Simulation-Based Analysis of Dependency Between Sales Volume and Service Level

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The Main Goal

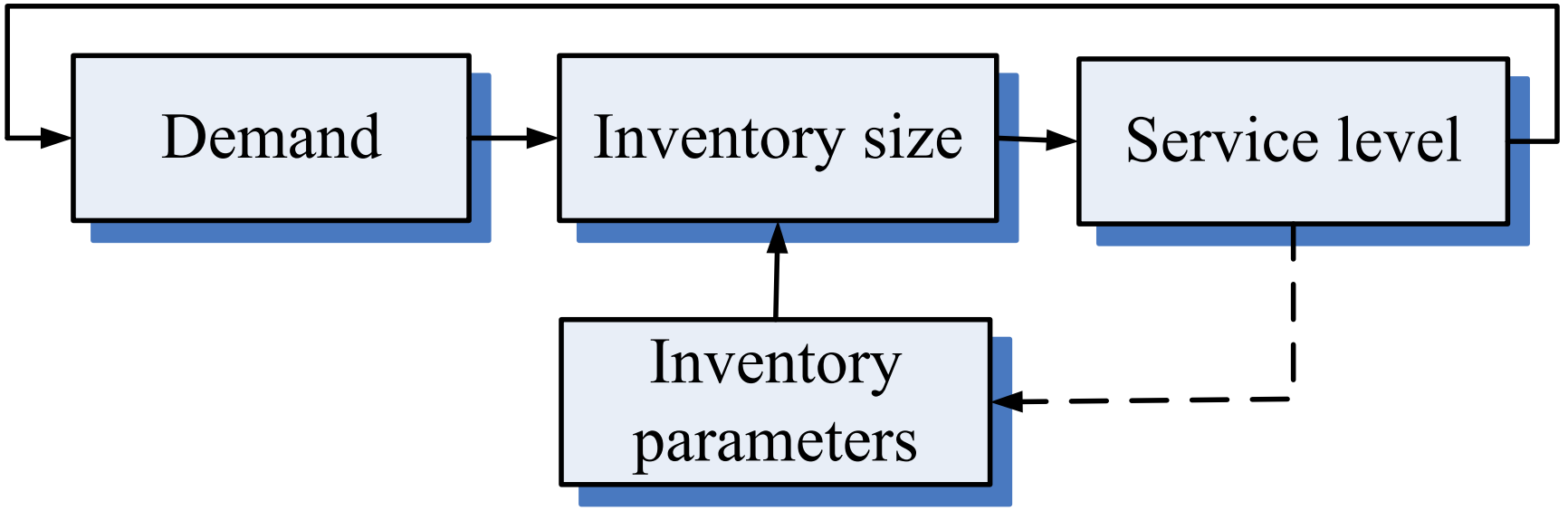
To analyse ability of traditional inventory systems to meet service level requirements in case of service dependent demand and to identify properties of such systems.

