System Dynamics Simulation Modelling of Managing a Maritime Shipping Organization

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Abstract. This paper is a result of the research team at the University of Split, Faculty of Maritime Studies in dynamics of conduct maritime transport organizations. Results of the paper are shown in paper [8], and wish of the authors is to present a model to wider audience. What is new in this paper are Subsystem of debts, Subsystem of credits, Subsystem of loans and Subsystem of commercial department.

System dynamics simulation modelling is one of the most suitable and most successful scientific methods of modelling of dynamics of complex, non-linear, natural, technical and organizational systems. System dynamics models are basically continuous models, as the subjects are presented by a set of non-linear differential equations, i.e. “equations of state”. However, they are also discrete, as their basic time step, i.e. sampling “DT” is defined in full accordance with the Sampling Theorem (Shannon, Nyquist and Koteljnikov). Such selection of the basic time step of DT enables computer modelling of continuous simulation models in digital computer, which is very suitable for training students at maritime faculty, engineering and electro technical faculties, and for theoretical and practical training of engineers of ship processes, as it enables them, by applying system dynamics approach, to acquire new information and skills about the complex dynamics of performance of maritime systems and processes. In a system dynamics model a shipping company is an integrated part of the surroundings and cannot be observed separately, without mutual interference.

Introduction

Maritime shipping is defined as a business activity which transports people and goods by the sea. Transportation by the sea participates in creating use values by covering the distance from the place of production to the place of consumption.

In terms of the object of transport there are two main kinds of maritime shipping:

a) Passenger shipping,

b) Cargo shipping.

In a system dynamics model a shipping company makes an entirety with its surroundings and cannot be observed separately without interaction.

In this model the shipping company is divided into several separate units:

- Commercial department,
- Account balance,
- Ships’ capacities,
- Debits,
- Credits,
- Loan department and goods to be transported by ship.

Subsystem of Ships’ Capacities

System Dynamics Mental and Verbal Model of Subsystem of Ships’ Capacities

The average loading time of a ship (PVUB1, PVUB2, PVUB3, PVUB4, PVUB5) depends on the type and number of available cranes, number of warehouses and the possibility for a simultaneous...
loading, on the preparation of the cargo for loading, the size of the storage space, weather conditions, human potentials, number of shifts, etc.

The rate of loading the capacities of each ship (BUKB1, bukb2, BUKB3, BUKB4, BUKB5) depends on the average loading time of each ship (PVUB1, PVUB2, PVUB3, PVUB4, PVUB5) so that if the average loading time is higher the rate of the loading of ship’s capacities is lower, which means a negative (-) cause-effect link, and on the discrepancy of loading of ship’s capacities (DISUBK1, DISUBK2, DISUBK3, DISUBK4, DISUBK5).

The higher discrepancy of loading of ship’s capacities means also the higher rate of loading of ship’s capacities, which is a positive (+) cause-effect link.

The desired state of occupancy of the ships’ capacities is known in advance for a particular period in the port and during navigation for each ship (ZSZK1, ZSZK2, ZSZK3, ZSZK4, ZSZK5) and cannot exceed the current capacities of each ship.

Discrepancy of loading of ship’s capacity for each ship (DISUBK1, DISUBK2, DISUBK3, DISUBK4, DISUBK5) depends on the occupancy of capacity of each ship (SZK1, SZK2, SZK3, SZK4, SZK5) and on the desired occupancy of capacity of each ship (ZSZK1, ZSZK2, ZSZK3, ZSZK4, ZSZK5).

If the occupancy of capacity (SZK1, SZK2, SZK3, SZK4, SZK5) is higher the discrepancy of loading of ship’s capacity for each ship is lower (DISUBK1, DISUBK2, DISUBK3, DISUBK4, DISUBK5) which means a negative (-) cause-effect link, and if the desired occupancy of each ship is higher (ZSZK1, ZSZK2, ZSZK3, ZSZK4, ZSZK5) the discrepancy for each ship is higher, which means a positive (+) cause-effect link.

The occupancy of capacity of each ship (SZK1, SZK2, SZK3, SZK4, SZK5) is higher if the rate of loading the capacity of each ship is higher (BUKB1, BUKB2, BUKB3, BUKB4, BUKB5), which means a positive (+) cause-effect link, and it is lower if the rate of unloading of capacity of each ship is higher (BIKB1, BIKB2, BIKB3, BIKB4, BIKB5), which means a negative (-) cause-effect link.

The rate of unloading the capacity of each ship (BIKB1, BIKB2, BIKB3, BIKB4, BIKB5) depends on the average time of unloading of each ship (PVIB1, PVIB2, PVIB3, PVIB4, PVIB5) and on the discrepancy of each ship (DISIBK1, DISIBK2, DISIBK3, DISIBK4, DISIBK5).

