# INVESTIGATING THE IMPACT OF INFORMATION SHARING IN A TWO-LEVEL SUPPLY CHAIN USING BUSINESS PROCESS MODELING AND SIMULATIONS: A CASE STUDY

Ales Groznik
University of Ljubljana, Faculty of Economics
Kardeljeva ploscad 17, 1000 Ljubljana, Slovenia
E-mail: ales.groznik@ef-uni.lj.si

Marinko Maslaric
University of Novi Sad, Faculty of Technical Sciences
Trg D. Obradovica 6, 21000 Novi Sad, Serbia
E-mail: marinko@uns.ns.ac.yu

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Supply chain, information sharing, business processes modelling, simulation, bullwhip effect

**ABSTRACT**

This paper reports on an oil/retail petrol supply chain which was undergoing a Business Process Re-engineering (BPR) exercise. The paper models and analyses the effect of information sharing on the performance parameters (inventory costs and bullwhip effect) of an actual Serbian oil industry supply chain. The main idea is to show through business process modelling how the BPR of existing processes needs to follow the introduction of the EDI system into organisations to improve information sharing between the supply chain echelons. Also, a simulation is employed to show how different levels of information sharing impact on inventory costs and the bullwhip effect. The model itself was has developed for a two-level supply chain structure, and it and its associated simulations highlight the significant benefits that are achievable through the use of improved information sharing and business process re-engineering on the observed supply chain performance parameters.

## 1. INTRODUCTION

Global marketplaces, higher levels of product variety, shorter product life cycles, and demand for a premium customer service are increasing supply chain complexity and cost. This coupled with advances in information technology are enabling companies to critically re-evaluate and improve their supply chain strategies and explore new modes for management supply chain activity. The supply chain, as a network of suppliers, factories, distribution centres and retailers through which materials are required, transformed and delivered to customers, often encounters the conflicting objectives of its members. Yet for success of the global optimisation of a supply chain collaboration between the different companies is vital. However, supply chain collaboration is only possible if supply chain partners share their information. It is well recognised that advances in information technologies have driven much change through supply chain and logistics management services. Traditionally, the management of information has been somewhat neglected. The method of information transferring carried out by members of the supply chain has consisted of placing orders with the member directly above them. This has caused many problems in the supply chain. These include excessive inventory holding, longer lead times and reduced service levels in addition to increased demand variability or the ‘Bullwhip Effect’ (BWE). Thus, as supply chain management (SCM) progresses, supply chain managers are realising the need to utilise improved information sharing throughout the supply chain in order to remain competitive.

However, the simple use of information technology (IT) applications to improve information transfers between supply chain members is not in itself enough to realise the benefits of information sharing. A mere increase in information transfers does not mean that information distortions (BWE) will be avoiding and the efficiency of logistics processes will be improving. The business models of existing processes have to be changed so as to facilitate the better use of the information transferred (Trkman et al. 2007). In this paper, by using business processes modelling and simulation we show how achieving only successful business process changes can contribute to the full utilisation of improved information sharing in supply chains. We analyse a two-level supply chain similar to that in (Trkman et al. 2007). There is a single supplier which supplies products to a retailer who, in turn, faces demands from end-customers. In this paper, we consider two information sharing strategies combined with three business process models, and two inventory control strategies that were being examined by the case-study company. In order to model the situation in detail, a discrete events simulation model of the supply chain has been developed. One aim of this study is to connect existing theoretical studies with a real-life complex case study in an attempt to provide people in the work world with the expected performance improvements discussed in this paper.

The next section briefly reviews related literature about the key concepts of the chosen topic. Section 3 formulates the case study and outlines business process models for the current and proposed state for the company under consideration. Section 4 details a

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simulation study with experimentation concerning information sharing, business process models and a type of inventory control, while Section 5 discusses the results and concludes.

## 2. SUPPLY CHAIN MANAGEMENT

The objective of supply chain management is to provide a high velocity flow of high quality, relevant information that enables suppliers to provide for the uninterrupted and precisely timed flow of materials to customers. Supply chain excellence requires standardised business processes supported by a comprehensive data foundation, advanced information technology support and highly capable personnel. It needs to ensure that all supply chain practitioners' actions are directed at extracting maximum value. According to (Simchi-Levi et al. 2003), supply chain management represents the process of planning, implementing and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods, and related information from the point of origin to the point of consumption for the purpose of meeting customers' requirements.

