistics chains, the Mediterranean ports try also to find their position in the new map, either by connecting northern and southern European regions or by servicing the needs of ports and regions distant from the main route of Suez – Gibraltar.

The idea of this research is to implement the social networks techniques in the field of the transportation networks. The proposal of the authors is to accept calculated measures that could be indicative in understanding the possible economic advantages derived from the geographic and transportation networks. Social network analysis is the mapping and measuring of relationships and flows between people, groups, organizations, animals, computers or other entities. In this study the nodes in the network are ports while the links show relationships or flows between the nodes. Social network analysis provides both a visual and a mathematical analysis of Mediterranean ports relationships

2.   Research Theory -the Network Approach

Main unit of the analysis is a network. A network can be viewed in several ways. One of the most useful views is as a graph, consisting of nodes joined by directed lines. A graph Γ consists of a two sets of information: a set of a nodes $N = \{n_1, n_2, \ldots, ng)$ also called vertixes, and a set of lines $\Lambda = \{ l_1, l_2, \ldots, l_L \}$ between pairs of nodes. There are g nodes and L lines. In a graph each line is an ordered pair of distinct nodes $l_k = <n_i, n_j>$. We will exclude a reflexive line, or loop , between a node and itself $<n_i, n_i>$. The graph with node set N, and line set Λ will be denoted as Γ (N,L).

The graph can be also presented by a diagram in which points depict nodes, and a line is drawn between two points if there is a line between the corresponding two nodes in the set of lines , Λ.

The information in the graph Γ (N,Λ) may also be expressed in a variety of ways in a matrix form. Especially useful is adjacency matrix Ξ of size g x g. The entries in the matrix $x_{i,j}$ record which pairs of nodes are adjacent, ie $x_{i,j} =1$ if exists $l_k = <n_i, n_j>$, and $x_{j,i} =-1$ if exists $l_k = <n_j, n_i>$ and does not exist $l_k = <n_j, n_i>$, otherwise $x_{i,j} =0$. It is possible that the cell $x_{i,j}$ has value different than $\{0,-1,1\}$, but in that case the incidence matrix becomes attribute-incidence matrix Z with cells defined as $z_{i,j}$.

To represent the network approach case study is implemented. Taking network perspective, rather than individual dyadic relationships, offers significant insight at the cost of considerable complexity. To cope with the complexity, the transport corridor is defined as a series of focal networks comprising the material flow.

The structure and behavior of networks are grounded and enacted by local interactions between ports. Despite the simplicity of ideas and definitions there are good theoretical reasons to believe that these basic properties all of the networks have very important consequences.

Because most countries are not usually connected directly to most other countries in a continent, it can be quite important to go beyond simply examining the immediate connections of ports, and the overall density of direct connections in network.

The second, closely related, approach in this paper has to do with the idea of hierarchy in the network. The level of hierarchy in the network is closely related to the behavior of the companies encompassed in network structure.

The size of a network is often a very important. For the network consisting of few actors it is ordinal to presume existence of the all links between them. For a network consisting of thousand of actors, it would be difficult that each actor has links to every other in the network. Size is critical for the structure of network because of the limited resources and capacities that each actor has for building and maintaining links. As a network gets bigger, density - as the proportion of all present links, gets smaller. The density of the links in the network is defined as the quotient of the links presented, and all possible links in the network.

Formulae for the density of the network is:

$$d_n = \frac{\sum_{i=1}^{g} d(n_i)}{g}$$ and the standard deviation is .

Standard deviation of the density is a measure of the uniformity of the links in the network. The variability of the nodal degrees means that the actors represented by the nodes differ in activity as measured by the number of links. Fully saturated networks (i.e. one where all logically possible ties are actually present) are empirically rare, particularly where there are more than a few actors in the population.

Another measure of structure is centralization. Centralization refers to overall integration or cohesion of a network graph. Centralization indicates the extent to which a graph is organized around its most central point.

There are few different measures of the centrality indicating different kind of measures in the network.

Actors who have more ties have greater opportunities because they have choices. This autonomy makes them less dependent on any specific other actor, and hence more powerful. The more ties an actor has then, the more power they (may) have.

