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The maritime supply chain of energy concerns all trips done between ports on the maritime space. The use of this space has increase since 1970. This increase is due to the globalization, a strong increase of the demand of energy and freight, containerization of goods and economies of scale (Rodrigue, 2013). Due to the development of maritime transport, a territorialization process appears on maritime space (Parrain, 2012). For Di Meo (2001) "Territorialize space is for a society to multiply places to install networks in both concrete and symbolic". These locations exist on the maritime space, and can be physical (e.g. weather, reefs) socio-economical (E.g use for navigation, exploitation) or political/legal (e.g. TSS, EEZ). All these locations formalize a spatial heterogeneity and a spatial dynamic, due to the permanent evolution of maritime locations. These maritime territories can be risky for maritime transport, taking into account the environment, human activities or deliberate actions. Risks can product disruptions and affect the capacity of a spatial mediator (maritime space) to link the different parts within this mediator (Gleyze, 2005). The main goal of this research is to propose a modeling approach of the maritime network; we use an agent-based system to simulate vessel trajectories. This approach will be able to measure, by the spatio-temporal features of disruption, the vulnerability of the maritime network and especially the maritime supply chain of energy.

Most of the studies related to the modeling of maritime network use the graph theory. A graph is defined as a set of nodes and links. Links connect nodes each other. Joly (1995) was the first to model the maritime network using the graph theory. Mains researches include now works of Veenstra et al (2005), Hu and Zhu (2009), Kaluza et al (2010), Zavitsas (2011), Ducruet (2013) and Xu et al (2014). These works focus on topological properties, clusters identification and maritime network configuration (small-world property, free scale network). But these works do not consider the features of maritime space; « *There are no physical links between airports and between seaports that have the characteristic of a line* ». (Veenstra et al, 2005).

In this paper, we propose in a first step, the formalization of the features of the maritime space and we focus on the relationship between this maritime space and the vulnerability. The spatial features can be divided between possibilities and restrictions. On the one hand, the network is totally connected (each port can be reach by another port) and the connectivity is theoretically infinite (each trip can follow an infinity of paths). On the other hand, the locations within the maritime space formalize barriers. Rodrigue(2013) distinguishes absolute, relative and arbitrary barriers. An absolute barrier prevents every movement and corresponds to sea/land interface. A relative barrier produces a friction to a movement, for example weather, straits or channels. An arbitrary barrier corresponds to mandatory areas (TSS, EEZ) on the maritime space. The barriers can be static (e.g. reefs) or dynamic (e.g. icebergs) and these barriers affect the global accessibility of the maritime space. This accessibility will be used to measure the vulnerability.

Accessibility is the capacity of a location to be reached from another one (Rodrigue, 2013). Disruptions are brutal changes of the spatial structure that affect the accessibility of this space due to a risk. Vulnerability can be assessed by the measure of disruption on the maritime network. These measures are the values of spatial distance and the spatio-temporal distance. The change of the value of the spatial distance is due to the decrease of accessibility within this space, and can be measured for example by the structural vulnerability (Gleyze,2005). The change of the spatio-temporal value is due to the change of duration to reach the destination port due to the dynamic of maritime space.

Considering previous elements, in a second step, we propose a conceptual model (Fig. 1) for building the maritime network. This network is built by the individual goal of a vessel (a port to reach) and this network is formed by the whole trips done on the maritime space. Indeed, trips are built by a spatial behavior depending of the individual goal of each vessel (supply and demand port locations – economic features) and their given spatial possibilities (accessibility of maritime space – geographic features). These trips formalize the maritime network. This approach allows the study of the relationship between topological reasoning (relationship between ports) and geometric reasoning (relationship with the spatial structure and dynamics).

To measure the vulnerability of a network by accessibility and time, a multi-agent system can be used in a third step. An agent is an entity which has its own goals and capacities in a shared environment (Ferber, 1997). In our case, this environment, the maritime space, is a dynamic spatial environment. Langlois(2013) proposes a paradigm Agent/Organization/Behavior which allows to simulate the relationship between social agents (vessels) and spatial agents (maritime space configurations). With simulations, it is possible to measure the spatial behavior of agents according to the dynamic of the spatial structure. These behaviors built trajectories depending of the accessibility on maritime space. This loss of accessibility and time is due to the spatial dynamics and can be compared to the shortest path on a given link of the network. An accessibility rate can be calculated for each maritime path. In case of disruption, this accessibility rate can be used to measure and quantify the disruption and its impact on the maritime network. With this method, an assessment of the maritime network vulnerability can be performed. This agent-based system can be used later for optimization of maritime network to avoid or decrease effects of disruptions. This system could be further used to support fleet management systems.

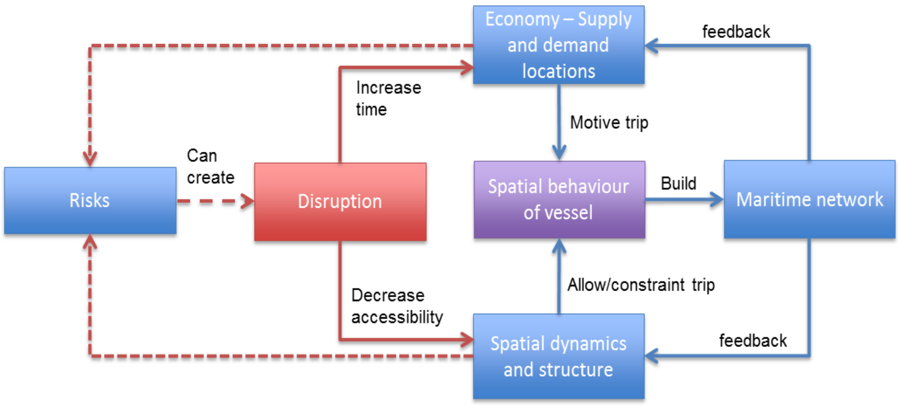

Figure 1. Conceptual model

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