### 2.1 Information sharing

In traditional supply chains, retailers make their own inventory replenishment decision based on their demand forecast and their cost structure. Many supply chain related problems such as BWE can be attributed to a lack of information sharing among various members in the supply chain. Sharing information has been recognised as an effective approach to reducing demand distortion and improving supply chain performance (Lee et al. 1997a). Accordingly, the primary benefit of sharing demand and inventory information is a reduction in the BWE and, hence, a reduction in inventory holding and shortage costs within the supply chain. The value of information sharing within a supply chain has been extensively analysed by researches. Various studies have used a simulation to evaluate the value of information sharing in supply chains (Towill et al. 1992; Bourland et al. 1996; Chen 1998; Gavirneni et al. 1999; Dejonckheere et al. 2004; Ferguson and Ketzenberg 2006). Detailed information about the amount and type of information sharing can be found in (Li et al. 2005).
The existing literature has investigated the value of information sharing as a consequence of implementing modern information technology. However, the formation of a business model and utilisation of information is also crucial. Information should be readily available to all companies in supply chains and the business processes should be structured so as to allow the full use of this information (Trkman et al. 2007). The objective of this paper is to offer insights into how the value of information sharing within a two-level supply chain is affected when two different models of business process re-engineering are applied. Moreover, the literature shows that, although numerous studies have been carried out to determine the value of information sharing, little has been published on real systems. The results in this paper have been obtained through a study of a real-life supply chain case study using simulation.

### 2.2 The bullwhip effect

Our study has two objectives. First, as mentioned above, to investigate the impact of business process re-engineering on information sharing value, as measured by lead times and transactional costs. Second, to examine the impact of information sharing with combinations of different inventory control policies on BWE and inventory holding costs.
An important observation in supply chain management is the BWE. Basically, this effect illustrates an increase in demand variability as one moves up the supply chain, i.e., from the retailer to the supplier. In order to effectively manage the BWE its primary causes must be understood. The main causes of the BWE were identified in (Lee et al. 1997a; Lee et al. 1997b) where solutions to manage it to were also offered. They logically and mathematically proved that the key causes of the BWE are: demand forecasting updating, order batching, price fluctuation, and shortage gaming. According to this researcher, the key to managing the BWE is to share information with other members of the supply chain. In these papers, they also highlighted the key techniques to manage the BWE.
We can measure the BWE in different ways, but for the purpose of this research we accepted the measures applied in (Fransoo and Wouters 2000). We measure the BWE as the quotient of the coefficient of variation of demand generated by one echelon(s) and the coefficient of variation of demand received by this echelon:

$$w = \frac{c_{out}}{c_{in}} \tag{1}$$

where

$$c_{out} = \frac{\sigma(D_{out}(t, t+T))}{\mu(D_{out}(t, t+T))} \tag{2}$$

and

$$c_{in} = \frac{\sigma(D_{in}(t, t+T))}{\mu(D_{in}(t, t+T))} \tag{3}$$

$D_{out}(t, t+T)$ and $D_{in}(t, t+T)$ are the demands during time interval *(t, t+T)*. For detailed information about measurement issues, see (Fransoo and Wouters 2000).

### 2.3 Business process modelling

The business process is a set of related activities which make some value by transforming some inputs into valuable outputs. A business process model is an abstraction of a business that shows how business components are related to each other and how they operate. Its ultimate purpose is to provide a clear picture of the enterprise's current state and to determine its vision for the future. Modelling a complex business requires the application of multiple views. Each view is a simplified description (an abstraction) of a business from a particular perspective or vantage point, covering particular concerns and omitting entities not relevant to this perspective. To describe a specific business view process mapping is used. It consists of tools that enable us to document, analyse, improve, streamline, and redesign the way the company performs its work. Process mapping provides a critical assessment of what really happens inside a given company. The usual goal is to define two process states: AS-IS and TO-BE. The AS-IS state defines how a company's work is currently being performed. The TO-BE state defines the optimal performance level of "AS-IS". In other words, to streamline the existing process and remove all rework, delays, bottlenecks and assignable causes of variation, there is a need to achieve the TO-BE state. Business process modelling and the evaluation of different alternative scenarios (TO-BE models) for improvement by simulation are usually the driving factors of the business renovation process (Bosilj-Vuksic et al. 2002). In the next section a detailed case study of a Serbian petrol company is presented.

