INDUSTRIAL ENGINEERING

INTERNATIONAL BUSINESS ENGINEERING

Study of Tied-up Capital Level in Supply Chain in Vehicle Sector

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No. 1/2012
V. I. Lenin

The separate processes of a specific production . . . should not be manufactured for their own sake, but only because they are more and more demanded by the branches of manufacturing articles consumption.
Abstract

In vehicle industry, it has been trends towards focusing on pull-based systems and elimination of waste (Lean), which decrease the tied-up capital level in the focal factory. Research by Holweg & Miemczyk (2002) showed that the relevant supply chain has low inventory level in the focal factory, but at upstream and especially downstream; the tied-up capital level is dramatically higher in comparison to the focal factory.

By conducting research and extensive literature reviews, this volatility of tied-up capital level has been studied and analysed with regard to push and pull systems. As the three main causes of this unevenness; bullwhip effect, CODP position in supply chain and intensity level of supplier relationship have been identified and explained.

As a practical solution for decreasing the tied-up capital level of finished vehicles, implementation of centralised warehouse structure has been suggested and discussed.

Moreover, as an application of game theory in logistics, iterated prisoners’ dilemma has been discussed as the base for a progressive relationship with suppliers (upgrading to win-win game) which is requisite for the success of pull-based supply chains.

Keywords: Bullwhip Effect, Centralised Warehouse Structure, Corporate Culture, Customer Order Decoupling Point, Game Theory, Inventory Level, Iterated Prisoners’ Dilemma, Lean, Logistics, Pull system, Push, Supplier Relationship, Supply Chain Management, Tied-up Capital, Vehicle Sector
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Contents

List of Acronyms vi

1 Introduction 1
  1.1 Background .................................................. 1
  1.2 Questions .................................................... 3
  1.3 Methodology .................................................. 3

2 Analysis 5
  2.1 Preface .......................................................... 5
  2.2 Comparison of Tied-up Capital Level in Push and Pull Systems ........................................... 6
  2.3 Main Causes of Volatility of Tied-up Capital Level ............................................ 7
     2.3.1 CODP Position in Supply Chain .................................. 8
     2.3.2 Bullwhip Effect .................................................. 9
     2.3.3 Supplier Relation .............................................. 11

3 Conclusions 14
  3.1 Outcome and Discussion ............................................ 14
  3.2 Centralised Warehouse Structure ............................................. 16
  3.3 Game Theory ........................................................ 18
     3.3.1 Applying IPD Game for Supplier Relationship ........................................ 18
  3.4 Further Research ................................................... 20

Bibliography 22
List of Figures

1.1 Unevenness of tied-up capital level in supply chain . . . . . 2
2.1 Forecasting errors for trucks and mini vans (n+3) . . . . . . 6
2.2 Comparison of Tied-up Capital in Push and Pull Systems . 7
2.3 The influence of CODP position on inventory level of fin-
ished vehicles . . . . . . . . . . . . . . . . . . . . . . . . . . . . 9
2.4 Bullwhip effect on a push supply chain . . . . . . . . . . . . 10
2.5 Success Level of Pulls systems with regard to supplier re-
lationship . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 11
3.1 Tied-up capital levels in push and pull systems . . . . . . . 14
3.2 Approximate reduction of tied-up capital level in supply
chain by upgrading from push to pull system . . . . . . . . . . . 15
3.3 Comparison of intensities of cooperative strategies with
regard to Kraljic (1983)’s matrix . . . . . . . . . . . . . . . . 20
3.4 Suggested flowchart for cost analysis of protective covers
for finished vehicles . . . . . . . . . . . . . . . . . . . . . . . . 21
List of Acronyms

ATO  Assembly-to-Order
BTO  Build-to-Order
CODP Customer Order Decoupling Point
ETO  Engineer-to-Order
IPD  Iterated Prisoners’ Dilemma
ITR  Inventory Turnover Rate
JIT  Just-in-Time
MTO  Make-to-Order
MTS  Make-to-Stock
OR   Operations Research
PD   Prisoners’ Dilemma
POS  Point-of-Sales
SCM  Supply Chain Management
TPS  Toyota Production System
WIP  Work-in-Process
WWII World War II
Chapter 1

Introduction

In this chapter; the background and significance of analysis of tied-up capital level in vehicle industry have been discussed and justified.

