Dynamic Supply Loops – A Concept for Flexible and Faster Automotive Supply Network Management

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Abstract. The situation of automotive industries can be characterized by low and fluctuating demands for final products. Components supply and as well production systems and networks are too often optimized for the operation at high degrees of utilization without explicitly supporting flexibility. Increasingly, production strategies like Build-to-Order (BtO) are applied to enhance the flexibility of the production networks in automotive industries. Customize-to-Order (CtO) is a promising approach to avoid the efforts for coordination and control that result out of BtO. Research and development to bring CtO to life by means of its process and technology enablers is done in the EU-funded project ACDC. ACDC develops a highly dynamic and robust supply loop concept, which is superior to the conventional hierarchic system in reactivity, reliability and costs while maintaining the 100 % guarantee of delivery. For the proof-of-concept a characteristic next generation automotive modular system is being developed, which merges different technologies, mechanics and electronics, into high quality modules to reduce part-count and cost, i.e. first cost, cost for stocks and stocks itself, and to achieve a customer-neutral component/supply concept.

Keywords: Automotive Supply Chain Management, Event Handling, Collaborative Forecasting, Product Development- Customize-to-Order.

1 Introduction

One essential effect of the financial downturn in late 2008 is the general lack of cash and financing sources with serious impacts on the automotive industries, concerning especially sales caused by dramatically decreased market demands and the pressure on suppliers.

The arising new challenges for the automotive industries and especially the suppliers are therefore the substantially reduced predictability, even higher capacity and

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flexibility demands of the OEM (Orginal Equipment Manufacturer). The ability to operate a supply chain network becomes a decisive role for suppliers.

Goal-oriented strategies to strengthen the European Car Industry are firstly branding & differentiation to deal with the increasing individuality, the needed flexibility and the call for a high-class image. Secondly, the reduction of delivery times resulting in fast responses of a highly flexible overall production system and low working capital. Lastly the questioning of traditional production strategies by introducing approaches like build-to-order.

In the past decades several schemes were proposed to support collaborative planning in supply chains (see [1] for an overview). Actually the supply chain in the automotive industry is organized as a hierarchical upstream planning system, proceeding top-down from the OEM to its suppliers [2]. In [3] we figured out, that the the planning process encodes restrictive planning conditions where the OEM forces the $tier_1$ suppliers to fulfil its specific demands without compromises and delivering the needed information to generate a robust and reliable plan for a longer time period at $tier_1$. The same pattern is repeated at $tier_n$ and $tier_{n+1}$. Hence, $tier_{n+1}$ supplier loses flexibility in its planning pro capacity overloads because of uncertainty according to future demand developments and the needs of an enhanced event handling system to react fast to uncertain demand changes and occurring material shortages.cesses while more often reacting $tier_n$ needs whether then controlling material flow and planning cycles.

Forced through the supply chain, this problem leads to

1. a loss of optimization potentials in local planning decisions, caused by restricted information policies,
2. capacity overloads because of uncertainty according to future demand developments and
3. the needs of an enhanced event handling system to react fast to uncertain demand changes and occurring material shortages.

These circumstances lead to an unstable and nervous system wasting time and money for keeping it running, therefore increase the product price while reduce the accounts.

Summarizing these problems the actual automotive supply chain is operated in local optima according to the specific situation of each partner in the supply chain. E.g., the OEM can optimize his costs unilaterally by forcing the tier1 suppliers to deliver only just in time. [3]

Therfore the vision behind the introduced concept of ACDC (Advanced Chassis Development for 5-Days Cars) is the development of a vehicle production & supply system to deliver a customer ordered vehicle in 5 days. This vision not only targets short order-to-delivery times and low stocks, but the overall flexibility of the automotive production grid. The approach to reach this vision is a dynamic supply network system for the automotive supplier industry that fully supports the “3 H’s”, i.e. to be “Highly reactive”, “Highly reliable” and “Highly flexible”.