## 3. CASE STUDY: BUSINESS PROCESS RE-ENGINEERING

The case study is a Serbian oil downstream company. Its sales and distribution cover the full range of petroleum products for the domestic market: petrol stations, retail and industries. The enterprise supply chain comprises fuel depot-terminals (distribution centre), petrol stations and final customers. The products are distributed using tank tracks. The majority of deliveries is accomplished with own trucks, and a small percentage of these trucks is hired. The region for distribution is northern Serbia. It is covered by two distribution centres and many petrol stations at different locations. In line with the aim of the paper only a fragment, namely the procurement process, will be shown in the next section. A broader description of the case study can be found in (Maslaric 2008).
From the supply chain point of view, the oil industry is a specific business, and for many reasons it is still generally based on the traditional model. The product is manufactured, marketed, sold and distributed to customers. In other industries, advanced supply chain operation is becoming increasingly driven by demand-pull requirements from the customer. There is a strong vertically integrated nature of oil companies and that may be a potential advantage. In other industries, much attention is focused on value chain integration across multiple manufacturers, suppliers and customers. In the oil industry, more links in the chain are "in house", suggesting simpler integration. In practice, there is still a long way to go to achieve full integration in the oil supply chain.

### 3.1 AS-IS model development

The next section covers the modelling of the existing situation (AS-IS) in the procurement process of the observed downstream supply chain case study. The objective was to map out in a structured way the distribution processes of the oil company. The modelling tools used in this case study come from the Igrafx Process. These modelling tools were applied in order to identify the sequence of distribution activities, as well as the decisions to be taken in various steps of the distribution process. The AS-IS model was initially designed so that the personnel involved in the distribution processes could review them, and after that the final model shown in Figure 1 was developed.
The core objective of supply chains is to deliver the right product at the right time, at the right price and safely. In a highly competitive market, each aims to carry this out more effectively, more efficiently and more profitably than the competitors. Because both the prices and quality of petrol in Europe are regulated, the main quality indicator in oil supply chains is the number of stock-outs. The main cost drivers are therefore: number of stock-outs, stock level at the petrol station and process execution costs. Lead time is defined as the time between the start (measurement of the stock level) and the end (either the arrival at a petrol station or the decision not to place an order) of the process (Trkman et al. 2007).
The main problems identified when analysing the AS-IS model relate to the company's performance according to local optimisation instead of global optimisation. The silo mentality is identified as a prime constraint in the observed case study. Other problems are in inefficient and costly information transfer mainly due to the application of poor information technology. There is no optimisation of the performance of the supply chain as a whole. Purchasing, transport and shipping are all run by people managing local, individual operations. They have targets, incentives and local operational pressures. Everything was being done at the level of the functional silo despite the definition that local optimisation leads to global deterioration. The full list of problems identified on tactical and strategic levels are identical to those in (Trkman et al. 2007), so for greater detail see that paper.
Based on the mentioned problems, some improvements are proposed. The main changes lie in improved integration of whole parts of the supply chain and centralised distribution process management.

### 3.2 Business processes re-engineering

The emphasis in business process re-engineering is put on changing how information transfers are achieved. A necessary, but no means sufficient condition for this is to implement new information technologies which enable efficient and cheap information transfers. Hence, IT support is not enough as deep structural and organisational changes are needed to fully realise the potential benefits of applying new IT. In this case study we develop two different propositions for business process re-engineering (two TO-BE models) to show how the implementation of new IT without business process renovation and the related organisational changes does not mean the full optimisation of supply chain performance. The first renewed business model (TO-BE 1) is shown in Figure 2 and represents the case of implementing IT without structural changes to business processes. In the TO-BE 1 model, there is no integrated and co-ordinated activity through the supply chain. Inventory management at the petrol stations and distribution centre is still not co-ordinated.

