Benefit Balancing - Concepts for a better collaboration

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Abstract

Decentralised decision making in supply networks leads to suboptimal performance, hence extended coordination and cooperation is necessary between the companies in order to dampen the disadvantageous effects of distributed decisions. Long-term strategic partnerships, clear regulation of responsibilities and vertically integrated supply chains can help improving the operational efficiency, but only if all partners share in the achieved benefits. Declaring a common mission statement, together with sharing technology and facilitating mutual growth, can prevent serious supply problems caused by weak links in the chain. In the paper we present both some theoretical background, as well as some practical possibilities for guaranteeing mutual benefit from improved supply processes. Our main focus here is on customise-to-order production in the automotive industry, within the European 5-Day Car initiative.

Keywords: benefit sharing, cooperation, dynamic supply loops

1 Introduction

The past decade has witnessed an explosive growth in computer, communication, and information technologies. High-performance computing, the world-wide web, universal access and connectivity, virtual reality, and enterprise integration are but a sample of this revolution's many facets. At the same time, organizations and markets have also changed dramatically, represented by developments such as production networks, virtual organizations, customer-focused supply chains, and electronic commerce. Although industry strategists and academics continue to debate the precise future trajectory of changes in technologies and organizations, they agree that information—its availability, and the ability to exchange it seamlessly and process it efficiently—is at the core of organizations' abilities of meeting escalating customer expectations in global markets. The various solution proposals unanimously imply that the future of manufacturing lies in the **cooperation of autonomous** production entities. New organizing principles and methods are needed for supporting agile and networked enterprises that—when acting together—can make use of opportunities without suffering from diseconomies of scale [JWW09].

The focus of the paper is set on such novel organizational principles, models and methods that support the planning of strategic and tactical level operations in networked production systems where decisions are made and production is carried out by autonomous partners who are open to cooperate. However, whether and how they cooperate with each other should depend solely on their local business interests. Hence, acting together in a cooperative way can only be an emergent property of the global system that should be facilitated by an appropriate cooperative planning mechanism. Heart of the problem is finding such a mechanism that makes the partners interested in cooperation on a longer horizon, by **sharing the benefits** of joint efforts [WSK08].

In the sequel we first illustrate by a simple example the effect of decentralized decisions. Next, we put the collaboration problem into the context of the AC/DC project and of **Dynamic Supply Loops** (DSL) in particular. Section 2 provides a sampling of a number of alternative practical approaches to benefit balancing. Next, in Section 3 we suggest a benefit balancing method that can readily be applied by two partners in a DSL who are in direct customer-supplier relationship. Section 4 gives an outlook to the theoretical handling of the coordination and cooperation problem through the looking-glass of mechanism design. Finally, Section 5 concludes the paper.

1.1 An illustrative example

Let us consider a simple example with a supplier and a customer (e.g., OEM) serving a market where the demand of the end-product is uncertain. The customer creates a forecast, and then orders components from the supplier. The supplier's profit is the following:

*supplier's profit = (wholesale price – production cost) * order quantity*

If the customer orders too much, obsolete inventory remains, which can have some salvage value (which can also be negative), therefore the customer's profit becomes:

*customer's profit = Min(order quantity, demand) * retail price*
*+ Max(order quantity – demand, 0) * salvage value*
*– order quantity * wholesale price*

Since the demand is stochastic, the customer wants to maximise its expected profit. Figure 1 shows the profits of both parties—with some definite parameters—as well as their sum, i.e., the total supply chain profit. Note that this latter is independent from the wholesale price.

As the figure shows, the customer's optimal order quantity is 700, which yields € 42,080 profit on the customer's and € 59,500 on the supplier's side, i.e., totally € 101,580. However, ordering 900 would result in € 112,770 total profit, which is € 11,190 more than in the previous case.