1.1 Efficient Supply Chains through Customize-to-Order

The enabler for this new supply network system is the Customized-To-Order (CtO) principle. To implement the CtO-principle we propose an integrated change in three major areas of today's automotive supply chain management, illustrated in figure 1. The future automotive supply chain will:

1. deliver new types of products based on mechatronic components that are widely configurable by software, called late-customization, and which can be developed in a distributed development system not limited to a specific location of a development center. From a technical point-of-view, the developed highly mechatronic automotive modules support a late customisation of order-neutral modules towards costumer-specific requirements. Derived from the novel automotive chassis technology developed in ACDC there is plenty of potential for even new drive trains, electrical propulsion, and new wheel systems as well as for radically reducing logistical planning complexity.
2. consist of rather flexible production systems that assure a certain amount of flexibility (plus and minus) according to an average utilization of a plant. The effect is that on the one hand the plants can react very fast to increasing or decreasing demands or supplies without higher stock levels, the delivery of parts can be easily guaranteed and the event handling process during the supply chain operation can be based on more reliable short time production capability data.
3. be based on a more collaborative but strictly organized management system throughout the whole supply chain called Dynamic Supply Loops. The level of collaboration could be determined according to the level of available information. The objective is to enable a fast and reactive demand and supply handling system while regarding certain interest of all partners in the supply chain to shift the efficiency of the supply network to a more global the local maximum.

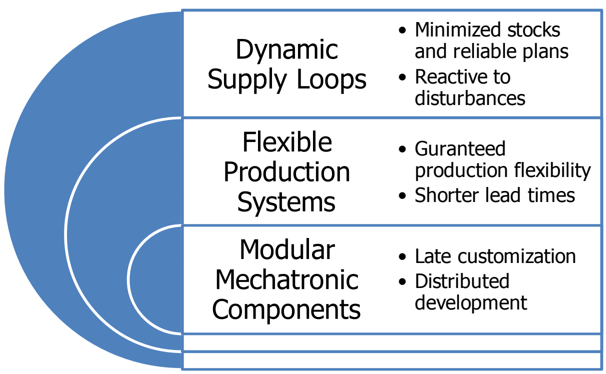

Fig. 1. Integrated view on the new Automotive Supply Network

The project ACDC is split into two incorporating work packages (WP). Work package 1000 implements the technical product oriented principles needed for the late customization approach. Work package 2000 takes care about the supply network planning and control tasks for the ACDC approach. Importantly, ACDC maintains the 100 % guarantee of delivery as an uncompromised constraint. It leaves hierarchic production concepts behind by building on multiple planning loops. This dynamic supply network management is an ideal test case for the integration of both the high-tech modular technology and the appropriate process configuration features.

2 Step-Change in Component and System Technologies

The ACDC objectives in component and system technologies are aiming at the development of component and system technologies, enabling a significant increase in variability and flexibility from a technical viewpoint and at the same time allow a reduction in stocks.

From a technical point-of-view the development of highly mechatronic and individualized automotive chassis modules – in this case a Methods, processes and tools developed in work package n advanced rear-axle module - is an enormous challenge. This enables further developments as of customer-neutral module design methodology to ample applications. Derived from this novel automotive chassis technology there is plenty of potential for even new drive-trains, electrical propulsion and new wheel systems. Existing safety functions will be enhanced and driving comfort options increased. Technical progress in intelligent software and sensor-actuator technology combined in customer-neutral mechatronic chassis modules pave the way to the next generation of automotive chassis, which needs to be taken into account by new automotive production processes.

The potentials and feasibility are exercised on the automotive chassis as a master component system, which comprises the necessary technology convergence of mechanics and electronics to mechatronics that can be featured very late in the production sequence via advanced software technology concepts.

One of the main results is the implementation of the rear axle setup to the ACDC project is to demonstrate the feasibility of the developed modularization concept. The concept is shown at a SUV (Volkswagen Touareg) rear axle. The rear axle is equipped with mechatronic actuators, an active stabilizer, a torque vectoring rear axle differential and electronic dampers. Also the rear axle has two wheel speed sensors. To meet the increase in variability and flexibility all the connections of the rear axle will be consolidated in two central connectors, a power and a signal connector.