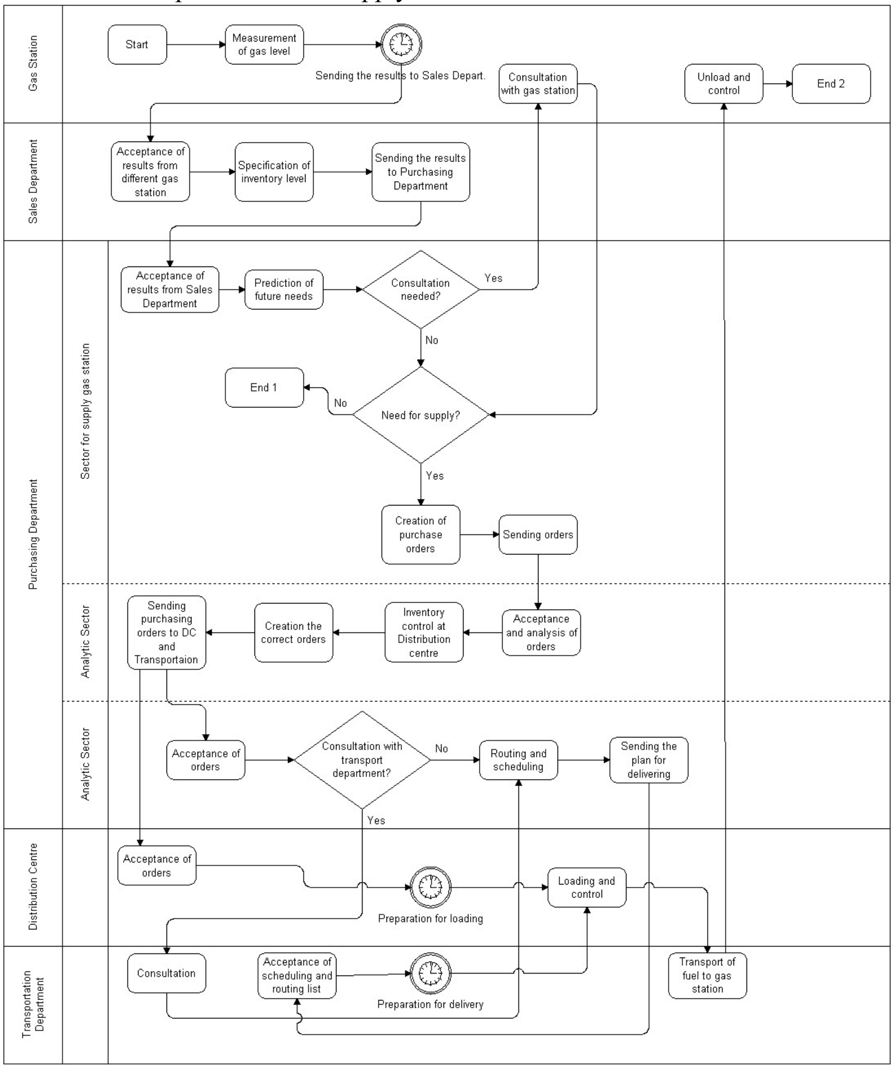


Figure 1: AS IS model of the process

The TO-BE 2 model assumes that the processes in the whole downstream oil supply chain are full integrated and the distribution centre takes responsibility for the whole procurement process. The TO-BE 2 business model is shown in Figure 3. The main idea is that a new organisational unit within the distribution centre takes on a strategic role in co-ordinating inventory management and in providing a sufficient inventory level at the petrol stations and distribution centre to fulfil the demand of the end customer. It takes all the important decisions regarding orders in order to realise this goal. Other changes proposed in the TO-BE 2 model are the automatic measurement of petrol levels at petrol stations and the automatic transfer of such data to the central unit responsible for petrol replenishment; the predicting of future demand by using progressive tools; and using operations research methods to optimise the transportation paths and times. The role of IT in all of these suggestions is crucial.