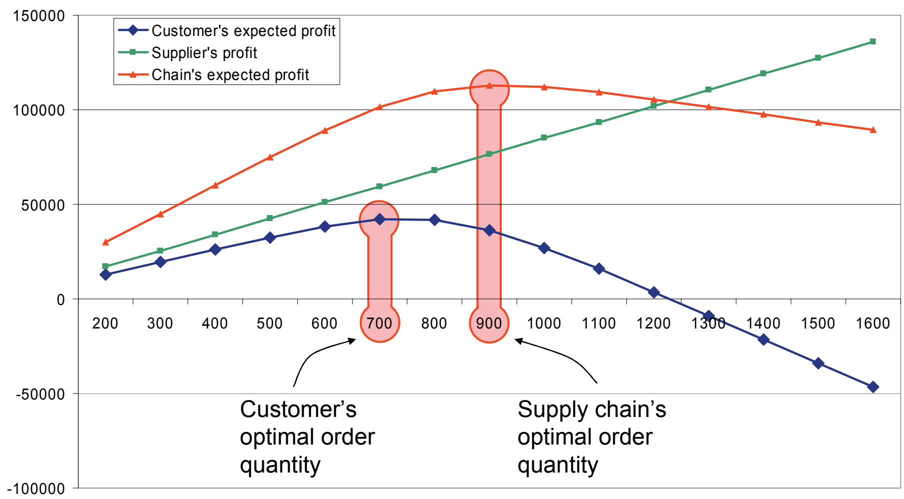

Figure 1 Example of suboptimal channel performance.

The goal is to achieve the optimal efficiency on the supply chain level—e.g., by inspiring the customer with discounts to increase order quantity—, so thus the extra profit can be shared between the partners. This is possible, because as we have seen, the total supply chain profit is independent from the wholesale price which modifies only the individual profit functions.

In the above example all parameters were considered to be common knowledge, therefore both partners can compute the expected profits, optimal order sizes and share the surplus fairly. In real situations this is usually not true; some parameters (e.g., the production cost or the demand forecast) are private information of the partners, which makes the coordination problem much more difficult. In such cases there is an **information asymmetry** which can be resolved by information sharing, however, the partners may have incentives to share distorted information in order to maximise their benefits.

1.2 Problem statement: benefit balancing in Dynamic Supply Loops

The AC/DC project developed a planning model and corresponding processes for controlling an automotive production network that is going to operate according to the **customize-to-order** principle [DDH+07]. Accordingly, the service level in DSL must be 100% after five days starting at the customer order and ending with the delivery at the OEM's car park, because from this point the system will be controlled as a customize-to-order system. At the same time, DSL must also handle all kinds of risks in real-time feed-back control loops between tier-n and tier-n+1. The main principles of the so-called **Dynamic Supply Loops** (DSL) are as follows:

- decentralised planning,
- only tier-to-tier communication,
- collaborative attitude (e.g., data visibility, event handling),
- customise to order using customer-neutral parts and
- demand-oriented planning.

The basic process of DSL consists of the steps below:

1. Based on the forecasts and demand from tier n-1, the tier n partner generates alternative plan scenarios.
2. The involved suppliers in tier n+1 evaluate the alternative plans; whether they can supply the required materials for a given plan and if so, on what conditions.
3. Eventually, the tier n partner examines the evaluations and chooses the plan that can be executed most efficiently.
4. A similar process continues at tier n+1.

Our initial assumption is that following the DSL method, partners and the overall network will achieve a better performance. Hence, the main questions are as follows: how to keep partners interested in the process on the long run; how to share the benefits of this collaborative planning; how to create and maintain win-win situations for the partners. We should also consider that the partners have some own **private information** (e.g., cost structure, profit margin, participation in other supply networks, etc.) that they do not want to share with each other.

2 Practical approaches

The expression **Supply Chain Management** (SCM) was founded in the early 1980s. Since then, several approaches and concepts have been applied to realise the main idea behind SCM. In this section, we are present three of these concepts shortly in order to clarify the foundations of a benefit balancing approach inside supply chains.

The three concepts presented below are: Quick Response (QR), Vendor Managed Inventory (VMI), and Collaborative Planning, Forecasting and Replenishment (CPFR).

2.1 Brief overview of QR, VMI and CPFR

QR. Historically, manufacturers and retailers have operated their distribution channels separately, each trying to minimize its own transportation and distribution costs. This setup has led to passable customer service, but with mediocre channel economies and inefficiencies. Supply chain integration optimization is achieved when the entire channel capabilities are promoted down the supply chain: this can be achieved by linking organizational policies and procedures, physical distribution structure, and information systems.

In retailing, a popular method is Quick Response, a business strategy for (1) shortening the total cycle time for a product, from production till retail, and for (2) reducing the overall cumulative inventory of that product in the supply chain.

VMI. Vendor Managed Inventory is a family of business models in which the buyer of a product provides certain information to a supplier of that product, and the supplier takes full responsibility for maintaining an agreed inventory of the material, usually at the buyer's consumption location. A third party logistics provider may also be involved to make sure that the buyer has the required level of inventory by adjusting the demand and supply gaps.