Formula for the calculation of the degree centrality is:

$$C_D(p_k) = \sum_{i=1}^{n} a(p_k p_i) \quad a(p_k p_i) = \left\langle \begin{array}{l} 1 \ if \ p_i \ and \ p_k \ are \ connected \\ 0 \ if \ p_i \ and \ p_k \ are \ not \ connected \end{array} \right.$$

where n is number of actors.

Power can be exerted by direct bargaining and exchange, and it also comes from acting as a "reference point" by which other actors judge themselves, or by being a center of attention who's views are heard by larger numbers of actors. Actors who are able to reach other actors at shorter path lengths, or who are more reachable by other

actors at shorter path lengths have favored positions. This structural advantage can be translated into power. .

Formula for the calculation of the closeness centrality is:

$$\overline{\overline{C}}_{DU}(p_k) = \frac{n-1}{\sum\limits_{i=1}^{n} u(p_k p_i)}$$

Where :

$d(p_i, p_k)$ number of actors connecting p_i and p_k.

Actor who lies *between* other pairs of actors, and no other actors lie between it and other actors has big advantages. For example if A wants to contact B, it may simply do so if it is connected with it. If C wants to contact B, they must do so by way of A who lies on the way between them. This gives actor A the capacity to broker contacts among other actors -- to extract "service charges" and to isolate actors or prevent contacts. The third aspect of a structurally advantaged position then is in being between other actors.

Betweenness centrality

$$C_D(p_k) = \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{g_{ij}(p_k)}{g_{ij}}$$

Where: g_{ij} – number of shortest connections between p_i and p_j.

The identification of cohesive areas of a network has been the goal of many network analyses. Techniques have been taken from multivariate statistics (MDS, clustering etc.) as well as from graph theory.

Many of the approaches to understanding the structure of a network emphasize how dense connections are compounded and extended to develop larger "cliques" or sub-groupings. The idea of a clique is relatively simple. At the most general level, a clique is a sub-set of a network in which the actors are more closely and intensely tied to one another than they are to other members of the network. The cliques are defined as a maximal complete subgraphs.

A graph is called complete if all its vertices are connected to all the other vertices in the graph. A maximal complete subgraph of a graph is called a clique. By "maximal" we mean that this subgraph is contained within no other subgraph that is also complete.

A set of size k has $\binom{k}{i}$ subcliques of size i, $1 \leq i \leq k$. This implies that any

algorithm that looks for a maximal clique must be careful to generate each subclique the fewest number of times possible. One way to generate the clique is to extend a clique of size m to size m+1 and to continue this process by trying out all possible vertices. But this strategy generates the same clique many times; this can be avoided as follows:

Given a clique X, suppose node v is the first node that is added to produce a clique of size one greater. After the backtracking process examines all possible cliques that are produced from X and v, then no vertex adjacent to v need be added to X and examined. Let X and Y be cliques and let X be properly contained in Y . If all cliques containing X and vertex v have been generated, then all cliques with Y and v can be ignored.

Another measure is called multidimensional scaling .From a non-technical point of view, the purpose of multidimensional scaling (MDS) is to provide a visual representation of the pattern of proximities (i.e., similarities or distances) among a set of objects. From a slightly more technical point of view, what MDS does is find a set of vectors in p-dimensional space such that the matrix of Euclidean distances among them corresponds as closely as possible to some function of the input matrix according to a criterion function called stress.

A simplified view of the algorithm is as follows:
1. Assign points to arbitrary coordinates in p-dimensional space.
2. Compute Euclidean distances among all pairs of points, to form the matrix.
3. Compare that matrix with the input matrix by evaluating the stress function. The smaller the value, the greater the correspondence between the two.
4. Adjust coordinates of each point in the direction that best maximally stress.
5. Repeat steps 2 through 4 until stress won't get any lower.

Normally, MDS is used to provide a visual representation of a complex set of relationships that can be scanned at a glance. Since maps on paper are two-dimensional objects, this translates technically to finding an optimal configuration of points in 2-dimensional space.

3.   The Model

The model used in this research is fundamental, but nevertheless in authors view they will show a method for measuring the Mediterranean liner transport system.

