

**‘HEBBAN OLLA VOGALA NESTAS HAGUNNAN HINASE....’:  
A SYSTEM DYNAMICS CASE STUDY OF SUPPLY CHAIN  
COLLABORATION IN THE PROCESS INDUSTRY**

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**ABSTRACT**

The existing knowledge base on supply chain collaboration (SCC) is primarily based on studies in electronics, automotive and fast moving consumer goods industries. The aim of this study is to explore the applicability of existing theoretical SCC concepts in the chemical process industry. A system dynamics model was developed and applied to analyse the impact of collaboration initiatives in the supply chain of the Special Products business unit of Royal DSM N.V., a leading company in the European chemicals industry.

Our research findings do suggest that there are industry-specific factors that make collaboration different in the process industry. In bulk chemicals production processes, the focus is on capacity co-ordination and less on material co-ordination, which is where most collaboration initiatives in other industries focus on. This overriding importance of capacity co-ordination does limit the degrees of freedom for collaboration in the process industries somewhat. However, substantial benefits can still be reaped from material co-ordination efforts, such as information sharing and inventory buffer sharing, in process industry supply chains. A complicating factor in all collaboration efforts is that benefits are not distributed equally amongst supply chain partners. This is one more reason why especially intra-firm buyer-supplier relationships are promising candidates for supply chain collaboration as here the distribution of supply chain benefits amongst parties can be resolved at corporate level.

**Keywords:**

System dynamics, supply chain collaboration, process industry

## INTRODUCTION

The importance of supply chain collaboration (SCC) has been widely acknowledged in the past decade. Available literature on the effects and implications of SCC mainly concentrates on studies in electronics and automotive industries. In those industries, SCC is an effective method to improve supply chain performance and reduce costs. Meanwhile, studies on SCC initiatives in the process industry are rather scarce. Here, the question arises whether the process industry could benefit from SCC like other industries. Apparently, everybody seems to be collaborating, so why not here as well? This sentiment is nicely captured in the phrase “*Hebban olla vogala nestas hagunnan, hinase hic anda thu*”. This has long been taken for the oldest sentence written in Dutch. It was discovered in an Oxford library in 1922 and has probably been written by a Flemish monk in the 11<sup>th</sup> century. It translates in contemporary English as: “All birds have started building their nests, except you and me...”

This classic text can be read as a paraphrase of our research question in this paper: *Is it true that other industries have started all sorts of collaboration initiatives to improve supply chain performance, while the process industry is limping behind? And, if so, how come? Are there industry-specific factors that hamper the emergence of collaboration efforts?* Our findings from a system dynamics case study at the Special Products business unit of Royal DSM N.V. (DSM), suggest that in the process industry collaboration is indeed different from collaboration in other industries. The primary emphasis is on capacity utilisation instead of materials coordination, which is where collaboration in other industries tends to focus on. This, however, does not imply that SCC in the process industry is useless. We will demonstrate that collaboration can still contribute significantly to a reduction in costs and better supply chain performance.

In this paper, we first discuss the relevant literature on supply chain collaboration and the process industry, followed by a brief description of our research method. Next, we introduce the case study and the simulation model, and then our main findings. In the discussion section, we present our synthesis on these findings.

## LITERATURE REVIEW

### *Supply chain collaboration*

Several studies have addressed the complex nature of collaboration and the wide variety of factors affecting the outcome of collaboration initiatives. De Jong and Nooteboom (2000) developed a model of long-term supply relationships based on transaction cost theory and tested it in the automotive industries of the United States, Europe and Japan. A distinction has been made between firm- and relation-specific characteristics. Akkermans et al. (1999) introduce ‘virtuous and vicious cycles’ as a framework in which different factors affecting collaboration efforts are represented. Virtuous and vicious cycles are reinforcing loops (see Sterman, 2000) of success and failure, respectively. Companies that are ‘caught’ in such loops can hardly escape from it.

Key drivers of the success of collaboration initiatives are trust, transparency and travail (Akkermans et al., 2004). Travail refers to the effort that is needed by supply chain partners ‘to make things work’. From these efforts improved transparency and higher trust levels result, which in return positively influence supply chain performance. Travail is not

the only driver for the levels of transparency and trust, several other factors influence these levels as well.