Moreover, the methodology for conducting this research and the necessary analysis for achieving the relevant results have been explained.

1.1 Background

It can be assumed that the tied-up capital level of finished vehicles is the most important factor to trigger price-related promotions in the market. Considering the frequent drop-off the prices, customers have the tendency to postpone their purchases until the prices reach their minimums (Zhang & Chen, 2006).

In this regard, studying and analysing tied-up capital level is a critical issue for any supply chain manager.

Jonsson (2008) defined the *tied-up capital* from a logistics perspective:

the capital involved in the flow of materials, that is, martials that are held in raw material and component stocks, in production (WIP), in finished stocks or distribution stocks and in transport.

In this regard, the *average tied-up capital* is generally expressed in three approaches (Jonsson, 2008):

- **Absolute Figures**: as a direct method, tied-up capital level is calculated by production of quantities per item with goods values per item. *Inventory graphs* represent this method.
1.1. Background

- **Inventory Turnover Rate**: or *stock velocity* is the relationship between the cost of goods sold during a given period and the average inventory (Fields, 2011).

\[
\frac{\sum (\text{cost of goods sold})}{\text{average inventory}} = \frac{\sum (\text{cost of goods sold})}{0.5 \times (\text{opening stock} + \text{closing stock})}
\]

the low ITR indicates high tied-up capital level and vice versa.

- **Stock Throughput Time**: furthermore, it represents the relationship between the cost of goods sold during a given period and the average inventory, but has the inverse relationship with ITR.

\[
\frac{\text{average inventory}}{\text{delivery value}}
\]

Regarding the vehicle industry, the tied-up capital level in the supply chain is not stable but as Harrison & Hoek (2011) explained at upstream and also especially at downstream (distribution and retail), is soaring. This volatility has been demonstrated in Figure 1.1.

![Automotive Inventory Profile](source)

**Figure 1.1**: Unevenness of tied-up capital level in supply chain (Holweg & Miemczyk, 2002)

Moreover, Copeland *et al.* (2011) stated the utilisation of traditional *push logistics* (e.g. MTS), is the main reason for fluctuation of tied-up capital level in supply chain.
Considering the significance of this issue, this thesis has analysed the root causes of this unevenness with regard to disadvantages of push systems.

1.2 Questions

This thesis has posed three primary questions:

1. Regarding the tied-up capital level in supply chain of vehicle sector, what are the distinguishable differences between push and pull systems?

2. What crucial factors do exert strong influences on the efficiency of pull-based supply chain in vehicle sector?

3. What does this thesis propose as the practical techniques and strategies to create more efficient pull-based supply chain in vehicle sector with regard to the preceding question?

1.3 Methodology

This thesis is a part of the programme: Industrial Engineering - International Business Engineering in Högskolan I Borås which includes different courses like Quality Management, Change Management and Psychology, Supply Chain Management and Purchasing, Logistics and Operations Research. The relationship of different sections of this thesis and the mentioned courses, has been demonstrated in Table 1.1.

<table>
<thead>
<tr>
<th>Section No.</th>
<th>Relevant Course</th>
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<tbody>
<tr>
<td>1.1</td>
<td>Logistics - Quality Management</td>
</tr>
<tr>
<td>2.1</td>
<td>Logistics</td>
</tr>
<tr>
<td>2.2</td>
<td>Logistics - Supply Chain Management and Purchasing</td>
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<td>2.3</td>
<td>Quality Management - Logistics - Change Management and Psychology</td>
</tr>
<tr>
<td>3.1</td>
<td>Quality Management - Logistics - Supply Chain Management and Purchasing</td>
</tr>
<tr>
<td>3.2</td>
<td>Logistics</td>
</tr>
<tr>
<td>3.3</td>
<td>Operations Research</td>
</tr>
</tbody>
</table>

Table 1.1: The relationship of sections of this thesis with the relevant studied courses

As an academic research, this thesis is based on extensive literature reviews. Many academic sources have been studied with regard to the
six major topics: unevenness of tied-up capital level of vehicle industry, CODP position in supply chain, bullwhip effect, level of supplier relationship, corporate culture perspective and also centralised warehouse structure.