As there is significant problem to retrieve information about liner services in all Mediterranean ports, authors have, in the first week of march , created snapshot of data shown on picture 1.
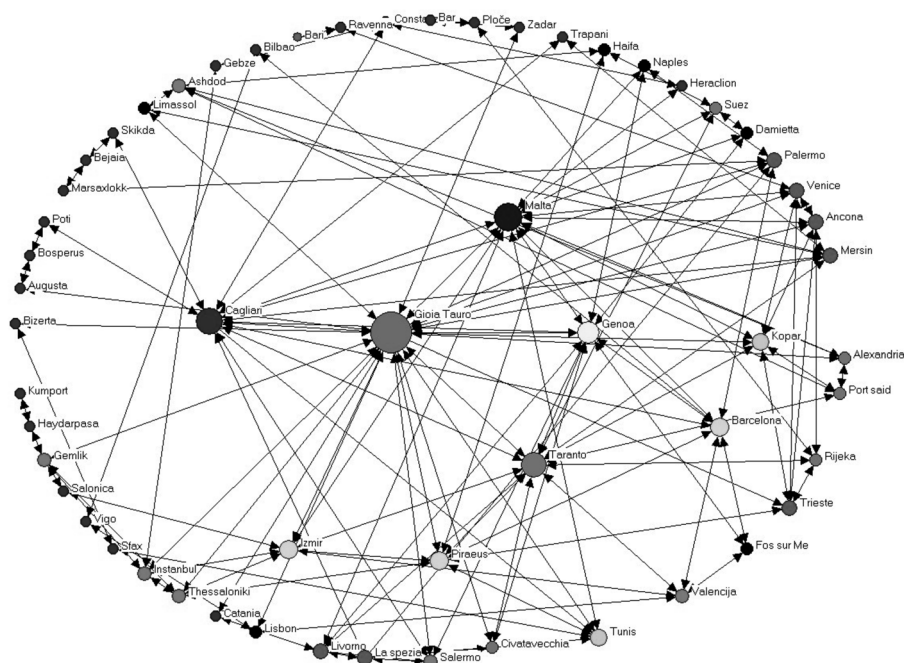
Fig. 1 Mediterranean liner network.

Model is created adding links between ports in liner service. All ports outside area of interest have been excluded together with their ties. This is significant limitation to the model, but as this is initial research authors do think that the results, with this restricted model are significant.

4.   The Results

The results from the investigation of these models show that the transport system has 264 from 3304 possible connections between ports, or mean value for density of 0,08 (8 %), with standard deviation of 0,271, showing a loosely coupled system with high variety. Network has total reachability, meaning that there is always a route between any port in network.

The relevance as a factor is directly coupled to the degree centrality. The degree centrality could be separated on two parts, first calculating in- and other out – degree , depending on the incoming and outgoing paths. In- degree centrality is known as prominence, and out – degree centrality is usually tied with the idea of influence. As a transportation system is not directed the in and out degrees are identical. The results of the calculation of the degree centrality are shown on the picture 2
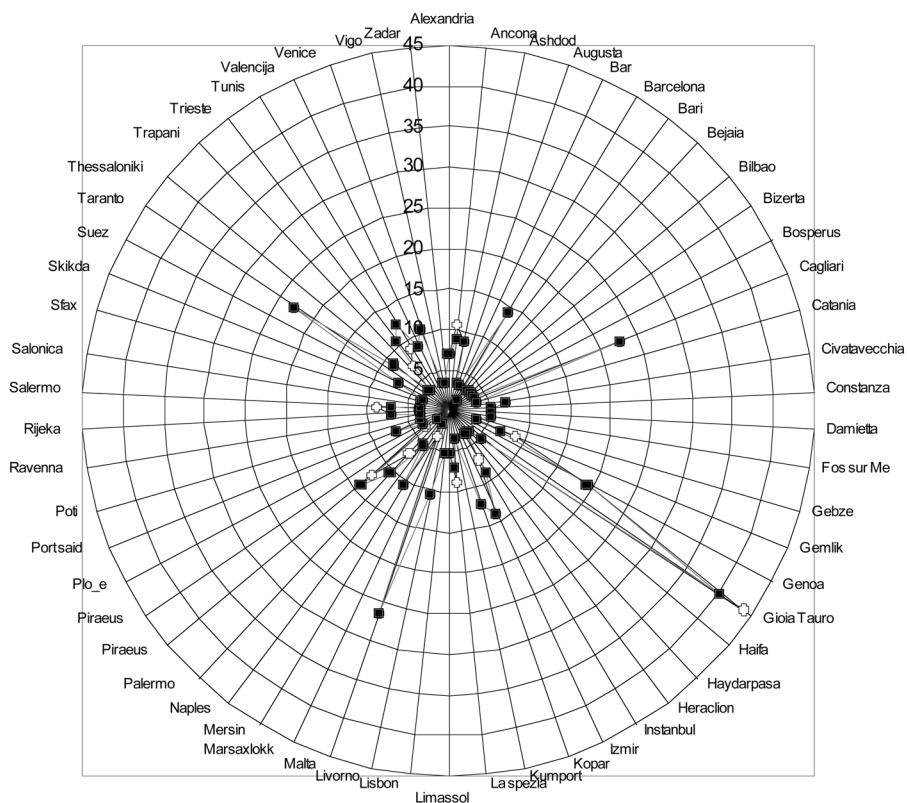
Fig. 2 Centrality factors for Mediterranean ports