VMI reduces stock-outs and inventories in the supply chain. Some key features of VMI include: shortening of lead-times, centralised forecasting, frequent communication of inventory, stock-outs and planned promotions, absence of manufacture promotions, as well as relationship with downstream distribution channels.

CPFR. The grocery industry realised the problems with VMI and in 1995 Wal-Mart, along with its supplier Warner-Lambert and the IT companies SAP and Manugistics and the consulting firm Benchmarking Partners, started up a new way to collaborate in the supply chain [Smar03]. This concept, first called CFAR, was later named Collaborative Planning, Forecasting and Replenishment (CPFR). The CFAR project was successful and soon the association Voluntary Interindustry Commerce Standards Association (VICS) was given the responsibility to develop the concept further.

CPFR has a more comprehensive approach than earlier concepts, and includes planning, forecasting and replenishment processes [STA03].

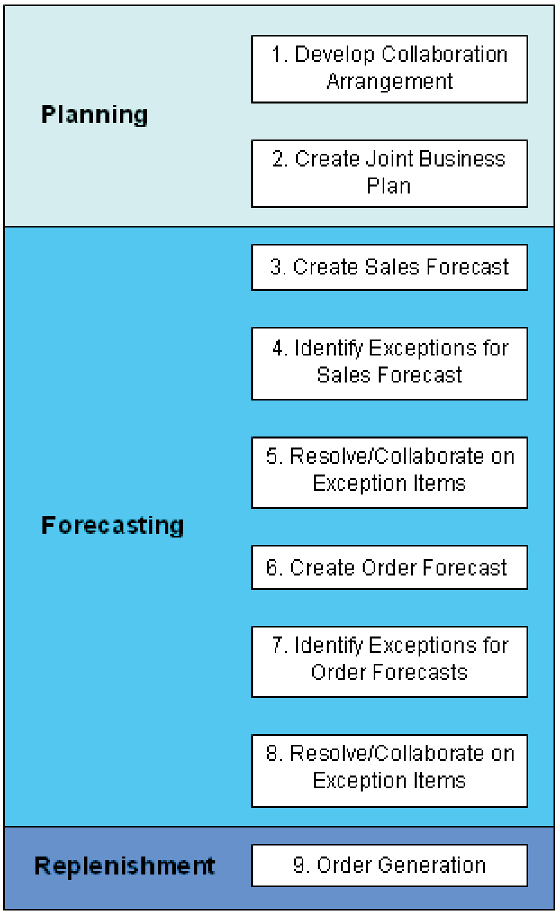

Figure 2 CPFR nine-step model

VICS has standardised CPFR to be implemented with the help of a nine-step model. These nine steps are shown in Figure 2 above.

In the literature, authors often state that CPFR is a joint concept, requiring that both the supplier and the customer side be active. CPFR not only facilitates information sharing, but it also demands that the partners jointly plan a number of supply chain activities.

2.2 Practical approaches in AC/DC

Three methods related to benefit balancing have been initiated by one of the industrial partners of the AC/DC project. In fact, they represent three basic principles of the benefit balancing task: the measurement of the performance, the cooperative evaluation from a set of alternatives, and the optimisation of the total cost instead of considering separate local objectives of the logistics.

2.2.1 Supplier evaluation

Measuring the performance of the processes is essential for every improvement effort. As far as benefit balancing in supply chains is concerned, one of the most important tasks is the measurement of the supply performance, which can be used as a basis for balancing among supply chain partners. In the AC/DC project a commercial software system has been chosen to rate the performance of the supplier [Ben09-ol].

The **delivery performance** is an important indicator to measure the demand fulfilment. In the case of AC/DC it is essential to have a delivery performance close to 100% in order to guarantee the continuous flow inside the complete supply chain. The evaluation of suppliers enables the entire reflection of all delivery-related processes of the own company, including the objective key figures of the delivery performances and quality, as well as additional criterion as e.g., certification and flexibility of the supplier. If the suppliers provide poor performance, they will be informed and helped to improve their process quality in order to raise their delivery performance and to avoid premium freights. If the supplier refuses to cooperate, in the worst case, it will not be considered for next projects and a new supplier will be contracted instead.

2.2.2 Trade conditions

With this activity the company will compare the own transport conditions with those of the supplier in order to figure out the cheapest one and to redefine the trade conditions (incoterm). If the conditions of the company are better than the suppliers' offers, it will overtake transportation; otherwise the transportation will be delegated to the suppliers. The benefits from this project are the decreased logistic costs in the supply chain and the possibility of rationalising supply processes. This project is at a very early stage, some further description can be found in Section 3.