Concerning the verification and backing of the proposed application of IPD game in section 3.3, relevant sources have been reviewed and cited.

No online source (e.g. wikipedia) has been used in this thesis, concerning the lack of stability of web links and also the reliability level of online sources, in comparison to the relevant academic books and journals.

For evaluation of the studied topics, the empirical results of the relevant researches have been collected, analysed and cited (e.g. the empirical results by Zhang & Chen (2006)).
Chapter 2

Analysis

In this chapter; push and pull logistics systems have been compared with regard to their tied-up capital levels in supply chain of vehicle sector.

Furthermore, as the main roots for the high tied-up capital level of finished vehicles, three major causes have been identified and analysed: CODP position in supply chain, bullwhip effect and level of supplier relationship.

2.1 Preface

Towill et al. (2002) stated that a successful and properly integrated supply chain management rarely exists. However, as D’Avanzo et al. (2003) explained performing proper SCM changes can cause imminent 7% to 26% increment of market capitalisation.

As Holweg & Miemczyk (2002) expressed vehicle industry still has the tendency to use "Push" systems (e.g. MTS) and "Forecasting" methods instead of newer "Pull" systems (e.g. MTO)\(^1\).

ICDP (2000) announced that 67% of sold cars were based on MTS production approach (approximately two months inventory time).

Holweg & Miemczyk (2002) explained that increase of tied-up capital level at downstream is more critical for US vehicle industry compare to Europe and East Asia, considering that traditionally vehicles are bought from dealers’ stocks directly in US instead of ordering and waiting for the delivery.

One of the main reasons that causes a swing for tied-up capital level at downstream, is employing forecast methods (Zhang & Chen, 2006).

\(^1\) MTO is also called BTO (US version).
2.2 Comparison of Tied-up Capital Level in Push and Pull Systems

Considering the methods of production planning, different production approaches have been compared in Table 2.1.

<table>
<thead>
<tr>
<th>Production Planning</th>
<th>MTS</th>
<th>ATO</th>
<th>MTO</th>
<th>ETO</th>
</tr>
</thead>
<tbody>
<tr>
<td>forecast</td>
<td>forecast and backlogs</td>
<td>backlogs and orders</td>
<td>customer orders</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1: Comparison of production approaches with regard to their production planning methods (Higgins et al., 1996)

2.2 Comparison of Tied-up Capital Level in Push and Pull Systems

As it has been mentioned before, push-based logistic is the major factor for creating swings of tied-up capital level in the relevant supply chains.

For more elaboration, the production of trucks and mini vans can be studied. As Zhang & Chen (2006) explained the major portion of production of trucks and mini vans are still heavily based on forecasting for the next three months (n+3). The errors of forecasting in this matter have been summarised in Figure 2.1.

![Figure 2.1: Forecasting errors for trucks and mini vans (n+3) (Zhang & Chen, 2006)](image)

In this regard, Zhang & Chen (2006) stated that since 1994, the percentage of private purchasers of vehicles has dramatically increased (21%). Furthermore, nearly 95% of bus and 85% of truck purchasers, are private owners. It can be argued that production of vehicles, based on economy scale and forecasting, gets even less desirable when the substantial portion of purchasers is not companies and organisations.
For more elaboration, Zhang & Chen (2006) has compared the inventory level of vehicles in supply chain for push and pull systems in Figure 2.2.

![Figure 2.2: Comparison of Tied-up Capital in Push and Pull Systems (Zhang & Chen, 2006)]

It can be observed that the inventory level of finished goods is nearly six times more in push system than the relevant pull system. Furthermore, on average the tied-up capital level in pull-based supply chain is approximately 44% of the relevant push system.

2.3 Main Causes of Volatility of Tied-up Capital Level

Different reasons have been suggested for the dramatic swing of tied-up capital level at downstream of vehicle supply chain.

The primary cause to create such swing, is the utilisation of traditional push system and mass productions instead of pull system and customisations (Harrison & Hoek, 2011; Zhang & Chen, 2006).