Mean value for in and out -– degree centrality for network is 7.76, with standard deviation of 7.03 and 6.83 respectively. Network centralization is 36.5 % showing moderate centralization , with most central ports of Gioia Turo , Malta, Livorno , Taranto, Barcelona and Genoa.

The closeness centrality has been calculated for models and shown on the picture 3.

Average closeness centrality for model is 46,5% with 6,99 standard deviation, indicating that the ports in the transport system have high closeness.

The betweenness centrality is always connected with the terms of bridging-over, because it gives the measure of the importance of being the mediator between two actors. In the transport system this factor is connected with the term transshipment.. Total betweenness centrality for nodes in model is 3,28% with standard deviation of 6,8%, with network centrality of 44.5 % defining that there are few central ports in system. Network analysis shows that most central is port of Gioia Turo with centrality factor of 47.02 %, followed by the ports of Cagliary, Malta and Taranto having centrality factor bigger than 10 %.
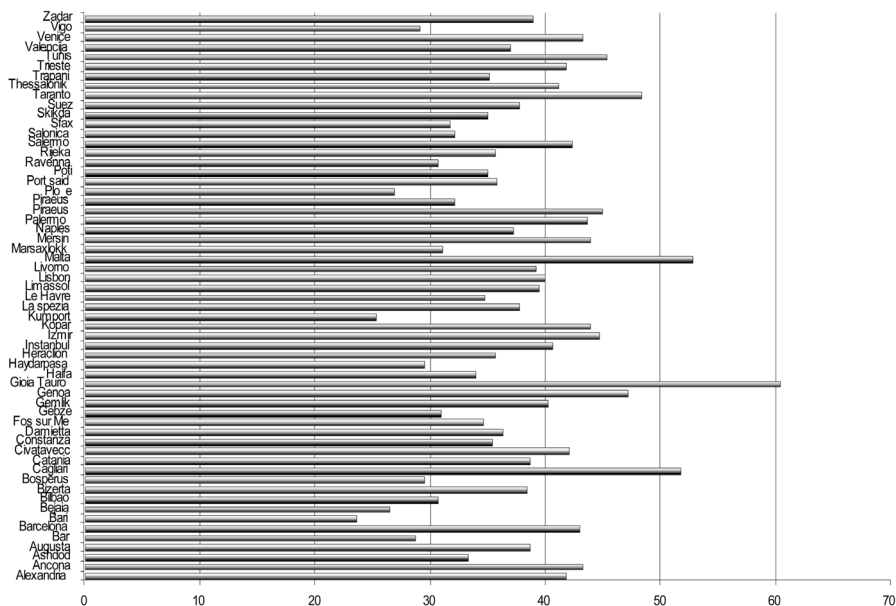
Fig. 3 Closeness centrality for ports.