2.2.3 Total Cost of Ownership (TCO)

The **Total Cost of Ownership** is an initiative to measure the total direct and indirect logistic costs in gross, to avoid the suboptimal replenishment processes caused by separate local objectives. For this purpose the Value Stream Mapping approach is being used.

The TCO is commonly used for comparing the full costs of two competing business alternatives. When properly applied, TCO reflects the full opportunity cost of a decision and reflects not only the initial purchase price of assets, but also initial costs of training personnel, costs related to upgrades over time, maintenance and operating expenses, net salvage value of the asset, etc.

All of these three initiatives are still in an initial stage, thus their results will be evaluated as a future work.

3 Benefit balancing in Dynamic Supply Loops

The planning processes in supply chains are usually done in a hierarchic manner: in tier n, demand information arrives from downstream and is then processed, transformed into part/material demand and sent further upstream, see Figure 3.

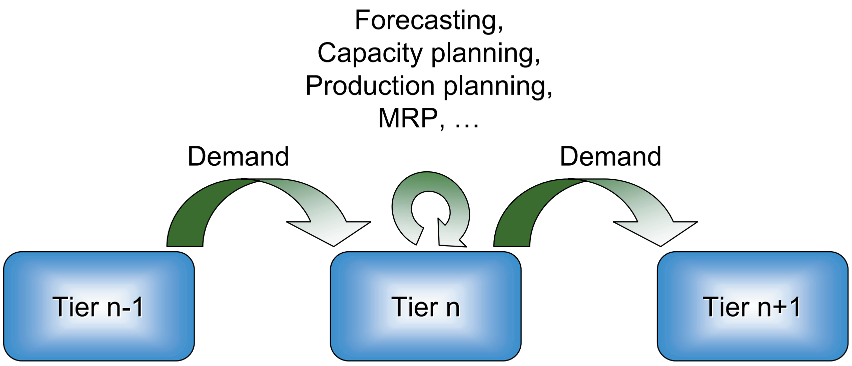

Figure 3 Hierarchic planning.

Two types of transformation can be differentiated:

- Technology-related, e.g., due to capacity constraints, lead-times, etc. This type of transformation can be considered as **necessary transformation** in the sense that if a purchase plan cannot fulfil the modified plan, the tier n enterprise cannot fulfil the original demand, and *vice versa*.
- Economy-related, e.g., optimisation by combining similar works, transportation of materials, etc. This type of transformation is **non-necessary**, i.e., a purchase plan could fulfil the original demand even if it does not fulfil the optimised plan—maybe, of course, with higher costs.

While the former transformation is necessary for fulfilling the demand, the latter one introduces new constraints to the problem which is propagated further along the supply chains. This gives the basic idea for the improvement of the performance in DSL: instead of propagating new constraints automatically, the partners in tier n and n+1 harmonise their plans. Since this means deviating from the (local) optimum of the tier n company, it works only if its supplier can achieve higher gain than the loss on the buyer side and the difference can be balanced.

In accordance, the DSL concept proposes replacing the hierarchic planning processes with the following approach:

1. The tier n company generates different alternative plan scenarios instead of only one "optimal" plan.
2. In tier n+1 these scenarios are evaluated and priced by the suppliers.
3. The tier n company chooses the best alternative, i.e., instead of considering only the production cost, herewith the total production, logistic and purchasing cost can be optimised.

This approach is being taken in an ongoing subproject in the AC/DC aiming at cooperatively optimising the trade conditions with the suppliers. In this case, the transportation alternatives are considered according to the standard INCOTERM definitions combined with the different supply strategies such as the VMI or the order-based replenishment. Accordingly, in this manner the buyer company considers the transportation logistics and inventory problems together, and can optimise for the total cost, while the suppliers have also greater influence in the overall supply planning by pricing the different alternatives.

Traditional **material requirements planning** (MRP) can be improved using a similar approach. The most widespread commercial MRP systems usually offer several algorithms for lot-sizing, e.g., lot-for-lot (LFL), economic order quantity (EOQ), fixed order period, part period balancing, Wagner-Whitin (WW), etc. For example, the SAP system offers different possibilities organised into 3 classes: static, period and optimum lot-sizing algorithms. This gives a natural way for **generating plan scenarios automatically**, and estimating the costs of their execution.

Table 1 Coordinating the MRP.