Also an impact sound sensor was developed. Essential benefits of this new sensor is that it can be customized late-in-time, that it has a scalable bandwidth and a two band evaluation (LF/HF). By that it is fitting for different tasks at different positions within the vehicle. To meet the desired increase in variability and flexibility the impact sound sensor can be equipped with add-on functionalities like road or manoeuvre detection. The benefit of the sensors flexibility and late-in-time customization ability for the future is a one sensor hardware solution with one single part number which can handle different tasks in different positions in the vehicle.

Algorithms for those add-on functionalities are developed by ACDC as well. The development already includes promising simulation results for the classification of different road conditions with different classification methods, based on the measurements of the impact sound sensor.

Fig. 2. ACDC Rear Axle Demonstrator (left) – ACDC Rear Axle Partners (right)

Another main result is a security concept for mechatronic automotive ECUs (Electronic Control Unit), that can be individually configured by uploading different software variants, for example for the already mentioned late-in-time customization. The security concept addresses the following threats and other non-desirable actions which include, but are not limited to:

– illegal copying of software from and to the ECU,
– illegal reverse engineering of control program source code,
– use of incompatible variants of software and ECU, and
– secure transmission of software between originator and recipient.

To test the interoperability of various ECUs in individualized automotive chassis modules a hardware-in-the-loop test bench was enhanced to integrate that various ECUs of the different sensors and mechatronic actuators. The enhanced hardware-in-the-loop test bench is able to validate the interoperability of the different ECUs with simulated driving manoeuvres. A focus of that validation is also to ensure that the electrical system within the chassis modules and between the chassis modules and the rest of the vehicle meets the necessary specifications. Part of that was also the development of simulation models for magneto–rheological dampers and an electric power steering system.

To test the interoperability of various automotive chassis modules within a vehicle a remote test framework prototype was developed. The Remote Test Framework creates a virtual car CAN (Controller Area Network) network over standard Internet TCP/IP connections which enables a connected hardware-in-the-loop testing scenario between automotive OEMs and its suppliers.

This new component & system technologies together with the highly reactive supply chain enable a highly flexible and late-in-time customizable vehicle production as well as a more responsive automotive industry.

4 Individually and Highly Reactive Supply Chain

Methods, processes and tools developed in work package 2000 “Dynamic Network Management” have the potential of a wide impact on the automotive supply chain. Their implementation will prove to be of huge benefit for the whole supply grid given the reality of the current unparalleled economic downturn. There is one important prerequisite for the success of the Dynamic Supply Loops (DSL) .Ideally the products have to fulfill the modularity and late customizable aspects, which are researched and realized on a rear axle in the WP1000.

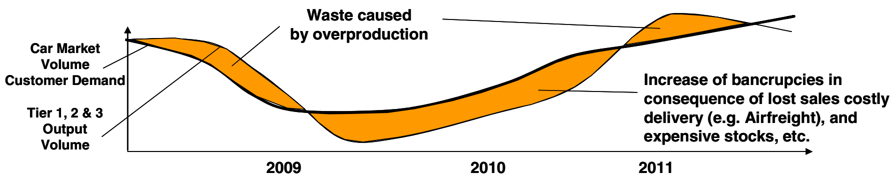

Fig. 3. Economic consequences of the recession on the automotive sector

The figure below mirrors the economic consequences of the recession on the automotive sector and its impact on the supply network. While car makers noticed a massive drop in customer demand in 2008, already, they still maintained their component orders in their systems without giving an early warning. This caused enormous overproduction throughout all supply tiers once the OEMs were forced to suspend or cut production short term.

As emergency measure, state aide in form of scrappage incentive schemes helps to prevent the worst and to provide the necessary kick-start to demand for the automotive industry. Caused by overproduction and lost sales, many suppliers are forced into bankruptcy or radical shrinkage of their companies let alone the cuts in research and development. Once the markets recover, there won't be enough supply capacities left to guarantee the badly needed rapid improvement of the motor industry. This is a typical scenario of the current existing (hierarchical) Supply Chains.