Another measure that is of interest is power defined by Bonachich. Degree centrality approach argues that actors who have more connections are more likely to be powerful because they can directly affect more other actors. Bonacich argued that one's power is a function of how many connections one has, and how many the connections the actors in the neighborhood had. The calculation of this measure is fairly complex, because it has to be done in recursive way. Calculation has been made using Computer program UCINET and is shown on picture 4.

Results show that overall power of network is 2,339 with standard deviation of 2.059.

Gioia Turo port has power of 12.5 or 9,06 % of all ports in network, followed by Malta 5,8%, Cagliary 5,07 % , Taranto 4,7 %, Genoa 3,99 %, Piraeus , Izmir and Barcelona with 2,90%.

Power is spread unevenly and first 10 ports have 42,3% of all power in the whole network consisting of 59 ports.

Although differences in power and scarse density of network Multidimensional scaling (MDS) shows interesting facts shown in picture 5.

Multidimensional scaling is a set of data analysis techniques that display the structure of distance-like data as a geometrical picture. Moreover some authors define it as a process of transforming geographical data into economic ones. MDS pictures the structure of a set of objects from data that approximate the distances between pairs of the objects.
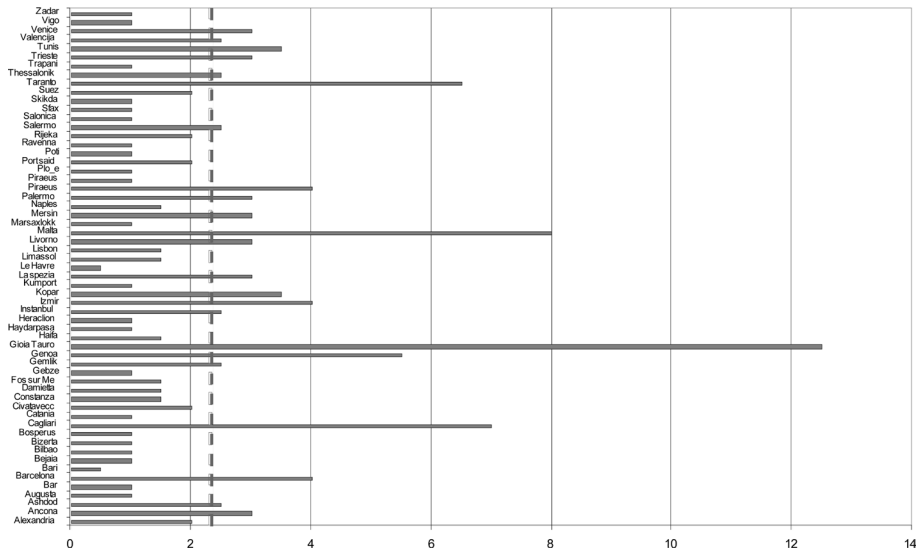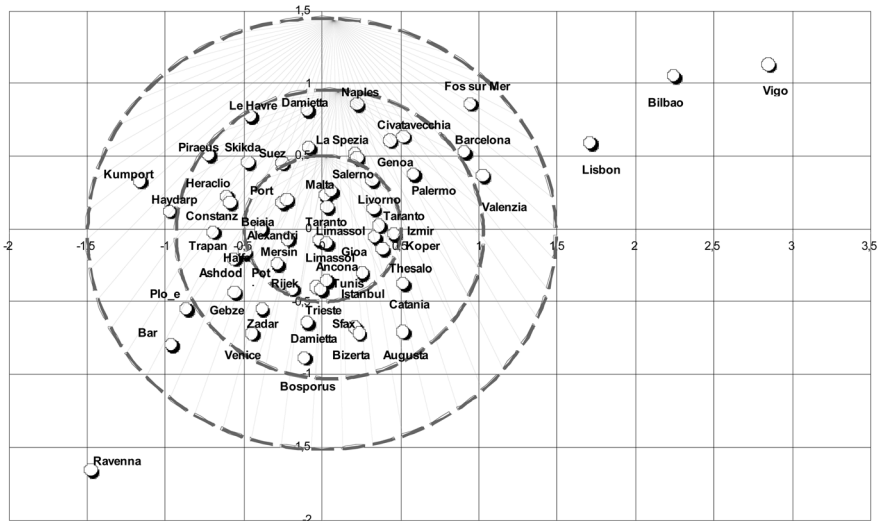
Fig. 4 Power coefficient of Mediterranean ports

