The Information Flows and Supporting Technology in the Automotive Supply Chain: a Suppliers Focus
Sebastiaan X. Koperberg
s.x.koperberg@student.utwente.nl

ABSTRACT
This paper presents a summary of information flows and technology enabling the supply chain within the automotive industry. The supply base of many automotive manufacturers is being restructured, with great consequence for the way suppliers communicate with their automotive partners. EDI is by far the most common communication method used in the automotive industry, although other methods are used as well. All these methods and the ways in which they support the information flows are explained in more detail.

KEYWORDS
Supply chain management, suppliers, information flows, information technology, automotive industry, motor industry.

1. INTRODUCTION
In today’s manufacturers’ world, suppliers play an ever more important role. The purchased materials of an average manufacturer account for over 50% of the cost of goods sold [RHS97]. Suppliers therefore have a large and direct impact on costs, in addition to quality, technology, speed, and responsiveness of buying companies. Reinforcing this point, Ragatz, Handfield et al. [RHS97] noted that the “effective integration of suppliers into product value/supply chains will be a key factor for some manufacturers in achieving the improvements necessary to remain competitive”. It is no longer company competing against company, but supply chain versus supply chain.

Figure 1: Integration in the supply chain. Source: [FW01]

Therefore the ultimate success of a single business will depend on management’s ability to integrate the company’s intricate network of business relationships. Figure 1 shows this integration along the supply chain. The management of multiple relationships across the supply chain is being referred to as supply chain management (SCM) [LC00].

1.1 Supply chain management
A useful definition of supply chain management: “SCM is the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders” [LC98]. For supply chains to be effective, operational information about the production process has to be shared between manufacturer and suppliers. Typically the goal is to create and coordinate the manufacturing process seamlessly across the supply chain in a way the competition can’t easily match [FW01].

For the purpose of this paper the above definition of SCM is put next to the definition of process innovation; the radical improvement of business process performance through the use of innovative tools and work designs [Dav93]. The concept of supply chain management is a form of process innovation. SCM represents the process innovatory element of this paper.

1.2 The automotive supply chain
In the automotive industry competition is fierce, supply chains are highly complex. The large number of suppliers and the large variety of products each of these suppliers have on offer (typically 5,000 upwards, with some suppliers having a catalogue of 100,000 items), results in a highly complex supply chain [CHM03].

When it comes to supply chain management, the automotive industry has been one of the early adaptors. Because of their early exposure to the Japanese challenge, Western automakers have been working longer than most other firms to adopt the kinds of close supplier relationships used by their Asian rivals [Hei91].

The automotive industry focus is especially interesting because of the shift made by suppliers. From small players that deliver individual parts they have developed to partners of the assemblers, with design, testing and manufacturing responsibilities [TCD02]. This development implies big changes in the way supply chain partners operate and communicate.

1.3 Information technology and the supply chain
Information technology is an important facilitator of supply chain integration, because of its capability to surmount both time and distance constraints. Integration using information technology includes electronic data interchange (EDI), sharing data from traditional planning and control systems [FW01], but also the internet [LSO00]. Information and communication technology (ICT) is evolving rapidly, which results in innovative use of these new technologies within supply chain management.
The above mentioned innovative use is made more concrete when it is linked with the definition of innovation: “the application of ideas that are new to the firm, whether the new ideas are embodied in products, processes, services or in work organization, management or marketing systems” [Rog98]. For the context of this paper, the definition is stretched by the author to encompass also the supply chain, instead of only a single firm.

2. PROBLEM STATEMENT
After studying the use of information technology to integrate and enable the supply chain, the author came to the conclusion that although this is a relevant research subject it is still a fragmented domain of academic research. There has been a lot of writing about supply chain management, also in combination with the automotive industry, but no overview of the different factors. Therefore, it would be very interesting to see how information flows enabled by the information technology result in a more efficient supply chain. The concrete problem statement is formulated as follows: There is a lack of concentrated knowledge about the innovative use of information technology within supply chain processes in the automotive industry.

2.1 Research Questions
To provide an answer to the above elaborated problem statement the following research question and sub questions have been formulated.

How do suppliers and their carmaker customers use information technology to integrate their supply processes?

To answer this question, the following sub questions have been formulated. The sub questions are:

- Which information flows can be discerned between supply chain partners? (section 4/5)
- How are the information flows depending on IT? (section 6)
- What are the current (abstract) information systems and technologies that are used between suppliers and carmakers? (section 6)
- Is IT the enabling factor, or just speeding things up? (section 6)

3. RESEARCH STRATEGY
This research paper encompasses a descriptive literature study only. First of all it is important to determine how suppliers within the automotive industry interact with their clients, the actual carmakers, and what type of relationships they maintain. Only after these types of relations within the supply chain are established, it will be possible to make an assessment of the types information flows exchanged within these “supplier to automotive manufacturer” relationships. Fortunately there is a reasonable amount of research already done on this topic.