Research on SCC is mainly concentrated in electronics and automotive industries. Bensaou (1999) used mutual specific investments to characterise four types of supply chain relationships in the automobile sector: market exchange, captive supplier, captive buyer and strategic partnership. This typology, and its different relationships, appear to be applicable to all industries. Classification solely based on specific investments, however, does not always reflect the actual relationship between supply chain partners. Buyers and suppliers may have different perceptions of the type of relationship despite the levels of mutual specific investments. Differences between the perception and reality of a relationship between supply chain partners can seriously hamper the effectiveness of SCC initiatives (Van de Vijver and Vos, 2004).

A more operational perspective on collaboration is proposed by Muckstadt et al. (2001) in their collaborative planning study in the fast-moving consumer goods industry. Four types of communication between supply chain partners can be distinguished: communicators, coordinators, cooperators and collaborators. These types differ in the intensity and means of data exchange.

To our knowledge, there are no studies that highlight the importance of collaboration in the process industry, nor that address the potential influence of (process) industry-specific factors on the applicability of collaborative efforts. Therefore, we intend to expand the traditional focus on SCC in well-known industries (automotive, electronics, FMCG) to other settings, such as the process industry.

### *Process industry*

Distinguishing features of this industry can be subdivided in product, process and sector characteristics (Van de Vijver and Vos, 2004). Although “the” process industry is very heterogeneous, still some generic characteristics appear to be present.

A relevant *product* characteristic is that, especially in the bulk segment of process industries, the share of customer specific products is typically much lower than in automotive and electronics industries. A similar statement can be made regarding the number of different product types offered to customers. These characteristics imply a reduced need for collaboration in managing and controlling supply chain processes.

An important *process* characteristic is the capital intensity of process industries, involving large investments in equipment and supporting facilities. This often results in strategies to maximise capacity utilisation levels in individual supply chain processes. Consequently, it is not surprising to observe a prevailing use of inventories as a dominant coordination mechanism, which is yet another relevant process characteristic. This use of inventory buffers is reinforced by inherent difficulties to control good flows in process industries due to variances in the quality of input materials (Fransoo and Rutten, 1994). It is interesting to observe that in other industries, such as electronics, SCC proved to be a viable mechanism to reduce this buffer function (see for example Akkermans et al., 2004).

A relevant characteristic at the *sector* level is the clustering of related processes in a specific geographic region. Such (petro)chemical clusters can, for example, be found in the harbours of Rotterdam and Antwerp. Still, Burgess et al. (2002) observed that, despite this clustering, a holistic view on managing supply chains is still a relatively new phenomenon in process industries.

## RESEARCH METHOD

### *Relevance*

SCC in the process industry is still an under investigated research area compared to the importance of SCC in other industries. Despite the traditional focus on capacity utilisation, SCC could help to increase sales revenues or decrease costs in process industry settings. Therefore, we decided to investigate the potential applicability and benefits of SCC in process industries in an exploratory case study.

### *Case selection*

In areas where only a limited amount of research has been conducted, an exploratory case study is a suitable research method (Eisenhardt, 1989; Yin, 1994). Within the process industry, the bulk chemical industry is an excellent illustration of the 'push' nature of supply chain processes. Maximising production volumes is the main priority in such settings. Since collaborative efforts have so far been applied primarily in pull type of supply chain, our *ex ante* expectation is that it will be more difficult to apply SCC principles in push environments. Therefore, bulk chemistry is a specifically interesting research setting to explore the potential applicability of SCC in process industries. At DSM, we specifically selected a bulk chemistry setting in which there was only limited experience with collaboration initiatives.

### *Case data collection and analysis*

Different methods of data collection, often referred to as triangulation, were employed during the project. We mainly used a combination of interviews and document analyses. These data were used for the development of a system dynamics simulation model with which results of different collaboration scenarios were calculated. Assumptions and preliminary simulation results were validated several times with key stakeholders of DSM SP, thereby conducting a so-called member check (Flick, 1998).

## CASE SETTING

DSM is one of Europe's leading chemical companies and offers a wide of variety of products. DSM SP is part of the life sciences cluster within DSM and a leading supplier of products produced by means of toluene oxidation technology. Most of their products are used for flavouring purposes and improved storage life of food and beverage products. In Europe, there are two production locations, in Rotterdam and Geleen. The main product groups are benzoic acid (Purox B), sodium benzoate (Purox S), benzaldehyde and benzyl alcohol. In this case study, we have focused on the distribution of one of these products (product A in the remaining of this paper). Distributors can order three different types of packages for product A.