In this regard; as the result of research and extensive literature reviews on the subject of tied-capital level in supply chain, three root causes have been identified:

- location of CODP in supply chain
- bullwhip effect
- level of supplier relationship
2.3. Main Causes of Volatility of Tied-up Capital Level

2.3.1 CODP Position in Supply Chain

Ji et al. (2007) defined the *customer order decoupling point* or *order penetration point*, as

the breaking point that between production for stock based on forecast and customization that respond to customer demand.

Wikner & Rudberg (2005) commented that the furtherer CODP is positioned toward downstream of supply chain, the value-adding activities *under uncertainty* will be increased more and vice versa.

CODP position in supply chain of different production approaches have been demonstrated in Table 2.2.

<table>
<thead>
<tr>
<th>Production Approach</th>
<th>CODP Position</th>
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<tbody>
<tr>
<td>MTS</td>
<td>finished goods</td>
</tr>
<tr>
<td>ATO</td>
<td>WIP</td>
</tr>
<tr>
<td>MTO</td>
<td>raw materials</td>
</tr>
<tr>
<td>ETO</td>
<td>suppliers</td>
</tr>
</tbody>
</table>

Table 2.2: Comparison of different production approaches with regard to their CODP positions (Jonsson, 2008)

Seguel et al. (2010) stated CODP position shows that how deeply the customer is involved in supply chain.

Moreover, Liu (2004) considered the *CODP position* in supply chain as an indicator for three more aspects of a supply chain:

- scale of postponement activity
- postponement type
- customisation degree

As CODP would be re-positioned further in supply chain toward downstream, the tied-up capital level of finished goods would be increased accordingly. Considering that MTS system has located CODP in stock of finished goods (furthermost position toward downstream of supply chain, in comparison with all other production approaches), consequently its inventory level of finished goods is the highest (for more elaboration, see Figure 2.3).

Moreover, Daaboul et al. (2010) explained that the re-position of CODP in supply chain, not only alters the tied-up capital level at downstream, but also dramatically influences the *order delay time* and *complexity of the value chain*. 
2.3. Main Causes of Volatility of Tied-up Capital Level

Jammernegga & Reiner (2007) mentioned that even upgrading CODP location from finished goods to WIP (MTS to ATO), can reduce the costs of shipment and inventory caring cost by approximately of 11%.

Nonetheless, Daaboul et al. (2010) emphasised on need for proper studies and relevant simulations prior to any re-location of CODP in supply chain.

In this sense, Ji et al. (2007) showed mathematically that it is not pragmatic for enterprises to upgrade CODP position in supply chain (furtherer towards downstream) without prior relevant analyses and simulations; or else the enterprises can face two major issues (van der Vlist et al., 1997):

1. the new system needs smaller batches and more frequent deliveries. These changes are costly.

2. lack of safety stock can make the company vulnerable to sudden increase of demand.

2.3.2 Bullwhip Effect

Lee et al. (1997) described the Cascade effect or Bullwhip effect or Whip-lash effect as

a phenomenon where orders to the supplier lend to have larger variance than sales to the buyer (i.e demand distortion), and the distortion propagates upstream in an amplified form (i.e. variance amplification).
2.3. Main Causes of Volatility of Tied-up Capital Level

Disney & Lambrecht (2008) defined the bullwhip effect mathematically in Equation 2.1.

\[
\frac{\sigma_{orders}^2}{\sigma_{demand}^2} = \frac{Var(orders)}{Var(demand)} \tag{2.1}
\]

Jonsson (2008) pointed out many reasons for creating bullwhip effect in supply chain like large order quantities, few customers, long lead times, non-aligned planning and control and price variations.

In addition, the rationing and shortage gaming can cause the bullwhip effect. It is a psychological effect, caused by lack of proper communication between customer and supplier (e.g. supplier is not aware of the real root of customer sudden escalation of demand).

Finally, bullwhip effect is due largely to lack of regular data sharing at POS between customers and suppliers.

In this regard, it can be assumed that by each step of supply chain, the bullwhip effect would be doubled (Jonsson, 2008). Bullwhip effect causes fake demands for upper members of supply chain and consequently brings overcapacity for focal factories (see Figure 2.4).