Secondly, when the most commonly found relationships and the corresponding information flows are established, there will be a need to determine how these are relaying on IT. Furthermore, the nature and degree of automation are important to distinguish, because of the innovatory value of the different IT applications.

Finally, based on this descriptive literature study, the most important points for the supply chain community of the automotive industry will be summarized.

4. SUPPLIER ENVIRONMENT
Supplier relationships with the automotive customers has been a field of constant change. Efficiency has been and remains very important to keep the entire supply chain competitive. According to Collins, Bechler et al. [CBP97], “just-in-time (JIT) is no longer enough to achieve competitive advantage. Increased pressure to attain annual cost reduction targets and streamline operations are driving automotive manufacturers and suppliers to move beyond JIT, to reevaluate their respective supply chain activities and relationships (this involves a reassessment of who does the value added work as well as where and how it is done) as they strive to improve overall performance.”

Automotive manufacturers are seeking to simplify the supply chain and improve efficiency. According to Gadde and Snehota [GS00] and Collins, Bechler et al. [CBP97], automotive manufacturers achieve this end by:

- rationalizing the supply base;
- defining a new set of supply requirements (including global sourcing, full service supply and design for manufacturing/design for assembly); and
- outsourcing activities which have historically been considered part of the automotive manufacturer's 'territory'.

Table 1: Supplier relationship from automotive manufacturers (companies) perspective. Source: [JVD00]

<table>
<thead>
<tr>
<th>Percentage of companies with less than:</th>
<th></th>
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<tbody>
<tr>
<td>10 suppliers</td>
<td>39.28</td>
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<tr>
<td>20 suppliers</td>
<td>57.14</td>
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<tr>
<td>Percentage of companies that have reduced their number of suppliers in the 1997-1998 period</td>
<td>14.28</td>
</tr>
<tr>
<td>Percentage of companies that do not change suppliers in less than 2 years</td>
<td>96.43</td>
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<tr>
<td>Percentage of companies that require certifications of their suppliers</td>
<td>96.43</td>
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4.1 Rationalizing the supply base
Closer collaboration between the manufacturer and suppliers is more resource intensive. It is not viable to maintain such costly relationships with a big group of suppliers, automatically leading to a smaller supply base. Where once contracts were short term, now relationships are long term and leading to partnerships between supplier and manufacturer [Hel94]. Table 1 illustrates the nature of the relationship which most automotive manufacturers maintain with their suppliers. Most relevant is the number of first tier suppliers that carmakers maintain. The additional information in table 1 will not be directly highlighted in this paper, but serves as background information.

Most automotive suppliers react to this trend with mergers and acquisitions. Furthermore suppliers are trying hard to maintain profit streams, which result in restructuring their own supply
base and consolidating their position. The resulting reorganization of the automotive supply base leads to the rearrangement in first, second and third tier suppliers, creating a layered structure within the supply base.

4.2 Defining a new set of supply requirements

Often the first tier supplier tries to enlarge the added value of their products and services by moving toward a more modular supply [CBP97]. The concept of modular supply is that the (first tier) supplier is responsible for the assembly and the online installment of a module. A module is a “physically proximate “chunk” of components, typically from multiple systems, which can be assembled into the vehicle as one unit” [Ulr95]. As on-line suggests, this happens directly into the assembly line of the manufacturer (i.e., the modular consortium system at VW’s Resende complex in Brazil). Lung and Volpato [LV02] state that “a weaker form involves setting up operations in a supplier’s park which is immediately adjacent to the automakers’ premises, delivering components and sub-assemblies by means of shuttles or tunnels that connect the workshops with one another (Ford’s Valencia plant in Spain or the Saarlouis plant in Germany).

4.3 Outsourcing activities

Outsourcing of activities from manufacturer to supplier is also an important development that is taking place. From small players that manufactured individual parts, suppliers have grown to be partners of the assemblers, the automotive manufacturers. Suppliers have increasingly taken up the responsibility of design, testing, and manufacturing, as is illustrated in figure 2 [CBP97][VF01]. This figure shows that a big part of the value adding capacity within the supply chain is available for first tier suppliers.