DSM SP has four distribution profiles: key accounts, contract customers, spot market customers and distributors. For most key accounts Vendor Managed Inventory (VMI) is used in the distribution of products, resulting in strategic partnerships between DSM SP and this type of customers. Despite the relatively large share of revenues from distributors, only little attention has been paid to collaboration between DSM SP and its distributors. Therefore, we focus on the impact of SCC initiatives in the distribution of product A by DSM SP and its distributors.

## SIMULATION MODEL

The dynamic complexity of supply chain collaboration asks for a research method that can cope with such complexity, for instance by way of scenario analyses. Furthermore, such scenario analyses are necessary due to the impossibility to experiment in real world situations. System dynamics simulation is a method to develop quantified causal models (Sterman, 2000), which can be used to perform such scenario calculations. We have modelled and analysed potential benefits of different types of collaboration between DSM SP and its distributors using a system dynamics approach. The core elements of the model developed are described in this section.

### *Stocks and flows*

The concepts of ‘stocks’ and ‘flows’ form the core of system dynamics. An example of a stock is the amount of unfulfilled orders at a certain time. Its value can only change through an inflow (new unfulfilled orders) or an outflow (completion of unfulfilled orders). Linkages between stocks and flows or between inflows and outflows may exist in a model. Flows can also change under the influence of exogenous variables, apart from changes resulting from values of other flows or stocks. Figure 1 shows the basis of the DSM SP simulation model in a stocks-and-flows format. In this simulation model only the supply chain of product A is included. End customers place their orders at the distributor; the distributor at DSM SP. The orders of the distributor are based on an estimate of the actual orders of the end customer. DSM SP has to make a forecast of the forecasted actual orders to determine expected demand per type of packaging.

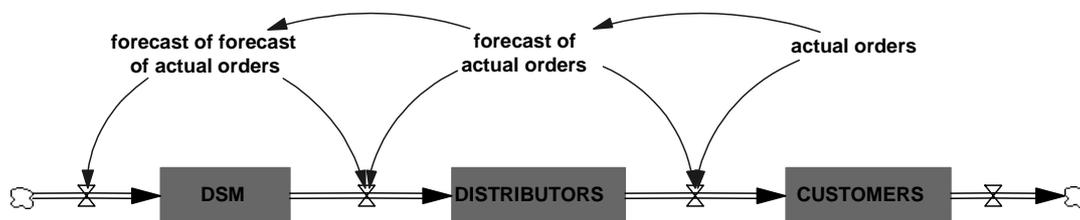


Figure 1 –Basic supply chain for DSM SP's product A

The ‘body’ of the simulation model is a detailed representation of DSM SP's processes: oxidation of toluene, distillation, granulation, packaging, storage and shipment of product A. Capacities and cost elements are modelled for each of these processes.

### *Causal loops*

The processes described above are influenced by different variables, which can also influence each other. This results in causal feedback loops. In the DSM SP project, three such causal loops have been identified and modelled quantitatively (see Figure 2).

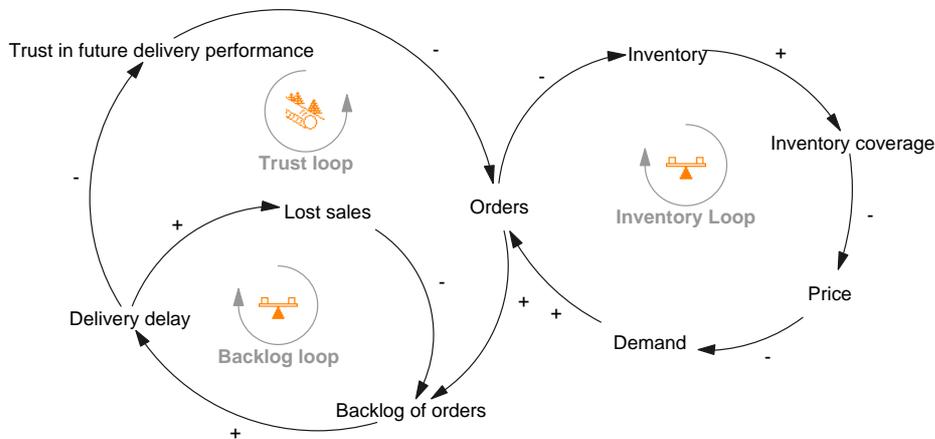


Figure 2 – Causal loops simulation model DSM SP

### *Order backlog loop*

The backlog of orders increases as the number of orders rises. A higher backlog causes longer delivery delays, which leads to an increase of lost sales. The increase in lost sales in turn reduces the backlog of orders. This is an example of a balancing or negative feedback loop (Sterman 2000).

