WP 6

Smart Information Flow along the Supply Chain

SMARTER
EXPERIENTIAL LEARNING TOOLS

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List of Abbreviations

4G ..... *Fourth Generation of Mobile Communication Technology*
5G ..... *Fifth Generation of Mobile Communication Technology*
APS ..... *Advanced Planning and Scheduling system*
BDG ..... *Beer Distribution Game*
CEP ..... *Courier, Express and Parcel Service*
CEVA ..... *Compagnie Européenne de Valorisation et d'Affrètement*
EETS ..... *European Electronic Toll Service*
ERP ..... *Enterprise Resource Planning*
ICT ..... *Information and Communication Technologies*
IT ..... *Information Technology*
LSVA ..... *Leistungsabhängige Schwerverkehrsabgabe - Performance-Related Heavy Vehicle Charge*
MES ..... *Manufacturing Execution System*
MIT ..... *Massachusetts Institute of Technology*
MRP1 ..... *Material Requirement Planning*
MRP2 ..... *Manufacturing Resource Planning*
OBU ..... *On-Board Unit*
OSL ..... *Online System Logistics*
PPS ..... *Production Planning and Control System*
SC ..... *Supply Chain*
SCM ..... *Supply Chain Management*

TKM ..... *Tonne-Kilometres*

VUCA ..... *Volatility, Uncertainty, Complexity, Ambiguity*

1 Teaching Exercise 1: Introduction Supply Chain Management & Logistics

A well-functioning Supply Chain (SC) is essential for delivering the greatest possible benefits like price, quality, delivery time, delivery location and more to end customers. Today, Supply Chains are highly complex and globally interconnected. Raw material extractors, manufacturers, intermediaries, and customers may be located in different regions in different continents. Furthermore, rapid demand and price changes are common. Supply Chain Management Information Systems support managing complexity and challenges and support in making the right decisions in a timely manner. (Kurbel, 2021, pp. 444–448)

1.1 Motivation and Objectives

Managing and coordinating the various aspects of planning, procurement, production, logistics, sales, and distribution is a complex task. Furthermore, the Supply Chain encounters additional challenges from regional and global events such as pandemics, natural disasters, political shifts, and conflicts, which can occur unpredictably. (Santhi & Muthuswamy, 2022) In the year 1987, the United States Army War College introduced the acronym "VUCA", which stands for volatility, uncertainty, complexity, and ambiguity. (Van Tulder et al., 2019, p. 1) Global economics is currently operating in a VUCA world. (Sthapit, 2020) Therefore, a shift towards resilience is essential. (Kleemann & Frühbeis, 2021, p. 43) The guiding research question addresses how efforts into resilience can counteract the challenges of a VUCA world, with a particular focus on Information and Communication Technologies (ICT) in Supply Chain Management (SCM). The objective of this work package is to emphasize the importance of smart information flow along the Supply Chain. It examines the development of information systems, highlighting their functions and benefits within the Supply Chain. The work package presents the Beer Distribution game as management simulation, provides a market overview of information systems and offers insights from a practical use case.

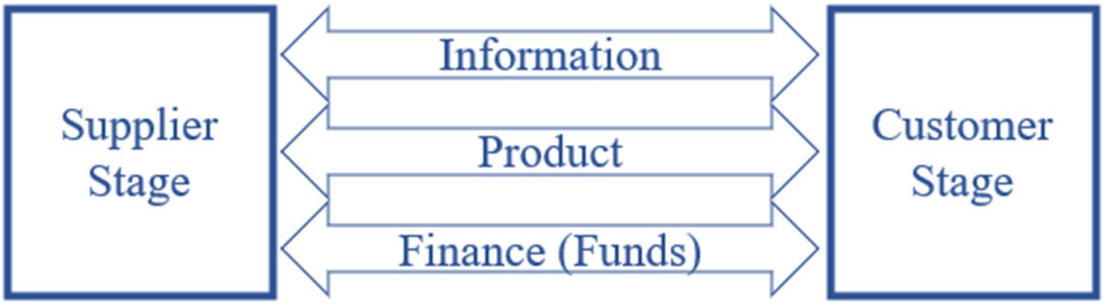
1.2 Structure of the Work Package

This work package is composed of 4 teaching exercises. Teaching exercise 1introduces Supply Chain Management and Logistics, and the structure of the work package. Teaching exercise 2 explores the challenges faced in Supply Chains and discusses strategies to enhance resilience. Teaching exercise 3 examines the evolution of ICT to the latest advancement, the Advanced Planning and Scheduling system (APS) and analyzes the IT providers for SCM and logistics markets. Teaching exercise 4 provides with the Beer Distribution Game a simulation of information in a SC. Each teaching exercise includes one subchapter entitled Learning Materials. These Learning Materials contain modules for further information and, in the case of teaching exercise 4, also the materials for the Beer Distribution Game. Finally, the Appendix presents a practical use case demonstrating the application of ICT at the company Gebrüder Weiss GmbH.