4.1 Main Benefits and Targets of Dynamic Supply Loops

ACDC provides an integrated approach for mid and long term forecasting as well as a highly reactive method to tackle all upcoming events that might hurt the supply of the OEM. The result is a fast, flexible and high reactive process supported via high level of automation. Dynamic Supply Loops create high transparency by combining a central forecasting approach with decentral information and supply loops that make sure events are being considered in real time [4]. Both aspects require a high level of collaboration in SC network. The result is minimization of leadtime to reduce inventory and cost and avoid loss of sales.

The resulting process is a one step negotiation Methods, processes and tools developed in work package process which could be implemented very easy and allows very fast reaction times. The calculation of planning scenarios can be done by using standard planning methods, e. g. offered by SAP or other ERP-Systems. Because of using implicit information of the $tier_{n+1}$ at the scenario generation of $tier_n$ the accepted plans will be more focused to the actual situation of $tier_{n+1}$ in opposite to the classical top-down driven planning procedures in today´s automotive supply chain. This information includes e.g., the knowledge of capacity capabilities, flexibility agreements, quality issues or specializations as well as the frame plan at $tier_{n+1}$. This implicit information will be gained by collecting information about $tier_{n+1}$ at $tier_n$ and by using new protocols based on EDI standards (Electronic Data Exchange).

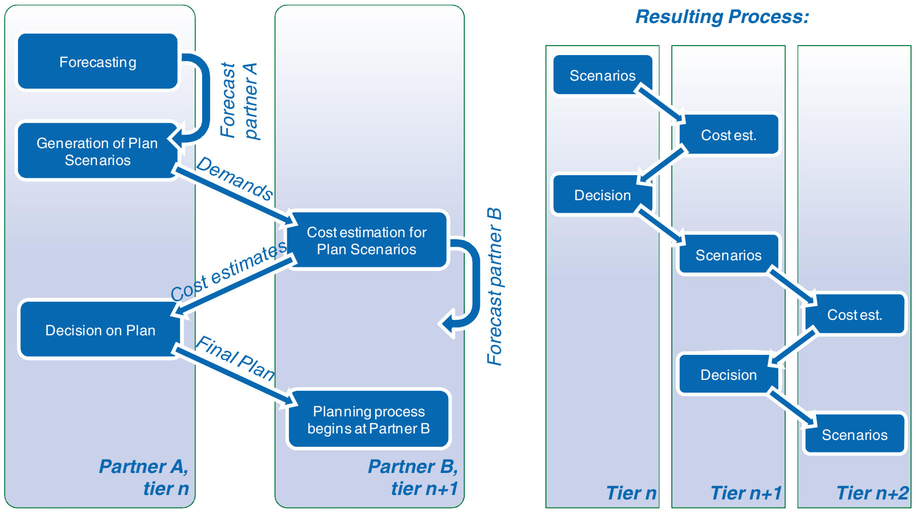

Fig. 4. Principle of the Dynamic Supply Loops

The suppliers are getting more flexibility, now able to reduce costs and stocks because of focused and reliable plans from their customers. Despite costs e. g. the optimization of lead times could also be factor in choosing scenarios.

To offer incentives to take part in this planning concept the $tier_n$ and $tiern_{n+1}$ could define some regulation for balancing the achieved benefits [5]. E. g. the supplier $tier_{n+1}$ offers supplier $tier_n$ a optimal managed vendor managed inventory without including the costs into the products and the $tier_n$ supplier regards the specific $tier_{n+1}$ suppliers situation while generating the planning scenarios. Both have profit in this situation: the inventory level is on the needed level at sufficient costs and the supplier tier-n+1 is able to operate a robust production system relying on expected customer-call-offs. Events will be avoided and costs as well as stocks can be reduced.

4.2 Selected Achievements

Basis (operational, tactical and strategical) Dynamic Supply Loop processes combined with “benefit balancing models” are defined and are implemented in the ACDC use case at Continental supply network. In the actual project phase optimization and adaption processes of the developed methods are started.