![Figure 2: The automotive supply chain Source: [CBP97]](image)

Suppliers are also establishing an increasing global presence. An A. T. Kearney/University of Michigan study suggested that the transfer of direct task responsibilities began in 1985, and will continue through 2005, with as much as 80% of the value added of the car being bought from the suppliers rather than generated by the assembler.

4.4 A warning about performance improvement

When reviewing the “performance improvements” claimed by new or changed business operations based on supply chain management, it is important to note that those performance improvements often came at suppliers’ expense [Heh94].

One example, taken from Helper [He94], is the adoption of just-in-time (JIT) within the automotive industry. A survey found that suppliers’ JIT delivery was often not matched by JIT production, so in 1989, 48% of suppliers ended up stockpiling inventory to meet their customers’ delivery demands, compared with 20% in 1984. In addition, customers often obtained price reductions by reducing supplier margins rather than supplier costs.

Although this perception is not a key element of this paper, it is relevant to take the example above into consideration, especially when trying to reach performance improvements within the automotive supply chain. The difference between cost savings through better supply chain management and cost savings through lower margins of the suppliers is fundamental, and the latter indicates bad supply chain management. Logic predicts that the entire supply chain will eventually suffer from weakened suppliers.

5. INFORMATION AND VALUE FLOWS

In this section the main types of information flows will be presented. Between (first-tier) suppliers and the automotive manufacturers there are different types of information being exchanged.

The traditional view of supplier to customer and customer to supplier interaction, suppliers have raw materials or services for sale that customers, like the carmakers, use to produce an output. The information, goods/services and value flows are basic: a customer orders a product, the customer receives the product and a bill, the customer pays supplier [Pre00].

![Figure 3: Supply chain flows. Source: [Pre00]](image)

In complex supply chains there is a lot more interaction between suppliers and manufacturers, but all different types of flows can be deduced from this simplified example. It is possible to distinct three types [Pre00], also illustrated in figure 3, with their respective flow direction:

- Goods and Services; from supplier to end user
- Payments; from end user to supplier
- Information; in both directions

Premkumar [Pre00] states that “to facilitate the movements of these three components, the services of other entities are required. While transportation carriers and logistics are used for movement of goods, banks and financial institutions are used for the movement of payments. Information flows between companies can occur directly or through an outsourcer or third party.” For the purpose of this paper, the author focuses on these information flows. Logistics and banking are also important and interesting fields of research, but outside the scope of this paper.

There is a finite number of different information flows which can be distinguished within general supply chains [LW00]:

- Inventory level
- Sales data and forecasting
- Order status for tracking/tracing
- Production/delivery schedule
- Performance metrics

The description of these information flows given in the subsequent section are based on Lee and Whang [LW00]. The
5.1 Inventory level
Information about the level of inventory can substitute for actual inventory. The uncertainty of not sharing inventory information results in reserve inventories at both supplier and manufacturer, which is inefficient. The other consequence is that, at times, both parties misjudge the situation and have no inventories at all, causing production delays.

Focusing on the automotive industry, sharing of inventory levels has been a major requirement of JIT. Although automotive supply chains are moving beyond JIT delivery towards modular supply, this still is a very important information flow [CBP97].

5.2 Sales data and forecasting
When sales data is based on order information a lot of uncertainty is introduced into the supply chain. This is mainly because order information provides a very irregular and potentially misleading view on the supply chain. To illustrate this problem, see figure 4.

![Figure 4: Difference between actual orders and sales. Source: [LPW97]](image)

This is because order information results in reserve inventories at both supplier and manufacturer, which is inefficient. It is then very contrary to find out that suppliers still have to respond to extremely volatile carmaker schedules, changed at the last minute with little adherence to the original plan. However, the schedule variability imposed on first-tier suppliers of top performing carmakers, can be three times lower than that observed from other carmakers [CHM03].

5.3 Order status for tracking/tracing
With the help of order status tracking or tracing the manufacturer can always find out which supplier is currently processing his order. This results in a high rate of first call problem resolutions. This means that when manufacturer wants to do an inquiry at one of its suppliers, the first call or internet lookup will deliver the answer, independent of where the order is processed within the supply chain at that moment in time.

5.4 Production/delivery schedule
By opening up internal production and delivery schedules by upstream supply chain partners, it is possible for downstream supply chain partners to improve their production schedules. For example, the U.S. carmakers have access to the production and delivery schedules of the steel suppliers. This principle also works the other way around, when manufacturers open up their production schedules for suppliers, it is then possible for the supplier to synchronize their own production and deliveries to meet those of the manufacturers.