1.3 Introduction in Transport Logistics and Supply Chain Management

The Supply Chain (SC) considers the following three flows: product, information, and finance. As depicted in figure 1, Chopra (2019) shows how the three flows are connected to each other and illustrates this with an example:

Figure 1: Supply Chain with three Flows
Based on Chopra (2019)



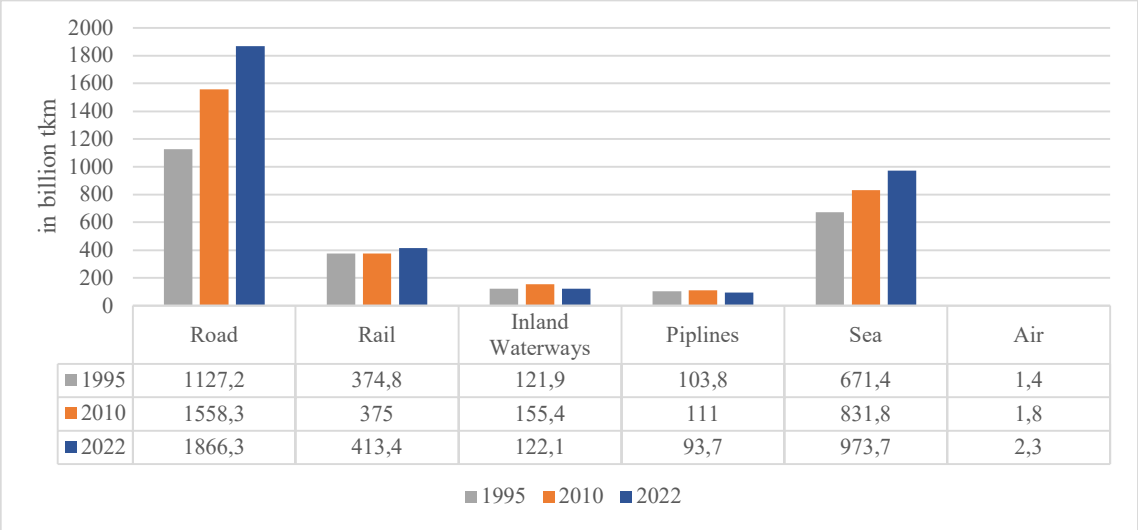
"A supply chain dynamic and involves the constant flow of information, product, and funds among different stages. In our example, the dealer provides the product, as well as pricing and availability information, to the customer. The customer transfers funds to the dealer. The dealer conveys sales data and replenishment orders to the assembly plant, which sends cars back to the dealer on a truck. The dealer transfers funds to the auto manufacturer after the replenishment. The manufacturer also provides pricing information and sends delivery schedules to each dealer. Similar information, material, and funds flows take place across the entire supply chain." (Chopra, 2019, p. 16)

1.4 Transport Logistics and Supply Chain Management

Logistics involves the handling of goods, the storage and retrieval of goods, many other services such as managing customer quotations and of course transportation. (Jockel & Femerling, 2025, pp. 8–9) According to the European Commission, freight transportation in the EU increased at an average annual rate of 1.4% between 1995, 2400 billion tonne-kilometres (tkm), and 2022, 3471 billion tkm. (European Commission. Directorate General for Mobility and Transport., 2024, p. 36) "A tonne-kilometre, abbreviated as tkm, is a unit of measure of freight transport which represents the transport of one tonne of goods (including packaging and tare weights of intermodal transport units) by a given transport mode (road, rail, air, sea, inland waterways, pipeline etc.) over a distance of one kilometre." (Eurostat, 2025)

Regarding performance by mode, as depicted in figure 2, road transport is the leading mode of transportation and was even able to increase its share from 47% in 1995 to 53.8% in 2022. Sea transport ranks second, with forwarding service increasing by 302.3 billion tkm between 1995 and 2022. However, the share of sea transport remained constant at around 28 % over the years, as its average growth rate matched that of total freight transport. Rail transport, the mode with the third-highest tkm, also increased its tkm over the period, but to a lesser extent than total freight. Consequently, its share declined from 15.6% in 1995 to 11.9% in 2022. Both inland waterways, from 5.1% to 3.5% and pipelines, from 4.3% to 2.7% experienced a decrease in modal share between 1995 and 2022. Inland waterway transport peaked in terms of tkm in 2010, but by 2022 it was only slightly above the level recorded in 1995. Pipeline transport was the only mode for which the tkm in 2022 were lower than in 1995. Despite an average annual increase of 1.8%, air transport had by far the lowest forwarding service among all modes in this ranking, with only 2.3 billion tkm in 2022. (European Commission. Directorate General for Mobility and Transport., 2024, p. 36)

Figure 2: Freight Transport Performance by Mode
Based on European Commission. Directorate General for Mobility and Transport (2024)



	Road	Rail	Inland Waterways	Piplines	Sea	Air
1995	1127,2	374,8	121,9	103,8	671,4	1,4
2010	1558,3	375	155,4	111	831,8	1,8
2022	1866,3	413,4	122,1	93,7	973,7	2,3

1.4.1 Submarkets within the Logistics Market

By refining the logistics market, the following submarkets can be identified.