The implementation of the Dynamic Supply Loops is based on a toolkit shown in figure 5. There are tools precise processes established for each mentioned planning level and for re-designing and operation flexible production systems.

Major achievements have been actually established in the area of collaborative demand prediction and event management.

The collaborative demand prediction takes its starting point from a model presented by Småros [6]. This model considers levels of complexity in collaboration and in what order to take these steps. In ACDC we have taken this from a “what-to-do”

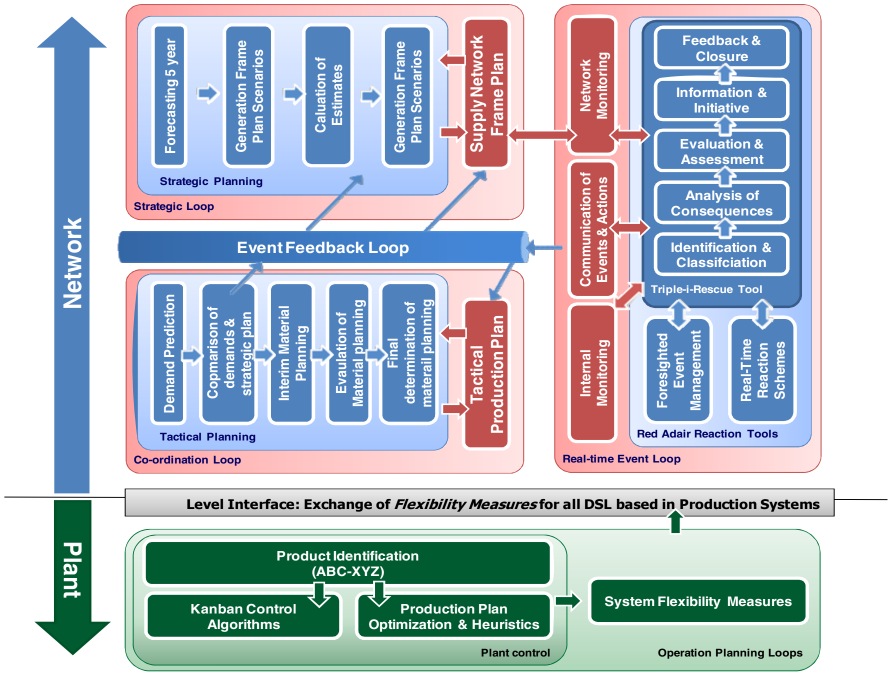

Fig. 5. Basic Process Approach in ACDC

model to an "how-to-do" model by specifying rigid frameworks for each level of collaboration, and the result are quite astonishing (e.g. reduced forecast error by 75%).

Collaboration about demand forecast can be made to the extent that fits the supply chain actors. The collaboration is based on an agreement between a customer and a supplier about the information that may be shared. In traditional methods for collaboration, there is typically a choice for a supply chain actor to share or *not* share information. ACDC suggest methods to limit the visibility of sensitive information without loosing the information that is essential for other actors.

In ACDC, four levels of collaborative demand prediction have been defined as shown in figure 7. Unsynchronized supply chain capacity is one of the major cost drivers in the automotive industry. For each level of collaboration, the rate of synchronized supply chain capacity will increase.

At the first level of collaboration the format for communication of demand data is defined. This includes not only to make the data visible to other actors, but also to clarify the understanding of the data. Already by increasing the understanding about the definitions of data and the rate of uncertainty in the data, the quality of the decisions based on the data will improve. Methods, processes and tools developed in work package.

At the second level demand forecasts are generated by statistical methods. In ACDC a range of time series models and explanatory models have been tested on a use case at Continental. In comparison, an advanced explanatory model can give 2-4 times less forecast error compared to a simpler time series model.