	Scenario	#1	#2	#3	#4
A	Tier n estimated	500	515	**450**	480
B	Tier n+1 estimated	90	80	200	210
C	Tier n+1 saving	110	120	0	-10
D	Compensation (C x 50%)	55	60	0	N/A
E	Tier n compensated (A-D)	**445**	455	450	N/A
F	Tier n+1 compensated (B+D)	145	140	200	N/A
G	Total SC cost (A+B = E+F)	590	595	650	690

Table 1 contains an imaginary example in order to demonstrate the idea. In this case, the tier n company generated 4 different MRP scenarios whereof the third one is preferred due to its lowest estimated cost. However, instead of sticking to this plan, the company offers all four alternatives to the concerned supplier, but the third one is indicated as the preferred one. Note that the supplier does not know the numeric estimates nor any further preference ordering of the scenarios.

In the second step, the tier n+1 supplier evaluates the alternatives and compares them to the preferred scenario of the buyer. This results in the second and third rows of the table. At this point, scenario #4 can be excluded, since it is worse for both companies than the third (buyer's preferred) one. Since both scenarios #1 and #2 are better for the supplier, it is worth to offer some compensation to inspire the buyer deviating from its preferred one. In this example, the supplier offers the half of the possible saving. Calculating with the compensation, the buyer will select the scenario #1, wherewith **both companies are better off**. Note that applying this benefit balancing approach, the partners have found the optimal scenario for the whole supply chain, although it is not locally optimal for either of the companies.

In the above example the supplier offered the 50% of its estimated saving. This is an *ad-hoc* ratio and it may not be enough to inspire the buyer and find the globally optimal scenario. If the supplier offers for example 60%, this inspires the buyer more, but lowers the supplier's profit. On the other hand, it can be seen that by decreasing the ratio to 48%, the supplier can increase its profit, since the buyer will still prefer scenario #1. However, only 45% compensation is too low inspiration for the buyer, who will stick to its preferred scenario #3, which results in suboptimal plan for both of them. This illustrates that determining the appropriate ratio is impossible if the cost estimations are private information, the 50% however seems to be rational and fair.

All in all, the proposed benefit balancing approach may sometimes fail to achieve the globally optimal plan, but it has several advantages:

- It is simple and easy to understand and to implement.
- It can be realised automatically, with existing planning systems.
- The sensitive private information does not have to be shared.
- It can possibly improve supply chain performance.

4 Prospects of mechanism design in supply chains

Mechanism design (MD) is a special subfield of microeconomics, with a rather unique engineering perspective [Nisa07]. It borrowed key concepts of game theory, like strategies, equilibrium and rationality, but instead of being interested in the output of a given game, it aims at determining the **rules of the game** in order to achieve certain behaviours. Accordingly, MD can resolve dilemmas and suboptimal performance in traditional games, such as the prisoners' dilemma, by aligning the objectives of the players. The founders of the theory were recently awarded with Nobel prise, and it has already been successfully applied in designing and analysing practical auction mechanisms for electronic markets. Since this theory considers strategic interactions of self-interested agents with incomplete (private) information, it offers promising applicability also in supply chain research. In this section we briefly overview the theory of mechanism design with the purpose of attracting the attention of the kind reader and giving a new aspect to handling the issue of benefit balancing. A more formal introduction can be found in [Nisa07] and several further references are enumerated in [Egri08].

MD considers a set of **agents** (or players), where each may have private information not known by others—this is called its **type**. Although an agent does not know the others' types, it may have some belief about them—this differentiates the games with

strict- and **non-strict incomplete information**. Each agent also has a set of **strategies**, which represent a complete contingent plan, a decision rule or a single action. Every agent chooses a strategy from its strategy set, and the execution of all the selected strategies results in a specific **outcome** of the system. Agents have their own **utility functions** (e.g., profit) depending on their type and the outcome, and the rational players intend to maximise their utilities by choosing the most appropriate strategies. Non-cooperative game theory studies the outputs in such situations by determining the optimal strategies, which constitute **equilibrium**.

The usual equilibrium concepts can guarantee that none of the agents can increase its utility by changing its equilibrium strategy unilaterally. However, such equilibrium can be suboptimal in the sense that it is not **Pareto-optimal**, i.e., there exist a better outcome which provides higher utility for some agents and not smaller for the others. If a Pareto-optimal solution is not equilibrium, it cannot be achieved by self-interested agents; the well-known dilemmas of game theory are based on this property.