The Main Tasks

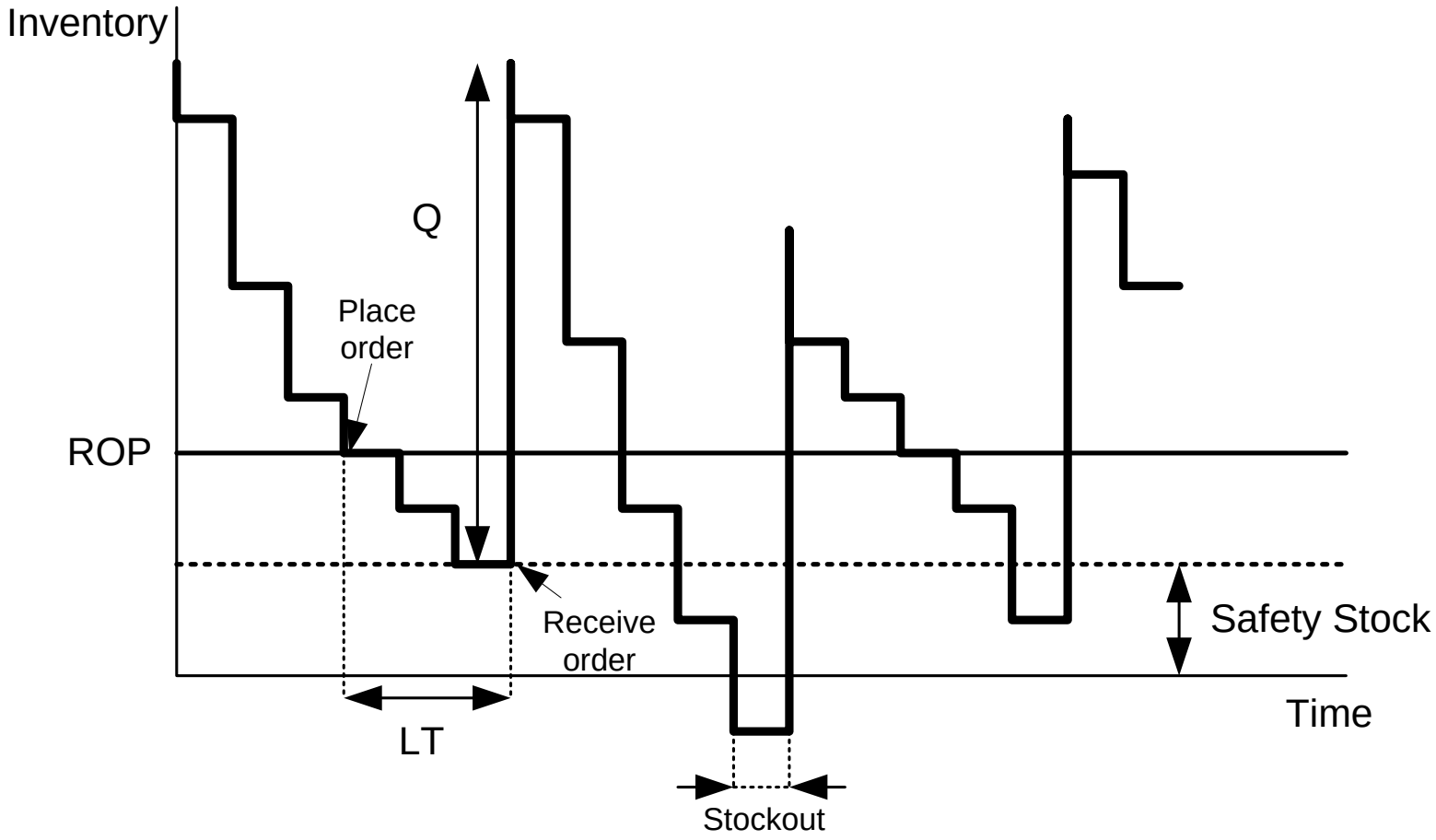
- ✓ Analyse re-order point inventory management systems under a service dependent demand using a hybrid simulation/analytical modelling approach.
- ✓ Develop a simulation model of an inventory system that incorporates analytical model for modelling a service dependent demand.
- ✓ Determine the difference in abilities of two types of inventory systems (traditional and with service dependent demand) to meet service level requirement.