Metters (1997) suggested that in a realistic business situation; by eliminating the forecast error of bullwhip effect, the imminent increment of profit by 5% to 10% can be expected.

Chen et al. (2000) emphasised that a centralised customer demand information can reduce the bullwhip effect dramatically.

With regard to forecasting, Dejonckheere et al. (2003) explained that regardless of what forecasting method has been utilised, bullwhip effect is
2.3. Main Causes of Volatility of Tied-up Capital Level

Lee et al. (1997) mentioned that even with a stable demand, bullwhip effect causes up-and-down swings in inventory level of the relevant supply chain.

Obviously, bullwhip effect is a major cause of creating the fake demand and overcapacity for the focal factory and consequently causes the high inventory level of finished vehicles. As a technique to decrease the bullwhip effect in the supply chain of vehicle sector, employing the centralised warehouse structure has been recommended and discussed in section 3.2.

2.3.3 Supplier Relation

As it has been demonstrated in section 2.2, efficient and successful pull supply chains conspicuously have less tied-up capital level compare to the relevant push ones. In this sense, the supplier relationship can be considered as a "conditio sine qua non" for pull-based supply chains of vehicle sector (Stuart, 1993; Macbeth, 1994; Wolters & Schuller, 1997). Efficient pull systems are heavily depended on long-term and reliable relationship with supplier. As Cooper & Gardner (1993) explained basic relationship with supplier (e.g. arm’t length relationship) is certainly not sufficient to achieve the goals of pull systems like Lean.

![Figure 2.5: Success Level of Pulls systems with regard to supplier relationship (Cooper & Gardner, 1993)](image)

In this regard, Moeller et al. (2006) emphasised the need for altering the supplier relationship:

a shift from an antagonistic transaction-oriented to a relationship-oriented perspective of cooperation.
Furthermore, Bergman & Klefsjö (2009) explained two major reasons to have robust relationship with suppliers:

- avoiding to receive poor-quality materials due to weak relationship with supplier (Quality Cost)
- the JIT philosophy\(^2\)

Moreover, Jonsson (2008) explained that the arm’s length relation is the cause of fragmentation and depletion of the supplier market. A company that has the competitive and bidding attitude (arm’s length perspective) towards its suppliers or is forced to deal with suppliers with such organisations’ culture, has severe issues with regard to its pull-based logistics.

**Corporate Cultural Perspective**

Lambert (2008) and Schein (2010) defined the organisation’s culture:

pattern of basic assumption that an organisation has invented, discovered or developed and that have worked well enough to considered valid. Corporate culture is taught to new members of the firm as correct way to perceive, think and feel.

Without considering the relevant cultural aspects and just emulating the examples of successful vehicle manufacturing plants like Toyota and Honda, in the hope of decreasing the inventory level of finished goods, can face dramatic errors and eventually causes a homeostasis condition\(^3\) (Benton, 2010).

Historically, there are many different metaphors for companies: machine (Taylor and Ford), Organism, political, flux and transformation, instrument of domination (Marxist perspective), brain and etc.

*Machine metaphor* developed by Frederick W. Taylor and Henry Ford, has been a common metaphor for vehicle companies especially in the first half of 20 century. Then *organism metaphor* became more and more popular and acceptable in second half of twenty century. The latter, considers a

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\(^2\) In this regard, Jonsson (2008) expressed that TPS exerted a strong influence over the initialisation of cooperative relations with suppliers in SCM.

\(^3\) Homeostasis condition: maintaining the firm’s equilibrium in response to disrupting changes (Cameron & Green, 2009).
2.3. Main Causes of Volatility of Tied-up Capital Level

Amirkiarash Kiani

company as a living and adaptive organ (Burns & Stalker, 1994; Cameron & Green, 2009).

Organism metaphor has interesting characteristics in direct contradiction to machine metaphor:

- organisation is an alive organ not a machine! it can adapt, evolve, develop and etc.
- organisation is adaptive to its environment; consequently the customer satisfaction and evaluation are vital and routine.
- places emphasis on flow of information inside organisation (awareness and even participation of employees in decision making processes) and also with outside environment (customers).
- unlike the machinist approach; it expresses that for accomplishing the organisation’s objectives, the benefits of individuals (employees) and the company (managers) should be close and demands and focuses on the participation of employees.