The goal of the MD is to assure the optimality of the equilibria by constructing the "rules of the game" properly. This means that the mechanism regulates the available strategies and the outcome given by the chosen strategies of the agents. Note that although the mechanism usually constraints the possibilities of the agents, it guarantees always better utility than without the regulations. The MD approach can be used in several optimisation problems which involve decentralised decision making. The specific form of the mechanism varies over the environment: for software agents it might be the execution environment, while in commodity markets it is usually a legal regulation.

In several cases the utilities of the agents are considered to be in a special form called **quasi-linear**. This means that the utility has two parts: a **valuation** of the outcome (depending on the agent's type) and a money **transfer** between the agents. For a specific example, let us consider a situation with an OEM and a supplier. In this case, the utility of the OEM might be the income minus the assembly costs (valuation) minus the payment for the supplied parts (transfer), while the utility of the supplier is the payment (transfer) minus the production and material costs (valuation) (see also our example in the Introduction). If we however include an end customer to the game, then the income of the OEM belongs to the transfer part, since it is paid between the agents.

What kind of mechanism is desirable in such quasi-linear games? It is a natural assumption that the sum of the transfers is zero, i.e., the mechanism does not take nor give money to the agents. This latter property is called **budget-balance**. Another property is the **efficiency**: will the mechanism maximise the sum of the valuations over the possible outcomes? It can be easily seen that efficiency and budget-balance together imply Pareto-optimality. A further requirement can be **individual rationality**: is there any guarantee that the utility of the agents is above a predefined minimum level, (e.g., the profit of the players is non-negative)? Unfortunately, these three properties are conflicting as it was proved by the Nobel Laureates [MDT07].

Then what could we do with this whole MD theory? Should we set it aside as a nice, highly theoretical ornament to network coordination? Definitely not! There are several successful applications of the theory by relaxing some of the above properties. For example, auction theory disregards the budget-balance requirement: auctions are designed just to maximise the transfer from the agents (bidders) to the mechanism (auctioneer). The parliamentary mechanisms exploit that the citizens are forced to participate in the "game" of the state, thus they do not require the individual rationality. In supply chains the most conceivable approach is to give up the strict optimality and seek for quasi-optimal mechanisms that can improve the overall efficiency anyway.

The buyer-seller relationship is perhaps the most well-studied MD situation in the economics, called the **principal-agent problem**. Two famous dilemmas of this setting are the **moral hazard** and the **adverse selection**. The former one describes the situation where the principal delegates some task to an agent whose efforts to perform it appropriately cannot be observed. The goal of the principal is to inspire the agent to better work. This model and the solution ideas can be directly applied for supply or outsourcing relations. The adverse selection problem studies the information asymmetry about a certain characteristic, instead of an action. As the famous model of the "market for lemons" (used cars) has shown, such situation can lead to the collapse of the market. To solve these dilemmas, the **contract** (or agency) **theory** has developed specialised forms of agreements including alternative offers or guarantees. Such constructions provide the foundations of the insurance business.

Recently, similar models have become applied in supply chain research resulting in the improvement of conventional contract types, considering not only the profit of an individual enterprise, but the mutual benefit of the partners [Cach03]. The **quantity discount** contract with appropriate parameters is proved to increase the order quantity together with the profit of both the buyer and the seller. The **buyback/return** contracts are successfully applied in the supply chains of the obsolescent goods, such as the newspaper, book, CD/DVD and fashion industries. The movie exhibition contracts often consist of **revenue sharing** agreements instead of fixed prices. The theory can be used to design contracts tailored to the Vendor Managed Inventory (VMI) supply which inspires the buyer improving and sharing demand forecasts [Egri08]. These examples are only the top of the iceberg, and the powerful theory of MD can provide a sound background to study the distributed optimisation and benefit balancing in supply chains.

5 Conclusions

In this paper, we studied the requirements of cooperative networked production, and argued that sharing benefits is essential for its prosperity and sustainability. We identified the principles of benefit balancing, and briefly presented the ongoing projects in the automotive AC/DC network aimed at enabling and achieving these goals. We also outlined the general approach of Dynamic Supply Loops, based on cooperative evaluation and decision between alternative plans. We illustrated this latter idea in case of collaborative material requirements planning. Finally, we shortly introduced the mechanism design theory that we suggested as a promising instrument for designing and analysing novel and innovative business relations.

6 Acknowledgements

This work has been supported by the EU AC/DC IST 031520 and OTKA grant No. T73376 projects.

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