Inventory System

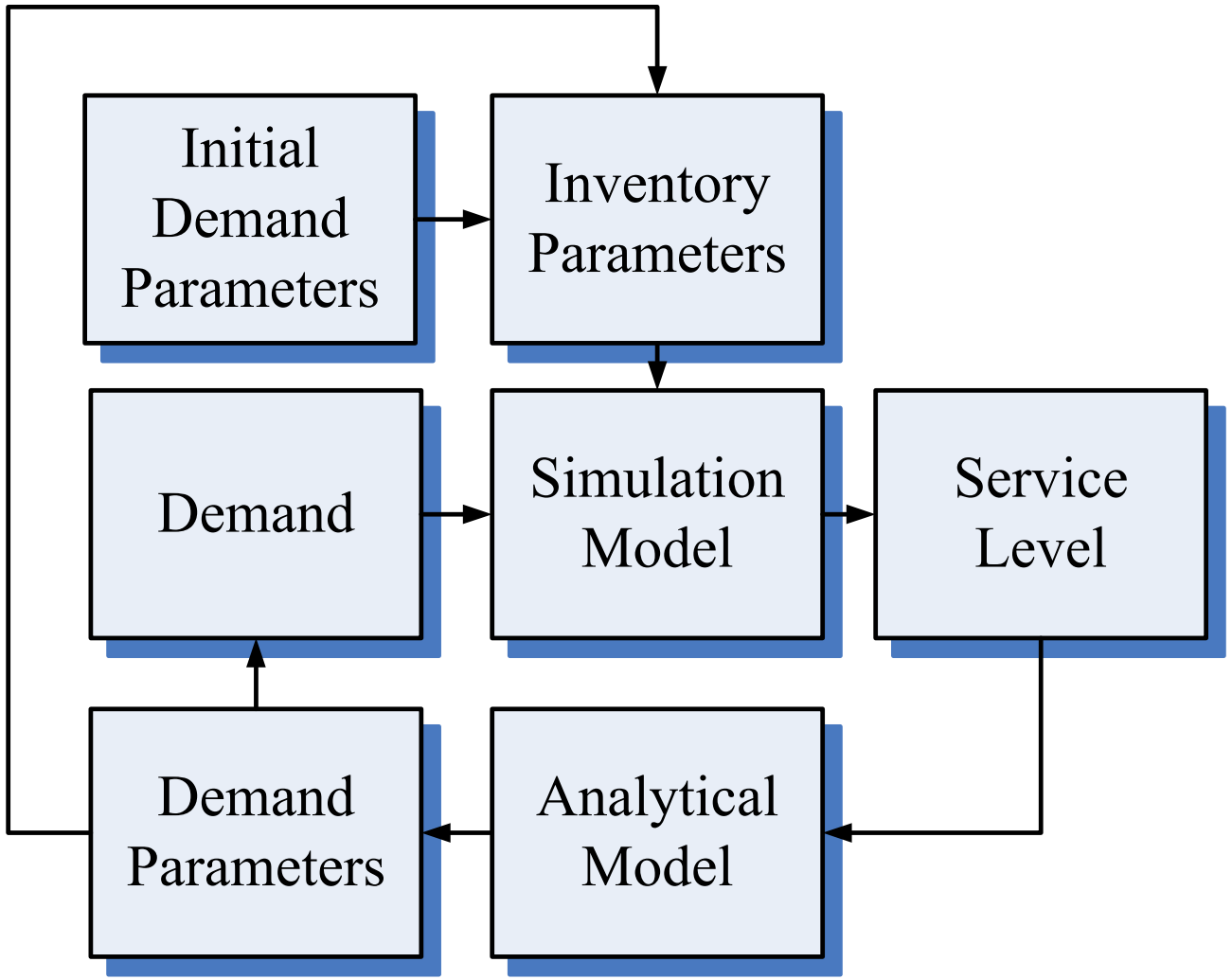
Interactions between Demand, Inventory Size and Service Level



Inventory Control Policy: Re-Order Point



Structure of the Hybrid Simulation/Analytical Model



Main Steps of the Simulation Analysis

1. Initialise the input data module, using the initial (received by traditional forecasting techniques) forecast of the customer demand.
2. Perform simulation of inventory control processes.
3. Calculate the observed service level for a current time period.
4. Calculate the customer demand distribution parameters based on the observed service level.
5. Update the demand and inventory management parameters in the simulation model.
6. Go to step 2 until simulation is completed.