### 3.3 Measuring the effect of re-engineering

The effect of the changes can be estimated through simulations. Because our study has two objectives, we have two kind of simulations. In our first example we simulated business processes to investigate the impact of business process re-engineering on the information sharing value, measured by lead times and transactional costs. The second simulation, which partly uses the results of the first simulation, represents an object-oriented simulation which helps define the impact of information sharing and appropriate inventory control on the BWE and inventory holding costs in the oil downstream supply chain under consideration. Both simulations are especially important as they enable us to estimate the consequence of possible experiments.

In the first simulation we estimated changes in process execution costs and lead times. First a three-month simulation of the AS-IS and of both the TO-BE models was run.

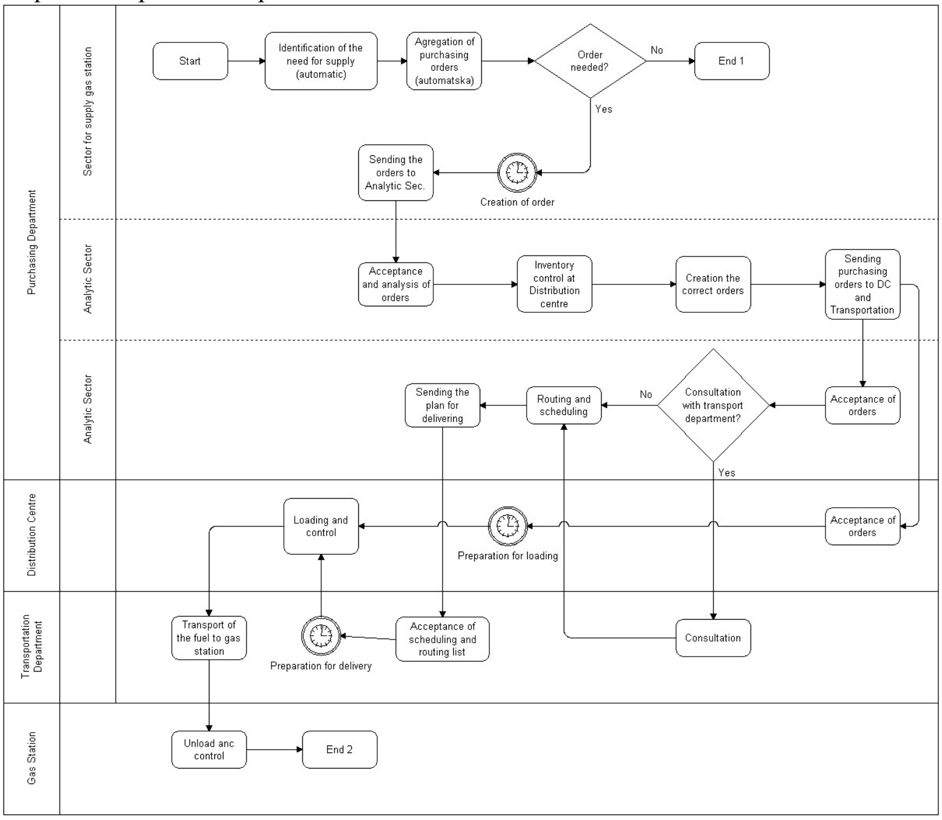


Figure 2: TO-BE 1 model of the process

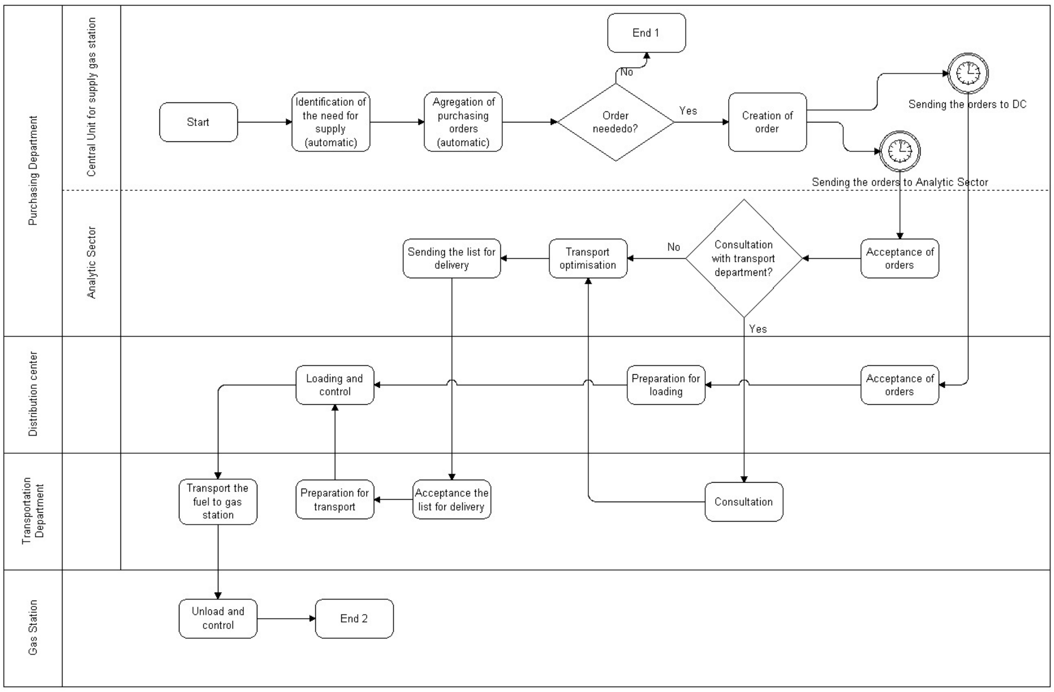


Figure 3: TO-BE 2 model of the process

In the AS-IS model a new transaction is generated daily (the level of petrol is checked once a day), in the TO-BE it is generated on an hourly basis (the level of stock is checked automatically every hour). The convincing results are summarised in Table 1. The label “Yes” refers to those transactions that lead to the order and delivery of petrol, while the label “No” means a transaction where an order was not made since the petrol level was sufficient.

Table 1: Comparison of simulation results for the AS-IS and TO-BE models

| Transaction | No. | Av. lead time (hrs) | Av. work (hrs) | Av. wait (hrs) | Average costs (€) |