5.5 Performance metrics
Performance metrics are additional information flows that are not encompassed in the above flows. Product quality data, lead times (of individual components), queuing delays and service performance are examples. By sharing this kind of information, bottlenecks within the supply chain can be identified and the overall performance improved.

Chrysler, for example, shares the quality and on-time delivery performance data of all its suppliers across the supply chain. Each supplier can log on to the system to check its performance and its relative standing among the suppliers in the same category. This creates a competitive environment for the suppliers, who can all see where they stand with regard to their competitors.

The design requirements are an additional form of performance metrics frequently exchanged between manufacturers and suppliers now a days. Because suppliers are designing a substantial number of components and modules, a clear way to transmit requirements of those parts is needed. By sharing this kind of information, bottlenecks within the supply chain can be identified and the overall performance improved.

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6. IT SUPPORT FOR INFORMATION FLOWS
Until now, information technology hasn’t been explicitly introduced. The information flows discussed in section 5 of this paper need a infrastructure to “flow” through the supply chain. In this section this infrastructure, which is IT, will be reviewed.

As already stated in the introduction of this paper, information technology is a important facilitator of supply chain integration, because of its capability to surmount both time and distance constraints. Communication technologies can increase the degree of collaboration while shared information resources, such as databases and imaging, can decrease the degree of mediation and the number of hand-offs¹ [Mar95].

According to Premkumar [Pre00], interorganizational systems, also called extranets, are application systems that link various

¹ A handoff is the act or an instance of passing something or the control of it from one person or agency to another.
partners in the supply chain using a public or private telecommunication infrastructure. These systems provide the ability for computer-to-computer communications of business transactions and documents and became popular with the introduction of electronic data interchange (EDI).

After extensive research, the author concluded that EDI has a very dominant position within supply chain management in the automotive industry [RKL00]. EDI is suitable and enabling for many types of information flowing between suppliers and carmakers, as will be illustrated in the next paragraph. However, not all information flows can be facilitated with EDI.

6.1 EDI
There are many definitions of EDI but it is generally defined as “the computer-to-computer exchange of inter company business documents and information through standard interfaces which requires hardware, software and communications technology that permit those computers to transfer the data electronically (such as purchase orders, invoices, medical claims and price lists)” [TK99]. The function of EDI is to bridge fundamentally different systems used by different parties within the supply chain. All these parties have information systems that track similar data, but the data is not integrated and used in the same way, nor do they use the same application programs and hardware.

The reason that EDI linkage is so expensive is because for it to work on a larger scale (more then one-on-one linkage), dedicated, private or third party proprietary communication companies are needed, called value added network (VAN). A VAN is “like a telephone switching station for data transmission” to send large amounts of data to a trading partner. The necessity of VAN’s becomes clear when you imagine how many separate EDI links one single supplier would need to connect to all supply chain partners. A VAN offers all these connection over a single channel, with additional services like security and data integrity guaranties [TK99].

6.1.1 Internet-based EDI
Internet-based EDI employs in principle the same standard with a different carrier of the communication. This is somewhat simplified, but sufficient for the use of this paper. Instead of very expensive dedicate private communication lines, the internet facilitates the information flow. Internet-based EDI allows for a very significant cost reduction in comparison with traditional EDI, between 50% to 90% depending on the intensity of use [TK99].

Internet-based EDI is often also used in combination with internet VAN’s (IVAN’s). One of big advantages of the use of IVAN’s is that some of them offer web services for supply chain partners that don’t have the expensive EDI front-end software, thereby not obligating every chain within the supply chain to adopt EDI. While transitioning to internet-based EDI, traditional EDI users can continue to connect with established suppliers through proprietary lines while deploying their supplier base using the Internet [TK99]. Innovative (I)IVAN companies are extending the boundary of EDI and developing mechanisms that directly connect information systems of multiple companies.

6.1.2 The current state of the automotive industry
Today, EDI has proven especially popular among companies in the automotive industry because of its inherent ability to facilitate just-in-time practices that are widely used by carmakers [JVD00]. The use of EDI has rapidly increased in the automotive industry during the last 10 years. The automotive Industry Action Group (AIAG) suggests two factors that have significantly influenced the US automotive supply chain’s dependence on EDI [JVD00] :

1. The Big Three (General Motors, Ford, and Chrysler) have strongly encouraged their first-tier suppliers to communicate with them via EDI since the end of 1997. Suppliers that cannot comply with this deadline may lose business with the Big Three.

