Proceedings of the 2016 Winter Simulation Conference
T. M. K. Roeder, P. I. Frazier, R. Szechtman, E. Zhou, T. Huschka, and S. E. Chick, eds.

COMBINATION OF AN EVOLUTIONARY AGENT-BASED MODEL OF TRANSITIONS IN SHIPPING TECHNOLOGIES WITH A SYSTEM DYNAMICS EXPECTATIONS FORMULATION

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ABSTRACT

The combination of System Dynamics (SD) and Agent-Based Modeling (ABM) has been strongly promoted in the past (e.g. Größler et al., 2003). However, relatively few studies have actually implemented this combination in a real application model. In this paper we show how one implementation (SD at the bottom, ABM at the top) serves to explore different dynamics in a ship transition model. With the ship transitions model two of the major concerns of shipping are addressed: bunkering costs and recent environmental legislation introducing strict controls on sulphur and NOx emissions. These factors among others are forcing ship owners and operators to consider alternative fuels. However, the decision process in developing and adopting new engines and propulsion systems is complex, because it involves a chain of decision makers.

Shipyards and propulsion system manufacturers must invest in R&D and then sell their designs to operators. Operators respond to demand for transport services from the logistics and tourist industry. There are already a range of low emission propulsion options and a wide range of designs for low carbon ships incorporating e.g. LNG, low sulphur diesel and wind technologies. This complexity means that simulations of this 'innovation system' are required to assess the market prospects for different technologies and their potential cost and performance improvements.

There are different modeling approaches to describe dynamical economic systems; the most widely accepted being System Dynamics (SD) and Agent-Based Modeling (ABM); Discrete Event Systems (DES) as the third big modeling approach is mostly used in manufacturing. While SD models describe changes in the state of a system with a set of differential (or difference) equations of interdependent macro-variables, which are then solved numerically, ABM's look at the actors of a system and the interactions between them from the bottom up. Thus they belong to fundamental different paradigms (Zeigler, 1976).

As pointed out in e.g. Bruckner et al. (1998), SD models are reliable as long as the taxonomy of the system stays the same, but get into trouble if the structure of the system changes because for example the occurring of a new technology. Thus to catch the complexity of a stochastically evolving system with structural changes it is suggested to model from the actor level with agents developing in an evolutionary sense, Winter et al. (2003) amongst others made a proposal for a baseline evolutionary industry model. We followed that line and developed a model of the shipping sector, modeling explicitly, but in a simplified manner, the basic actors – engine developers, shipyards and shipping companies - as agents acting according to evolutionary constraints. Albeit we are not yet going this far to allow for completely new technologies to arise in our model, we extend that logic by the insights of the works of Kerber and Saam

(2001), with our agents performing a research process in a "technology space". This evolutionary research process consists of innovation and imitation steps as proposed by Hayek, changing the genetic code representing our technology, similar to the work by Frenken et al. (1999).

The SHIPTECH model presented here (Senger and Köhler, 2014) is an agent-based model, using genetic mechanisms from evolutionary economics, to simulate the distribution of different engine technologies in ships with a focus on investments in efficiency enhancements. There are four types of agents in the SHIPTECH model:

- Engine developers: implemented according to an evolutionary logic: they produce engines according to orders they get from ship yards, with a certain propulsion technology. This is represented by analogy with biological evolution, where genes, consisting of a series of alleles, representing parts of the engine such as system design, prime mover, ancillaries or the control system which determine the cost and fuel consumption and hence competitiveness of the engine in the market. A process of imitation and research is performed in every time step to increase the competitiveness.

- Shipyards: offer several classes of ships in different sizes. They buy engines from the developers depending on costs over lifetime and developer capacity. Depending on managing philosophy, they decide whether they invest more of their budget in improving their ship designs by R&D or in increasing their capacity. By R&D, they can improve ship design to be more energy efficient, to reduce other operational costs and explore wind propulsion systems and enhance them.

- Shipping companies: simplified agents that own and operate fleets and change fleet composition to meet global transport demand. For their investments, they make predictions about future development of global demand and supply using a system dynamics forecast.

- Ships: operated by shipping companies with certain operational costs and fuel consumption, if demanded by the economical landscape.

During time steps, the simulation performs starting from an initial configuration, shipping companies change their prices and fleet composition according to transport demand, fuel prices and policy regulations (CO_2 pricing etc.) derived from an economical landscape following the chosen scenario for the particular simulation run. Yards and developers build ships/engines on order of the shipping companies/yards. Agents who are not successful will fail if depts become too high.

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