If the discrepancy of unloading of each ship is higher, the rate of unloading of each ship is higher, which means a positive (+) cause-effect link, and if the average time of unloading of each ship is higher (PVIB1, PVIB2, PVIB3, PVIB4, PVIB5) the rate of unloading of capacity of each ship is lower, which means a negative (-) cause-effect link.

The average unloading time of each ship (PVIB1, PVIB2, PVIB3, PVIB4, PVIB5) depends on similar parameters as for loading the ship.

**System Dynamics Structural Model of Ships’ Capacities Subsystem**

Based on the designed verbal model it is possible to determine the system dynamics structural model of the observed subsystem in Figure 1.
Testing Performance Dynamics of a Maritime Shipping Organization

Simulation model shows a shipping organisation which has five ships. The plan of loading and unloading of each ship is given in the variable ZSZK. The docking of the ship is adjusted by the function PPS. The needed state of the ships’ capacities PSBK illustrates the policy of the company and is adopted according to the situation in the market of ships’ capacities and goods to be transported. The transport result is measured in covered ton miles and the freight is paid accordingly. Port fees and cargo costs are included in the variable TS. Fuel consumption is changed together with the change of the speed by a trend equation for each ship and depending on the age of the ship and the current time of its docking. When the cumulative increase of the cost SKPT increases to the value of the cost of docking which is a known figure, then docking is performed. The depreciation period of the ship in the model is 25 years, and the depreciation fund is used for purchasing a new or a second-hand ship’s capacity, depending on the adjustment of the simulation model. Account balance only shows the liquidity of a maritime organisation, while the real financial state is given by the variable UDOBFT. The loans may be taken only if the account balance is positive. The loan repayment period and the amount of repayment are dictated by the DISCOUNT FACTOR taken from the tables. It is possible to observe financial operations of each ship separately.

Some significant data of computer simulation are:
- Ships’ capacities are:
  - SKAP1=14,900 DWT; SKAP2=13,450 DWT; SKAP3=13,450 DWT; SKAP4=8,538 DWT; SKAP5=24,374 DWT
- Voyage length is 2,000 nautical miles.
- Discount factor is 1.6091 (loan repayment period is 2 years at 12% interest).
- Daily cost of the company’s management is 4,000.00 $.
- Freight rate for all ships is 0.0042 $ per ton mile.
- Unit purchase price of new capacities is 550.00 $ per ton.
- Basis for depreciation is 4%.
- Speed for all ships is 15 knots.
- The price of heavy fuel is 100.00 $.
- The price of light fuel (Diesel) is included in the overhead costs for each ship.
- They are:
  - TF1=3,500.00 $; TF2=3,400.00 $; TF3=3,400.00 $; TF4=3,300.00 $; TF5=4,500.00 $
- The cost of stay in the ports for each ship is:
  - TS1=7,000.00 $; TS2=7,000.00 $; TS3=7,000.00 $; TS4=5,000.00 $; TS5=10,000.00 $
- Docking period for all ships is assumed the same and is 10 days.
The cost for canal pass (Suez) is:
TK1=83,000.00 $; TK2=80,000.00 $; TK3=80,000.00 $; TK4=60,000.00 $; TK5=85,000.00 $

Trend equations have been made on the following data:
- For the first ship:
The main engine uses 23, 25 and 28 tons of heavy fuel at the speed of 13, 14 and 15 knots.
Trend equation: \( TG1=6.371826*1.103354569 \) B1
- For the second and the third ship:
The main engine uses 21, 23 and 26 tons of heavy fuel at the speed of 13, 14 and 15 knots.
Trend equation: \( TG2=TG3=5.212289*1,11269728B2 \) (or instead of B2, we use B3 for the third ship)
  - For the fourth ship:
The main engine uses 13, 14.5 and 16 tons of heavy fuel at the speed of 13, 14 and 15 knots.
Trend equation: \( TG4=3.747*1.1094003924 \) B4
- For the fifth ship:
The main engine uses 27, 30 and 32 tons of heavy fuel at the speed of 13, 14 and 15 knots.
Trend equation: \( TG5=9.80847*1.088662 \) B5

Graphic results of the simulation:

Figure 2. Receivables to the account-UNNZR
Account balance-SNNZR.

Figure 3. Payables-SDUG.

Conclusion

Managing a shipping organisation illustrates all the complexity an organisation deals with during its business operations. The complexity of operations is affected by internal and external factors. Internal factors are the need and expectations of the employees and the company, while the external factors are dynamic a maritime market which cannot be anticipated. By applying the system dynamics modelling of managing a shipping organisation and by simulating the performance dynamics of investment practice and various complex situations in a shipping organisation, we have the opportunity to select the most convenient solutions aimed at improving business operations of
the shipping organisation. The function “pulse” which shows the periodic repetition of events was used in the model, so that the same state of subjects in different situations could be compared and conclusions brought. The function “step” may be used to present the subject in any amplitude and in any time, so it will be used for simulation of management of a specified shipping organisation.

References


