Innovative Inventory Management in Multi-Echelon Supply Chain

Team Advisor: Pro. Kung-Jeng Wang
<table>
<thead>
<tr>
<th>Dr. kung-Jeng Wang</th>
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<tbody>
<tr>
<td>Professor, National Taiwan University of Science and Technology (Taiwan Tech)</td>
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<tr>
<td>PhD in Industrial Engineering from University of Wisconsin at Madison (USA) in 1997</td>
</tr>
<tr>
<td>Research interests: Technology and operations management, intelligent systems, and supply chain management.</td>
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</tbody>
</table>
Team Members

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- Supply Chain and Logistics, Inventory Management

Bunjira Makond (IM PhD Program)
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- Forecasting in Supply Chain and Management
Research Issue

Stochastic Two-Stage Inventory System Design and Control for Multi-Echelon SC

Forecasting-Based Decision-making in SCM

New Business Modeling & Evaluation Using System Dynamics
Stage I: System Design
Determine the number of warehouses for Multi-Echelon SC

Stage II: Operational Decision

System decision
Operation information

Distributor with n warehouses

Manufacturer

Customer with Stochastic Demand

Inventory System
Stage I: System Design

- Stochastic modeling of two-stage inventory system design and control for a multi-echelon SC.
- Consider the cost for building warehouses of storage capacity of $W$.
- Consider the setup cost of transportation service between the manufacturer and warehouses.
- Make an optimal strategy for number of warehouses under current operation design and stochastic demand.

Stage II: Operational Decision

- Make an optimal inventory policy for multi-echelon SC under current system design.
- Consider deteriorating item and warehouse rental incentive.
Stochastic Two-Stage Modeling

- **Stage I**  \( \max E_{\xi} OR(W, \xi) - BC(W) - x \ SR(\xi) \)

  \[
  s.t \quad W \geq 0, \quad x = \begin{cases} 
  1, \text{rent a warehouse} \\
  0, \text{otherwise} 
  \end{cases}
  \]

- **Stage II**  \( OR(W, x, \xi) = \max \ f \sum_{i=1}^{n} T_i(\xi) - OC_M - xOC_d \)

  \[
  s.t \quad OC_M = \sum_{i=1}^{n} \frac{SC + TRc_i + HC_{Mi} + DC_{Mi}}{T_i} \\
  OC_d = \sum_{i=1}^{n} \frac{C_d + HC_{RWi} + HC_{OWi} + DC_{RWi} + DC_{OWi}}{T_i} \\
  T_i \geq t_{ai} \geq 0, T_i \geq t_{ai} \geq 0 \quad \text{(Case 2 only),} \\
  Q_i \geq q_i \geq 0 \quad \text{System Dynamics}
  \]
An AI-Based Hybrid Solution Algorithm

Step 1
Initial population for stage I variables

Step 2
Use Gradient-based procedure for stage II
Evaluate the whole system

Step 3
For stage I variables
Reproduction
Crossover
Mutation

Step 4
Termination Criteria met?
Next generation population for stage I variables
Yes
End
No

Step 5
Use Gradient-based procedure for stage II
Evaluate the whole system

Inventory System
## Operational Stage Decision

Preliminary research on operational stage

<table>
<thead>
<tr>
<th>Warehouse configuration</th>
<th>Inventory policy</th>
<th>$q$</th>
<th>$(t_m)$</th>
<th>$t_1$</th>
<th>$t_2$</th>
<th>$T$</th>
<th>Total profit ($TP$)</th>
<th>PTPC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both OW and RW available</td>
<td>26,512.86 1.1364 1.6122 2.0649 2.0649</td>
<td>288,734.28</td>
<td>0.00%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Only OW available</td>
<td>10,000.00 0.4211 0.0000 1.1917 1.1917</td>
<td>265,673.25</td>
<td>-7.99%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Only RW available</td>
<td>27,468.69 1.1786 2.1014 0.0000 2.1014</td>
<td>283,800.85</td>
<td>-1.71%</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Inventory System
Forecasting–Based Decision-making in SCM

Independent Variables
- Demand
- Production rate
- Holding cost

Forecasting
- Weighting factors
- Transformation
- Correlation Analysis

Dependent Variables
- Performance (Total profit etc.)
- Decision variables (replenishment cycle, production cycle etc.)
Procedure

Select variables as predictors and responses

Transform input variables through functions

Correlation analysis to choose appropriate variables

Build forecasting model \((Y=x\beta)\)

Justify model accuracy
Selection of N input variables

Transformation of the input variables through the function \( f_i(x_i) \)

Limitation from N to n input variables through correlations

Correlation Analysis of input variables and y

Correlation value > 0.2

NO → End

YES

Correlation value < 0.8

YES

Calculation of vector and covariance matrix of constant coefficients

Evaluation of model

Final Prediction

YES

NO → End

Correlation Analysis of combination of input variables

Correlation value > 0.2

NO → End

YES

Forecasting
## Results

### Table 7: The computational time (in Second)

<table>
<thead>
<tr>
<th>Approach</th>
<th>Training data</th>
<th>Testing data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average time</td>
<td>The longest time</td>
</tr>
<tr>
<td>Lin's procedure</td>
<td>4,207.218</td>
<td>604,800.000*</td>
</tr>
<tr>
<td>Forecasting model</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
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</table>

* Since the computational time of Lin's procedure might be longer than a week, we set the longest computational time is a week (604,800 second).
New Business Modeling & Evaluation Using System Dynamics

Research Issues of System Dynamics

• To suggest potentially effective new business model.

• To evaluate new business models as well as their advantages by system dynamics simulation.

• To assist enterprise with application of this business model.
Methodology

1. Suggest New Business Model
2. Find Important Factors
3. Construct Feedback Loop
4. Simulation
5. Rework System
6. Conclusion

System Dynamics
New Business Modeling & Evaluation Using System Dynamics

Equipment company

Renting company

Customer

Dealer

Delivery

Order

Selling

Delivery

Order

Payment

Installment

after-sales activities
System Dynamics
Key Factors of New Business Model

1. Order
2. Cost
3. Inventory
4. Interest Rate
5. Risk
6. Discount Percentage
Feedback Loops of A New Business Model

System Dynamics
Simulation by Using System Dynamics Software

System Dynamics
Research Outcomes

Journal Paper

• Y. S. Lin, Jonas C.P. Yu and Kung-Jeng Wang, An efficient replenishment model of deteriorating items for a supplier-buyer partnership in hi-tech industry, Production Planning & Control 20 (5), pp. 431-444. (SCI)

Patent

• 游兆鵬、王孔政、黃惠民、林鈺祥(2009)供應鏈雙倉管理系統及其計算聯合成本極小值的方法。（台灣、美國專利申請中）

Project

• 經濟部商業司協助服務業研究發展輔導計畫-服務業創新研發計畫：智泰科技股份有限公司多媒體儀器專業網暨多元整合服務模式計畫。
Conference Paper


Graduated Students

Caesar Yeh (TM Master)

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- New Business Modeling & Evaluation Using System Dynamics
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