Obviously, the organism metaphor has many links with Pull systems (e.g. Lean thinking) and showed many successes (e.g. TPS).

It should be noticed that organism metaphor is not prefect and has its own disadvantages.

Nevertheless, emphasising that some countries (e.g. Japan) have (or used to have) collective culture and consequently better organisations’ culture (i.e. better supplier relationship), without suggesting a solution to create such required organisation’s culture, can be considered as a sign of apathy.

By raising the relevant awareness in organisations (top-down), the desired cooperative organisations’ culture and process thinking, can be created: this time based upon academic disciplines.

Game Theory can help to create such organisations’ culture. An application of game theory has been explained in section 3.3.

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4 Morgan (1998) expressed that the organism metaphor has a tendency to become an ideology (call it philosophy): individuals should be fully integrated with the organisation. Work should be defined in a way that people fulfil their personal needs through organisation. This brings the employees into two types: 1- believers 2- nonbelievers.
Chapter 3

Conclusions

In this chapter; outcomes and results of the analyses of tied-capital level in supply chain have been summarised and discussed.

The centralised warehouse structure, has been suggested and analysed as a modern technique to decrease the tied-up capital level of finished goods in the supply chain, concerning its general advantages and drawbacks.

Furthermore, as a pragmatic strategy and creating scientific awareness, research on game theory and its proposed application in logistics (i.e. IPD game), has been suggested with regard to improvement of supplier relationship as a necessity for effective pull systems.

3.1 Outcome and Discussion

As it has been explained in the preceding chapter; pull logistics trend to cause smaller swing of tied-up capital especially at downstream of supply chain of vehicle sector (see Figure 3.1).

![Figure 3.1: Tied-up capital levels in push and pull systems (Zhang & Chen, 2006)](image-url)
The major portion of vehicle buyers are altering from business owners to private owners. Therefore, the traditional forecasting methods get even lesser accurate (Zhang & Chen, 2006). Furthermore, manufacturing vehicles based on economy of scale causes many logistic issues like bullwhip effect.

The general benefits of pull systems and customisation methods are known facts and different types of pull systems are being utilised globally (Lamming, 1996).

![Reduction: Push to Pull](image)

**Figure 3.2:** Approximate reduction of tied-up capital level in supply chain by upgrading from push to pull system

(Zhang & Chen, 2006)

Rother & Shook (2003) emphasised that *value stream mapping*, as an important technique for elimination of waste, must be done for the entire supply chain (upstream-to-downstream) and not only for the focal factory. In this regard, this research has showed that the tied-up capital level in focal factory is not the key issue but at upstream and especially at downstream of supply chain.

Moreover, it can be discussed that the hybrid systems\(^1\) like "lean six sigma" cause a more robust and flexible logistics (Andersson, 2007). In addition, systems like *leagility* can be effective with regard to volatile customer demands (Naylor *et al.*, 1999).

As a new technique for decreasing tied-up capital level and also bullwhip effect, the centralised warehouse structure has been recommended

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\(^1\) The legitimacy of *hybrid* systems in logistics can also be argued as an application of famous Hegelian dialectic.
and analysed in section 3.2.

Nonetheless, as Daaboul et al. (2010), JI et al. (2007) and Benton (2010) explained the blind emphasis on emulation of other companies’ examples (e.g. upgrading a supply chain from MTS to MTO), can face failure with regard to the true integration of supply chain and even causes a homeostasis condition.

As Andersson (2007) stated that in near future different logistics systems will compete with each other and not the companies.

Considering that deep studies on logistics has started during WWII, logistics is still a new and modern science like OR. It has many potentials that will cause many more scientific breakthroughs in near future. Logistics will be studied more and more as an academic and theoretical subject.

Goldratt & Cox (2004) explained that only searching for new techniques is not sufficient but also new process thinking is necessary. As a pragmatic process thinking that can help to create the necessary organisations’ culture and efficient strategy with regard to supplier relationship, an application of IPD game in logistics has been discussed in section 3.3.