### *Inventory loop*

When the number of orders increases, inventories will decrease. The inventory coverage ratio also decreases (inventory level / demand). As a result, prices increase (with lower coverage ratio). Higher prices lead to a decrease in both demand and orders. This is another example of a balancing loop.

### *Trust loop*

An increase in orders leads to a higher backlog of orders (see also order backlog loop), and to more delivery delays. The increase in delivery delays results in lower trust in future delivery performance. Customers will order more to assure that products will be delivered on time. This phenomenon is often referred to as ‘shortage gaming’ (see Lee et al., 1997). In system dynamics terminology, this is an example of a reinforcing or positive feedback loop.

In addition to the causality between variables, several other assumptions are made. For example on cost levels, instable demand patters due to seasonality factors and fixed percentages for residual products. All assumptions and the causal loop structure have been validated with DSM representatives.

## CASE STUDY FINDINGS

In the simulation study on the role of distributors in the supply chain of product A, several scenarios are defined. All scenarios are compared with the base case scenario in terms of normalised benefits, costs and profits. These scenarios vary in the degree in which collaboration takes place. Scenario 2 is a more drastic departure from the current way of working than scenario 1, and scenario 3 goes further than scenario 2.

### *Scenario 1: Improvement of forecasting accuracy*

Currently, distributors make a forecast of customer orders, and DSM SP estimates orders of distributors (they make a forecast of their customer's forecast). In scenario 1, the effect of an improvement in forecasting accuracy is analysed. The simulation results revealed that such an increase in accuracy does not contribute to higher profits. Because of the primary emphasis on production and the exchangeability of packaging units, only modest advantages result. For the participating managers of DSM SP this was an interesting and also somewhat surprising finding since they had been spending considerable amounts of effort in improving forecasting accuracy.

### *Scenario 2: Sharing of customer orders between distributor and DSM SP*

In this scenario, distributors transfer their own order information directly to DSM SP. In this way, DSM SP does not have to make a forecast of the expected orders of the distributors anymore. Such an improvement in quality of end customer information leads to lower inventory levels. Interestingly, this results in higher prices, as shown in the inventory loop depicted in Figure 2. This is because prices drop when inventories are too high, and inventories only become high if the forecast is erroneous. These higher prices increase the profits of DSM SP as well as the costs of the distributor. So, the net effect of order information sharing between DSM SP and its distributors is only a small increase in total profits, as higher profits for SP are partly offset by lower profits for the distributor (see Figure 3).

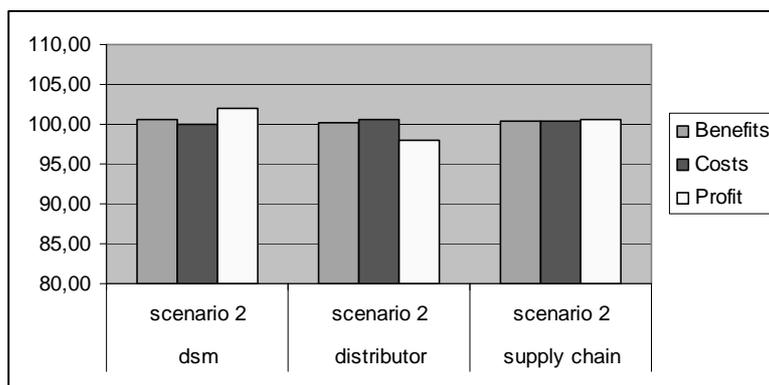
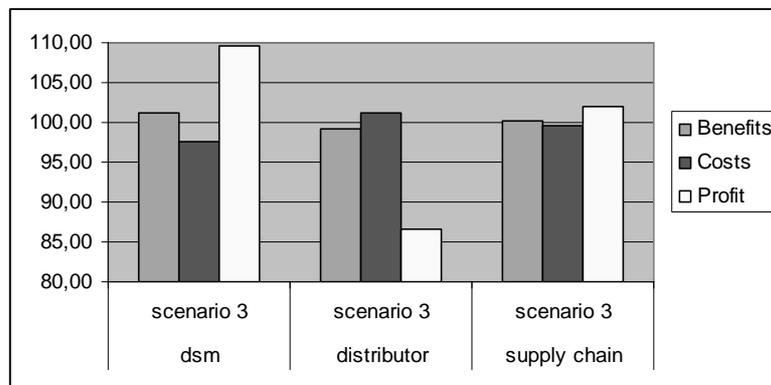