|---|---|---|---|---|---|
| Yes (AS-IS) | 46 | 33.60 | 11.67 | 21.93 | 60.10 |
| No (AS-IS) | 17 | 8.43 | 2.40 | 6.03 | 8.47 |
| Yes (TO-BE 1) | 46 | 27.22 | 10.26 | 16.96 | 56.74 |
| No (TO-BE 1) | 1489 | 0.00 | 0.00 | 0.00 | 0.00 |
| Yes (TO-BE 2) | 46 | 12.85 | 4.88 | 7.98 | 32.54 |
| No (TO-BE 2) | 1489 | 0.00 | 0.00 | 0.00 | 0.00 |

The average process costs are reduced by almost 50%, while the average lead time is cut by 62% in the case of the TO-BE 2 business model. From this it is clear that this renovation project is justifiable from the cost and time perspectives. The results in Table 2 show that a full improvement in supply chain performances is only possible in the case of implementing both IT which enables efficient information sharing and the redesign of business processes. The mere implementing of IT without structural and organisational changes in business processes would not contribute to realising the full benefit.
The results of the previous simulation (lead time) were used as an input for the next simulation so as to help us find the impact of information sharing on the BWE and inventory holding costs in the given supply chain.

## 4. INVENTORY CONTROL SIMULATION

In this section we employed an object-oriented simulation to quantify the benefit of information sharing in the case study. The system in our case study is a discrete one since supply chain activities, such as order fulfilment, inventory replenishment and product delivery, are triggered by customers’ orders. These activities can therefore be viewed as discrete events. A three-month simulation of the level of stock at a petrol station that is open 24 hours per day was run.
In order to provide results for the observed supply chain performance, the following parameters are set:

- *Demand pattern*: Historical demand from the end-customer to petrol stations, and from petrol stations to distribution centres was studied. From this historical demand, a probability distribution was created.
- *Forecasting models*: The exponential smoothing method was used to forecast future demand.
- *Information sharing*: Two different types of information sharing were considered: (1) NoIS - no information sharing (AS-IS model); and (2) IS - Full information sharing (TO-BE models).
- *Lead time*: Lead time from the previous simulation business process was used.
- *Inventory control*: Three types of inventory replenishment policy were used: (1) No inventory policy based on logistics principles. There was a current state in the viewed supply chain (AS-IS model; (2) The petrol station and distribution centre implement the (R,Q) inventory policy according to demand information from the end-customer, but the distribution centre was not responsible for the petrol station’s replenishment policy – no VMI policy (TO-BE 1 model); and (3) VMI – full information sharing is adopted and the distribution centre is in charge of the inventory control of the petrol station. The one central unit for inventory control determines the time for replenishment as well as the quantities of replenishment (TO-BE 2 model).
- *Inventory cost*: This is the cost of holding stocks for one period.
- *Bullwhip effect*: The value of the BWE is measured from equations (1), (2) and (3).

To investigate the effect of information sharing upon supply chain performance (BWE and inventory costs), three scenarios are designed with respect to the above parameters:

- Scenario 1: No IS, no defined inventory control, (AS-IS model);
- Scenario 2: IS, no VMI, (TO-BE 1) model; and
- Scenario 3: IS, VMI, (TO-BE 2) model.

The simulation was run using GoldSim Pro 9.0. The results from Figure 4 show that the value of the BWE is smallest for Scenario 3, which assumed full information sharing with appropriate structural changes of business processes, and full co-ordination in inventory control across the supply chain. These results also show that fully utilising the benefit of implementing IT and inventory management based on logistics principles can decrease the BWE by 28% in the observed case study.
In Figure 5 a comparison of inventory costs with regard to the scenarios is shown. The minimum inventory holding costs are seen in Scenario 3, like in the first case. The results from Figure 5 show that benefits from the application of new IT, business process re-engineering and co-ordinated inventory policy,

expressed by decreasing inventory holding costs, could be 20%.

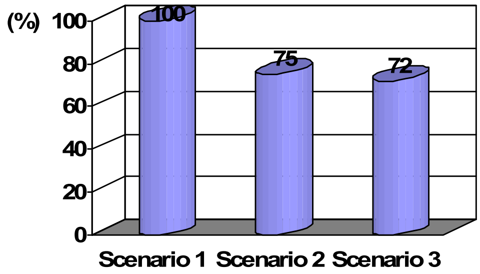


Figure 4: BWE value comparison of the three scenarios

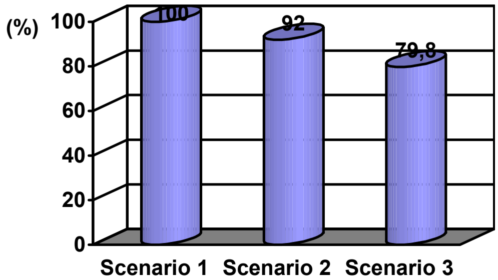


Figure 5: Inventory costs comparison of the three scenarios

## 5. CONCLUSION

SCM has become a powerful tool for facing up to the challenge of global business competition because SCM can significantly improve supply chain performance. This paper explores the effect of information sharing with regard to the performance of a two-level oil downstream supply chain. The conclusions of the simulation experiments are: information sharing can enhance the performance of the supply chain. In addition, business process re-engineering, co-ordination and collaboration are also important mechanisms in the supply chain to improve performance. Collaboration can reduce the influence of the Bullwhip effect and improve cost efficiency.

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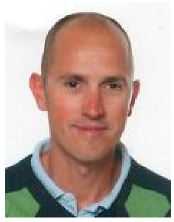

**ALES GROZNIK** is assistant professor in the Department of Information Sciences at the Faculty of Economics, University of Ljubljana. He holds a first degree and a M.Sc. in Engineering and a M.Sc. and Ph.D. in Information Sciences from University of Ljubljana. His research interest is in management and strategic information system planning, modeling and simulation of business processes, information technology management and the role of information systems in ever changing business environments**.**

**MARINKO MASLARIC** is an Assistant Lecturer for Logistics, Intermodal Transport and Supply Chain Management at the Faculty of Technical Sciences, University of Novi Sad, Serbia. He is the author of several conference papers about logistics and supply chain management, especially integration and co-ordination in supply chains, inventory management and intermodal transport technology in supply chains.