Analytical Model for Service Dependent Market Demand

Relationship between the mean demand and the short-term service level:

$$\overline{D}_{t+1} = (1 + \alpha * (SL_t - SL_{t-1})) * \overline{D}_t$$

where

t - current time period;

$\overline{D}_{t+1}$ - mean demand for the next time period;

$\overline{D}_t$ - mean demand of the current time period;

SL_t - short-term service level in the current time period;

SL_{t-1} - short-term service level in the previous time period;

α - coefficient of change in the mean demand with increased/decreased service level.

Analytical Model for Service Dependent Market Demand

Relationship between a standard deviation of the demand and the short-term service level:

$$\sigma_{t+1} = \left[1 + \beta^2 \alpha (SL_t - SL_{t-1})\right]^{\frac{1}{2}} \sigma_t$$

where

σ_{t+1} - standard deviation of the demand for the next time period;

σ_t - standard deviation of the demand of the current time period;

β - coefficient of the change in standard deviation of demand with increased/decreased service level.

Simulation Model

Simulation model - ARENA simulation modelling environment.

Analytical models (market demand parameters updating and inventory management) - Visual Basic.

Experimental Study

Objective:

To determine achieved long-term service level for the same safety stock factors in both inventory systems (traditional and with service dependent demand).

Conditions:

The model was run in 5 replications. Each replication was 250 weeks long and a warm-up period is 20 weeks.

Experimental Design

A set of experiments with and without the feedback from simulation model to the analytical models is performed:

$$z \in [-1.7; 1.7]$$

Other factors of inventory management system such as initial market demand and its standard deviation, lead time, order size coefficient, etc. are supposed to be the same values for all experiments.

Experimental Results

Performance measure: Long-term service level (SL_T). Simulation results for one particular experiment are averaged over all replication.