2. There is general agreement that the flow of paperwork needs to be reduced, and delays in transit of goods and information need to be eliminated. Especially the first factor is of great importance for suppliers. When an entire conglomerate of carmakers decides to use a specific communication technology, in this case EDI, to communicate with their first-tier suppliers, there is little choice for suppliers but to comply. Even if there is a list of less attractive properties of EDI, which there is. (For details see Lee and Whang [LW00])

According to Rassameethes, Kurokawa et al. [RKL00], “EDI is a powerful supply chain technology allowing automakers and many of their first-tier suppliers to quickly communicate their requirements to component and material vendors and to receive back precise delivery schedules.” US carmakers have taken the lead in pushing EDI down the supply chain. The effects of EDI implementation within the supply chain are linked with the supply chain rationalization. (See section 4)

Because carmakers are very big and influential corporations it also happens that they themselves are the founders of their own VAN, as the following examples illustrate [RKL00] :

- GM has a substantial track record in supplying complete automation systems using EDI to its vendors. The company runs a global network called EDSNET linking more than 30 GM data processing centers with over 2,000 suppliers via EDI.
- Ford relies on a private telecommunication network called Ford Net for establishing EDI connections with its suppliers.
- Chrysler has the Extended Enterprise Network that is an Internet-based system that allows suppliers to access information on purchasing, delivery schedules, invoices, and products. The company expects suppliers to start using this service instead of traditional communication methods such as phone, mail, fax and courier service

6.2 Internet
For implementation of supply chain linkage using the internet, a more elaborate representention of the internet is functional. Threlkel and Kavan [TK99] have a nice summarization describing the most important advantages of the internet:

“The Internet is the largest computer network in the world, established in some 150 countries and reaching some 57 million users with the fastest growth seen in any industry. Its most remarkable and appealing characteristic is ubiquity reinforced by the fast growing mass of users, private and commercial alike.”

These favorable characteristics are used within the supply chain of the automotive industry. Ford, in addition to the earlier mentioned Ford Net, also runs another network called NetCDX which uses ISDN (Integrated Services Digital Network)
technology and the internet to achieve greater bandwidths needed for CAD/CAM communications. Ford also uses the Internet to track small quantities of spare parts shipped to customers on a daily basis [LSO00].

The use of the Internet in managing purchasing in the supply chains has also developed rapidly over the last 10 years. Research by other authors demonstrates that the Internet is utilized in a variety of procurement applications including the communication with vendors, checking vendor price quotes, and making purchases from suppliers catalogs [RKL00]. The purchasing function in firms has been streamlined through the use of the Internet. Paperwork flows have been reduced. Order-cycle times, the time from when the order is purchased to the time it is delivered to the company, has decreased by 40 percent [RKL00].

6.3 Implementation within ERP systems
All links between suppliers and manufacturers systems are becoming automated in order to achieve higher efficiency. Both EDI and the internet play an intricate part in this development. This is best summarized by Kelle and Akbulut [KA05], as the earlier discussed types of information flows are used:

“Enterprise Resource Planning (ERP) software systems have focused on internal process integration of traditional functions, such as sales, production, and inventory management. The transaction based integrated processing provides different tools that can support supply chain integration but at the same time it has several aspects that obstruct the integration with business partners. By gaining access to the suppliers’ production and delivery schedules, buyers can improve their own production plans and delivery schedules. Correspondingly, suppliers can use the buyer’s real time store level data to plan their inventory levels, and production schedules. Sharing order status information among the supply chain partners improves customer service quality, speeds up the payment cycle and provides cost savings. Sharing data regarding to performance metrics such as lead times, quality specifications, return status, etc., helps supply chain partners to identify and overcome the bottlenecks in the supply chain.”

6.4 IT enabling the supply chain
It seems clear that without the support of information technology these information flows could not be facilitated. Answering the third sub question stated at the beginning of this paper, there is no substitute for the electronic integration witnessed in today’s supply chains. When looking at the sheer volume of information exchanged in the automotive supply chain, it is unimaginable that this could be achieved without computers and the advanced infrastructure connecting these systems.

7. CONCLUSION
The use of EDI and the Internet in SCM is rapidly increasing. The key ingredient for success in managing a supply chain is fast, accurate data from a wide range of information including inventory level, sales data and forecasting, order status for tracking/tracing, production/delivery schedule, performance metrics and purchasing/procurement. Integration of all the different information flows in the internal information systems is automating the supply chain and realizing efficiency benefits. The ability to react quickly to market changes and to adjust inventory, production, and transportation systems accordingly is necessary for the automotive supply chain to remain profitable. Suppliers are still under pressure to conform to carmaker demands in the field of information technology, to minimize the risk of losing the business. The consolidation into larger first-tier suppliers has been one of the results and one of the initiators of new supply chain partnering.

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9. REFERENCES