Fig. 5 Multidimensional scalling

Each object or event is represented by a point in a multidimensional space. The points are arranged in this space so that the distances between pairs of points have the strongest possible relation to the similarities among the pairs of objects. That is, two similar objects are represented by two points that are close together, and two dissimilar

objects are represented by two points that are far apart. MDS representation shows that mainly all ports are close together, representing unique similarity between them. Most of ports are within circle representing scale of 1 measurement unit, showing collectiveness and representing very closed community.

5.   Conclusion

In the paper the authors propone the measures to calculate different features of Mediterranean liner network. Model that has been proposed, and proposed measures have been calculated showing significant conformity with the real situation. The authors are certain that the considerations about the other research of differences in the transport system must now take into account the results reported here.

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Korištenje mreža za mjerenje svojstava sustava mediteranskoga linijskog prijevoza

Sažetak

Obične zemljopisne i prijevozne karte predstavljaju mreže na kojima pozicioniranje subjekta odražava Euklidove udaljenosti među subjektima. Udaljenosti među subjektima odražavaju skup strukturnih podataka: prostorne udaljenosti. U načelu, u ovom se radu ponovno ucrtava prostorni kontekst u ekonomski kontekst korištenjem mrežnih struktura.

Zamisao se odnosi na primjenu tehnika socijalne mreže na području prijevoznih mreža. Autori predlažu prihvaćanje izračunatih veličina koje bi mogle biti indikativne za razumijevanje mogućih ekonomskih prednosti izvedenih iz zemljopisnih i prijevoznih mreža. Iako je ovo istraživanje tek u začetku, izračunati podaci izneseni u radu pokazuju da bi takav pristup mogao biti značajan za iskazivanje novih trendova kada je u pitanju mrežna struktura. U radu je najprije iznesen pregled teorije istraživanja, a nakon toga je prikazan model sredozemnoga linijskog prijevoza. Autori su svjesni da su stvarni modeli drukčiji i da je svaki model tek trenutačna snimka linijske mreže te da postoji i mreža brodova u slobodnoj plovidbi...

Bez obzira na to, autori su uvjereni da su modeli i rezultati izneseni u istraživanju dovoljni da potaknu daljnje istraživanje.

Ključne riječi: prijevozne mreže, luke, socijalne mreže, sredozemni prijevozni susta

Uso di reticoli per valutare le prerogative del sistema di trasporto di linea nel mediterraneo

Sommario

Le consuete carte geografiche e mappe di trasporto sono sistemi reticolari dove la posizione di ciascun partecipante in relazione all'altro riflette distanze basate sulla geometria euclidea. Le distanze indicate sulle mappe sono un insieme di dati strutturali che raffigurano distanze spaziali. In teoria, la ricerca tende ad innestare il concetto di spazio nel contesto economico grazie all'impiego di strutture reticolari, applicando le tecniche dei reticoli sociali al settore del trasporto. La proposta degli autori consiste nell'accogliere misurazioni e dati indicativi utili per valutare le prerogative economiche del trasporto di linea. Anche se in fase primaria, i risultati ottenuti dimostrano la validità di approccio e sono la conferma come l'uso della struttura reticolare possa aprire nuove vie. Il lavoro riesamina la teoria di ricerca e presenta un modello di trasporto di linea mediterraneo. Gli autori sono consci che i modelli nella realtà fattuale differiscono da quelli qui elaborati, essendo questi colti e fissati quasi in itantanea, mentre si sa che accanto al trasporto di linea esiste quello volandiero. In conclusione i modelli e i risultati della ricerca sono sufficientemente incoraggianti da incentivare ulteriori ricerche.

Parole chiave: reticoli di trasporto, porti, reticoli sociali, sistema di trasporto mediterraneo