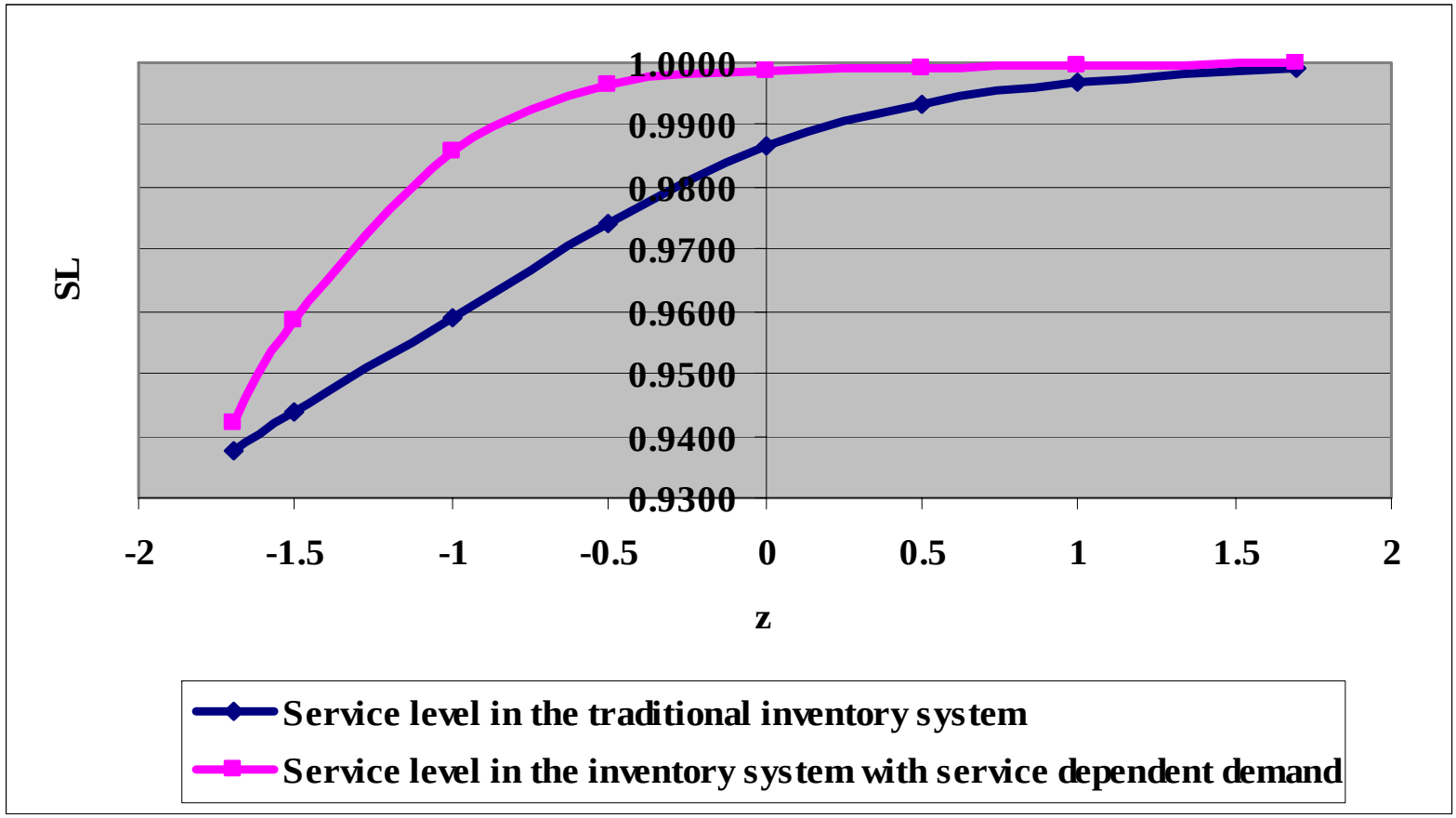
Traditional Inventory System

z	Average SL_T	95% Confidence interval		
		Lower interval	Upper interval	Average relative error
-1.7	0.938	0.931	0.944	0.0024%
-1.5	0.944	0.936	0.951	0.0028%
-1	0.959	0.955	0.963	0.0008%
-0.5	0.974	0.972	0.977	0.0003%
0	0.987	0.985	0.988	0.0002%
0.5	0.993	0.991	0.995	0.0002%
1	0.997	0.995	0.999	0.0002%
1.7	0.999	0.998	1.000	0.0001%

Inventory System with Service Dependent Demand

z	Average SL_T	95% Confidence interval		
		Lower interval	Upper interval	Average relative error
-1.7	0.942	0.912	0.972	0.0467%
-1.5	0.959	0.933	0.984	0.0334%
-1	0.986	0.966	1.006	0.0196%
-0.5	0.997	0.994	0.999	0.0003%
0	0.999	0.998	0.999	0.0000%
0.5	0.999	0.999	1.000	0.0000%
1	1.000	0.999	1.000	0.0000%
1.7	1.000	1.000	1.000	0.0000%

Long-term Service Level Dependence on the Safety Stock Factor



Long-term Service Level Dependence on the Safety Stock Factor

- ✓ The standard method for setting the safety factor z in the case of constant demand parameters gives slightly higher safety stock levels (e.g. to provide service level 0.97 the standard method provides value z=-0.5, but in the case of service dependent demand z=-1.4).
- ✓ Safety stock requirements grow relatively quickly if the long-term service level increases from 0.93 to 0.98.
- ✓ The long-term service level curve stabilises above 0.99 and further safety factor z increasing is insufficient.
- ✓ Characteristics of the service level versus safety factor curve depend upon particular values of the inventory system parameters.

Conclusions

- ✓ The simulation-based approach was advocated as an appropriate technique for conducting analysis of inventory systems with service dependent demand.
- ✓ A simulation model that incorporates analytical models for inventory management and modelling of a service dependent demand was developed to study behaviour of the inventory management system in this situation.
- ✓ Appropriate values of the safety factor were determined to maintain a specified long-term service level in inventory systems (traditional and with a service dependent demand).