Figure 3 – Normalised results scenario 2: order information sharing

### *Scenario 3: Removal of storage facility at DSM SP*

In the base case, both DSM SP and the distributors have storage facilities. To investigate the collaboration option of sharing buffer inventories in the supply chain, we simulated a situation in which DSM SP eliminates its own storage facilities. All packaged products are directly shipped to the distributors, resulting in reduced costs for DSM SP. Furthermore, the negative impact of the price mechanism in relation to inventories is reduced in this scenario. Direct distribution eliminates the need for inventories in period of low demand, which in turn avoids the need for price decreases (see the inventory loop in Figure 2). Consequently, this scenario enables DSM SP to charge higher average prices than in the base case. Again, the downside is that distributors have to accept lower profits (see Figure 4). The net effect is a modest profit increase in the supply chain consisting of DSM SP and its distributors.



*Figure 4 – Normalised results scenario 3: removal storage facility DSM SP*

## **DISCUSSION AND CONCLUSIONS**

This study started off from two *ex ante* assumptions: (1) that supply chain collaboration was relatively absent in the chemical process industry and (2) that this had to do with the strong need for capacity co-ordination in this sector. The second assumption is especially relevant since published collaboration efforts in other industries focus primarily on material co-ordination. So, we assumed that in the chemical industry the birds had not yet “built their nests”, and that they had good reasons to do so, referring back to the historical title of this paper.

What we have found is that these assumptions were partly wrong and partly right. They were partly wrong because there is a long history of collaboration between companies in this industry. Still, they were also partly right as these collaboration efforts clearly focus on sharing capacity, like plants and distribution networks, and *not* on material co-ordination. So, what are our findings regarding material co-ordination in collaborative settings in this important industry? Here, we have to be cautious since, obviously, a single case study can never yield conclusive evidence. Therefore, we present our synthesis of findings here as four propositions that can be investigated more thoroughly in follow-up research.

*Proposition 1: The “push” nature of bulk chemical supply chains, which follows from the imperative of high capacity utilisation, does to some extent limit degrees of freedom for supply chain collaboration on material co-ordination.*

Many collaboration techniques that are standard practice in electronics and automotive, such as adapting supply plans to changes in end customer demand (e.g., Akkermans et al. 2004), are less feasible in bulk chemicals production, as supply tends to be a given. Although there may be some degree mix flexibility, for example in types of packaging, the costs associated with changing the volume of the capital-intensive plants at the beginning of the chains make this kind of collaboration impossible. So, collaboration efforts do have fewer degrees of freedom to start off with in the process industry.

*Proposition 2: Even in “push” oriented bulk chemical settings, supply chain performance can be improved significantly by collaboration between parties on material co-ordination, notably through sharing of end customer demand information and through sharing of inventory buffers.*

Our simulation experiments illustrate the potential of material co-ordination even in a setting where all the emphasis seems to be required on capacity utilisation. The more drastic the nature of the collaboration, the higher the benefits: eliminating a stock point and thereby in effect sharing an inventory buffer is even more worthwhile than sharing end customer information.

*Proposition 3: Internal supply chains, so decentralised supply chains consisting of partners that belong to the same parent company, are especially promising candidates for collaboration in material co-ordination.*

Our analysis illustrates that, often, the benefits of collaboration are unevenly distributed between parties. As in other industries, the upstream partners often benefit more than the downstream ones. This may be less of an insurmountable hurdle in intra-firm supply chains than in inter-firm settings. Of course, fair gain sharing mechanisms can be devised between independent parties as well, but it does imply an additional roadblock in the design of successful collaborative efforts.

*Proposition 4: The dynamic performance of process industry supply chains under different collaboration and control regimes is very complex. Therefore, dynamic quantitative analyses, such as system dynamics simulation, are necessary in the defining stage of any supply chain collaboration project.*

A good example in our DSM SP case study was the existing preoccupation with improving forecasting accuracy. It took the analytical simulation effort to clearly demonstrate that more advanced SCC initiatives were much more promising in terms of improving supply chain performance. Also, correctly estimating the relative benefits of collaboration for the individual partners will be essential in devising profit allocation mechanisms that will be acceptable to all. So, simulation models turned out to be essential building materials for creating nests of enduringly close supply chain relationships in the process industry.

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