### 3.2 Centralised Warehouse Structure

There is an increasing tendency for supply chain managers to decrease the number of warehouses and the level of inventory structure in the supply chain (Harrison & Hoek, 2011).

Jonsson (2008) emphasised that the centralised inventory structure in supply chain can dramatically decrease the level of tied-up capital by elimination of duplication and reduction of safety stock. On contrary, it increases the transport cost. The general pros and cons have been listed as

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
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<tbody>
<tr>
<td>- Less tied-up capital level</td>
<td>- More transportation cost</td>
</tr>
<tr>
<td>- Less bullwhip effect</td>
<td>- More CO₂ emission</td>
</tr>
<tr>
<td>- Less non-value adding activities</td>
<td>- More D-time</td>
</tr>
</tbody>
</table>

In this regard; it has been suggested that by decreasing the number of warehouses in the supply chain, the total amount of tied-up capital can be
3.2. Centralised Warehouse Structure

Amirkiarash Kiani

reduced approximately by (Jonsson, 2008):

\[ 1 - \sqrt{\frac{n'}{n}} \]

where, \( n \) is the initial number of warehouses in the supply chain and \( n' \) is the new number of warehouses.

As the number warehouses decreases, the non-value adding activities like unnecessary loading and unloading of finished vehicles and costs of extra administration declines accordingly (Lee et al., 1997).

Furthermore, Jonsson (2008) stated that the bullwhip effect in supply chain can be amplified by double with regard to each level of warehouse structure.

It is a known fact that as the number of warehouses in the supply chain decreases, transport cost increases inversely. However, with regard to the innovative breakthroughs in logistics science, the commoditisation\(^2\) of transport and overcapacity of basic transport, the overall transport cost is declining (Harrison & Hoek, 2011).

Different sources pointed out that the centralised inventory structure increases the transport and consequently escalates the \( CO_2 \) emissions (Aronsson & Brodin (2006) and Cooper et al. (1994)). However, recent researches have suggested that with regard to the environmental impact, centralised warehouse structure has the benefits that were been neglected in decentralised inventory structure. Kohn & Brodin (2008) explained three major factors that can dwindle the amount of \( CO_2 \) emissions in a centralised warehouse structure supply chain:

1. consolidation of freight flows
2. changes in transport mode, enabled by the centralisation
3. decrease in the amount of emergency deliveries, a result of centralisation

It has been shown that the cumulative effects of the drawbacks of centralised warehouse structure are declining (e.g. transport cost and \( CO_2 \))

\(^2\) The business term commoditisation should not be confused by its philosophic meaning: a famous concept by Karl Marx with regard to alienation of people from their human nature by class society. See Capital: A Critique of Political Economy by Marx (1992).
emissions). In this sense, studies and investments on centralised inventory structure for decreasing the tied-up capital level of finished vehicles, is even more logical and pragmatic.

3.3 Game Theory

Game theory has many applications in different sciences like economics, sociology, OR, biology, political science, evolutionary genetics studies (Darwinian natural selection), anthropology and etc.

First in-depth researches on game theory has been done and published during WWII by John von Neumann (member of the Manhattan project) and Oskar Morgenstern (distinguished German-born Jewish economist) in US.

Heretofore, eight scientists won the Nobel Prize in this filed: John Forbes Nash, Reinhard Selten, Thomas Schelling, Leonid Hurwicz, Eric Maskin, Roger Myerson, John Harsanyi and Robert Aumann.

The explanation of game theory is out of the range of this thesis. Nevertheless, a simple example of IPD game has been discussed.

3.3.1 Applying IPD Game for Supplier Relationship

Prisoners’ dilemma game is a well-known concept of game theory. It was attributed by A. W. Tucker in 1950.

van Vuuren et al. (2011) explained the PD game structure:

two suspects are arrested by police. Having insufficient evidence for convicting the prisoners on a major charge, the police offer both the same deal. Each prisoner is told that if he defects from the other prisoner by testifying against him while the latter cooperates with the former by remaining silent, the betrayer goes free, while the silent accomplice receives the full sentence for the major charge. If the prisoners both cooperate by remaining silent, they are each sentenced to a short prison term on a minor charge (for which the police do have sufficient evidence to convict). However, if the prisoners both defect from

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3 For further reading on this subject, see "Theory of Games and Economic Behavior" by Von Neumann et al. (2007) or "Game Theory" by Owen (1995) or "Thinking Strategically: the competitive edge in business, politics and everyday life" by Dixit & Nalebuff (1993).
one another (i.e. betray each other), then they share the prison sentence, each receiving a medium term.