- **Tank and Silo Services:** Tank and silo services are logistics services that are provided in connection with liquid, gaseous or powdery goods. A classic tank service is the transport of mineral oils.
- **Bulk Goods:** Bulk goods cannot be counted, for example coal, grain, etc. (Jockel & Femerling, 2025, p. 61)
- **Heavy Lift Logistics:** Heavy goods logistics involves the movement of oversized and heavyweight cargo, such as a large marine engine.
- **Full Truck Loads:** Full loads are any type of goods where a load is transported in its entirety from the consignor to the consignee.
- **General Cargo Transport:** This is the individual transport of goods. E.g., the one-off posted parcel etc.
- **CEP Services:** CEP stands for courier, express and parcel services. These goods are of comparatively low weight. (Jockel & Femerling, 2025, p. 109)

1.4.2 Environmental (and Political) Influence on the Logistics Market

“To tackle climate change, the European Parliament adopted the European Climate Law, which raises the EU’s target of reducing net greenhouse gas emissions at least 55% by 2030 (from the current 40%) and makes climate neutrality by 2050 legally binding.” (European Parliament, 2018)

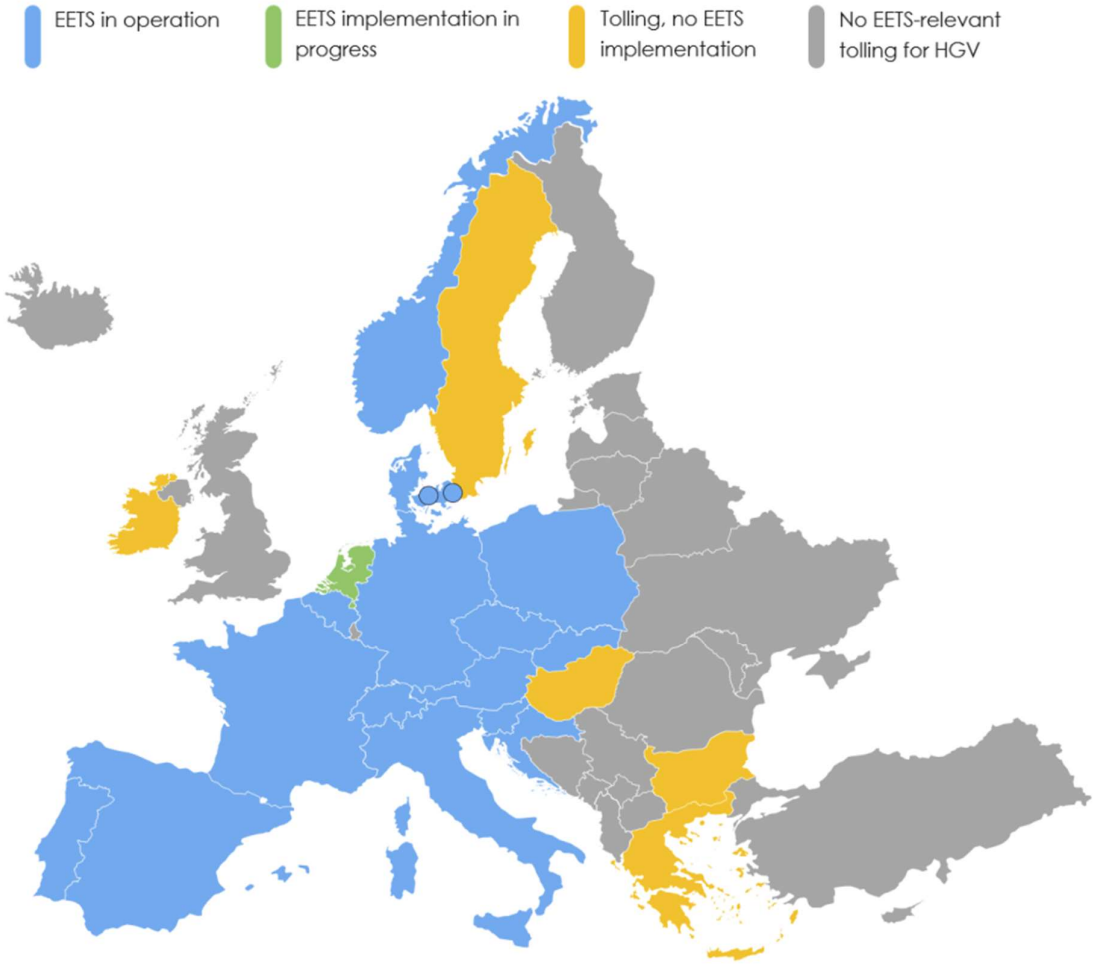
The Austrian federal government has set the goal of becoming a climate neutral state by the year 2040. (Bundesministerium für Land- und Forstwirtschaft, Klima- und Umweltschutz, Regionen und Wasserwirtschaft, 2025) Germany plans to reduce its emissions by at least 65% by 2030 and by at least 88% by 2040, compared to 1990 levels. By 2045, Germany aims to be climate neutral and the goal is to be climate negative after 2050. (Wilke, 2013)