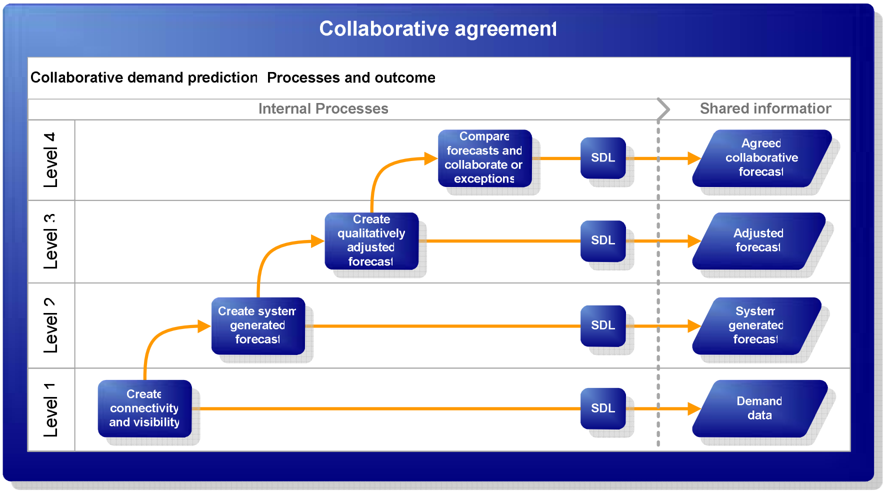

Fig. 6. Levels of Collaborative Demand Prediction

The statistical model cannot possibly cover all aspects that drive the demand. At level three the system generated forecast is adjusted based on expert judgments and management decisions. This can for instance include the impact on the demand from sales actions from a car manufacturer. To start the understanding of causal factors that has not been included in the demand model, ACDC suggest to regularly measuring the forecast precision. This is a factual basis for discussions between the actors, and can also be used to identify reasons to single or systematic deviations in the forecasts.

Finally, at level four, the actors come to closer collaboration by discussing a joint view on the demand, and synchronized capacity decisions. At this level the actors are approaching something that is close a common business plan.

The first two levels are currently being tested and the last two are already realized at Continental.

The topic of event handling is driven by several methods combined under the “Red Adair Reaction Toolkit”. Most of them are actually implemented at Continental. The Red Adair Toolkit is a consequence out of the requirement of larger companies to handle disturbance in the supply chain properly.

With the toolkit events can rapidly be identified and analyzed. Former similar cases can easily be used to find a proper solution for the problem. By that the dependence on single individuals becomes less. A “lessons learned” process can be run. Here analogies to the Quality management process established in automotive industry were used.

Solutions on unforeseen events mostly require extra resources. To provide them a proper and fast escalation process has to be implemented. The Red Adair tool systematically and automatically supports the escalation process in a company while by using the tool it is safeguarded that the whole organisation is aware of severe problems.

One speciality is implemented as well. During events that cause a shortage, the available material very often is not sufficient to fulfil the standard plans of internal and external customers. The material therefore has to be allocated to avoid loss of sales for the OEM.

To provide a tool for that process, the Red Adair toolkit contains an Allocation tool that enables allocation managers to handles larger shortages. They can always have an overview about the most critical locations and projects.

Value Stream Mapping and Value Stream Design as the essential steps towards production process optimization are executed in the used case plants at Continental.

The first tests for quasi online testings are done (VW-ATB).

5 Conclusion

The European automotive industry is facing enormous challenges as a result of the financial crisis, the high prices for oil and steel and emission controls. To tackle these challenges, traditional approaches have to be questioned and novel ones have to be applied. The European funded project ACDC supports this transition towards a sustainable automotive economy by means of knowledge-based products and processes by innovative approaches. For the product side, the shift from traditional mechanics towards the combination of mechanics, electronics and software, i.e. mechatronics, will be researched and developed further using the chassis as a master case. Mechatronics supports the customization of neutral components by means of software and parameterization at low costs at a very late stage of product realisation, even at the car dealer. This transformation enables the application of Customize-to-Order as a lean complement to complex BtO-approaches. Basic instrument to exploit the accompanying advantages are Dynamic Supply Loops as an iterative but fast network-based planning and operations approach.

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