The payoffs have been demonstrated in Table 3.1 for each prisoner (D = Defective act, C = Cooperative act, P = punishment for defection, S = punishment for the person who is doubled crossed, R = reward for both cooperation and T = temptation for double crossing).

<table>
<thead>
<tr>
<th>Player 1</th>
<th>Player 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>(P,P)</td>
</tr>
<tr>
<td>C</td>
<td>(S,T)</td>
</tr>
</tbody>
</table>

Table 3.1: Pay-off Matrix of Classic Prisoners’ Dilemma (Winston & Goldberg, 2004)

Where,

\[ T > R > P > S \]

When prisoners are not aware of each other decision beforehand, it is rational that both prisoners defect and condition (P,P) is optimal though prisoners could have better off result with condition (R,R) (both cooperative) (van Vuuren et al., 2011).

Winston & Goldberg (2004) defined the condition that both parties defect (P,P), as the equilibrium point of nonconstant-sum game\(^4\).

As an expansion of PD game, Iterated Prisoners’ Dilemma game is a situation that two players do not play once, but for finite times (\(\mathbb{N}\)) and can decide based on their previous encounters.

As Axelrod (2006) explained that in IPD game; if both parties defect (equilibrium point), the cumulative pay-offs will turn out poorly. On contrary, the cooperative strategies (e.g. tit for tat) are the best optimised solutions, in direct contraction to classic PD.

The short-term relationship with supplier can be perceived as an application of PD game and the long-term relationship with suppliers, which is requisite for robustness of pull systems, can be studied as an application of IPD game.

- **Arm’s length relationship** can be considered as the equilibrium point of PD game: the condition that both parties (supplier and customer)

\(^4\) This is a nonconstant-sum game, considering that it is very infrequent that business competitors to be in total conflicts (Winston & Goldberg, 2004).
base their relationship on competitiveness and price bidding; suitable only for short-term relationship.

- Cooperative strategies (as the optimised strategies of IPD game) can be implemented whenever customer and supplier are certain that they have long-term relationship (they play the game for finite times, not once). In this sense, for upgrading the level of relationship with suppliers, from elementary cooperation (e.g. partnership) to a sophisticated relationship level (e.g. vertical integration), the cooperative strategies should be implemented (upgrading to win-win game)\(^5\).

- It should be considered that a firm may not implement the same strategy for all of its suppliers, the intensities of cooperative strategies are directly depended to their levels of necessities (e.g. it is more pragmatic to have cooperative strategies with first-tier suppliers than second-tier suppliers) (Harrison & Hoek, 2011). In this regard, Kraljic (1983)’s matrix can be utilised (see Figure 3.3).

![Figure 3.3: Comparison of intensities of cooperative strategies with regard to Kraljic (1983)’s matrix](image)

3.4 Further Research

As an in-depth study of the relevant factors that cause the dramatic fluctuation of tied-up capital level at downstream of supply chain (finished

\(^5\) See Figure 2.5 for comparison of different levels of supplier relationship with regard to success of the relevant pull system.
vehicles), the costs of protective fabric covers, has been not fully analysed.

For finished vehicles, protective fabric cover is mainly used to avoid getting scratched or dented during transport.

Furthermore, it can be required to be thermal protective, water resistant and anti-uv. The fabric cover should be environmentally sustainable too.

It can be interesting to study the different types of protective fabric covers that major vehicle manufactures use (e.g. Volkswagen or Volvo) with regard to their costs as a portion of tied-up capital of finished vehicles.

If the found portion is 0.1% or less of the relevant vehicle cost, the investment is justified. Else, alternative methods should be invested and implemented (e.g. foams). The flowchart for the process of this research has been presented in Figure 3.4.

![Flowchart for cost analysis of protective covers](image)

Figure 3.4: Suggested flowchart for cost analysis of protective covers for finished vehicles
Bibliography