To achieve these goals, incentives such as subsidies or tax benefits are provided, while fees, for example tolls, are collected.

Toll System

An increase in both volume and proportional share of road transport has been observed within the EU. (European Commission. Directorate General for Mobility and Transport., 2024, pp. 35–36) A well-developed and safe infrastructure is therefore essential. To maintain this, governments have developed toll systems on their own (e.g., Switzerland – LSVA, actual version LSVA III) or in co-operation with other countries (e.g., EU - Go toll). The calculation of tolls differs between countries. In Austria the sections of toll roads that have been traveled, the vehicle type, the number of axles and the emission class are relevant for the toll calculation. (BAZG, 2025b) Whereas in Switzerland, for example, the formula is: kilometers driven * permitted gross vehicle weight in tons * a rate depending on the vehicle's EURO emission class. (BAZG, 2025a) To simplify cross-border toll collection across Europe, the EU introduced the framework for the European Electronic Toll Service (EETS) through Directive 2019/520. In countries where EETS is operational, as depicted in figure 3, users can operate with a single On-Board Unit (OBU) under one contract, with unified billing across multiple toll systems. (European Union, 2019)

Figure 3: European Electronic Toll Service in Europe
Reproduced from Hamele & Eriksröd (2024)



1.4.3 Development of the Logistics Market

The following trends can be identified for freight forwarding and logistics software providers:

Shift to Intermodal Transport Chains: The available cargo space is becoming scarce. One measurable solution lies in the adoption of intermodal transport chains. These involve combined transportation using

various modes such as road, rail, air, and sea freight. Intermodal transport units (such as containers, swap bodies, etc.) carry goods from the sender to the recipient (e.g., warehouses, container terminals, hubs). Once the transport unit reaches its destination, the individual shipments are delivered to their final recipients. The International Union of Railways and the International Union for Road-Rail Combined Transport recorded an overall growth of 89% in combined transport between 2010 and 2023. (International Union of Railways, 2024, p. 8) The EU and depot operators (such as ÖBB – Rail Cargo Austria – Container Terminal Wolfurt) are actively promoting these environmentally friendly transport methods. (International Union of Railways, 2024, pp. 84–89)

Freight Space Optimization / 3-D Storage Space Planning: Not all goods can be transported using intermodal transport units and must instead be transported by conventional means (local transport, long-distance transport). Consequently, there is a growing trend towards optimizing freight space through the efficient use of available loading capacity and improved utilization of transport modes. (Chen et al., 2024)

Freight Forwarding Networks: Freight forwarding networks such as OSL (Online System Logistics), CEVA Logistics (formerly GEFCO) and others provide small and micro-sized freight forwarding companies with a means of remaining competitive amid the growing pressure of international competition. These freight forwarders organized within these networks mutually agree to assign the transportation of goods exclusively to fellow network members. (Tan et al., 2024, p. 1)

Routing and Routing of Lorries: Modern fleet management systems use real-time data transmission via 4G, 5G, or satellite networks to send the routes calculated by dispatchers directly to the lorry's on-board computer or driver tablet. These systems integrate, for example, traffic data, delivery time windows, legal driving times, and vehicle-specific restrictions. The driver receives clear, dynamic instructions that support time- and cost-efficient transport operations. (Chinonso et al., 2021, pp. 6–14)

1.4.4 Technological Developments in the Logistics Market

Logistics Sector: Good economic development is also increasing the volume of transport. Nevertheless, logistics has not been able to keep pace with this development, resulting in a shortage of cargo space. As a result, various trends are recognizable.

- Shipping goods with intermodal transport units
- Shift to rail transport
- Information on consignments

IT Sector: The IT sector is probably the fastest developing industry. Based on Moore's Law, hardware and software are improving at a rapid pace. Data that was previously archived in a cellar can now be stored on servers and made accessible at any time for information and post-processing purposes. Trends are visible:

- Data archiving
- Scanning (barcodes)
- Status feedback
- FTP/SCP connections to customers, partners, and lorry drivers

1.5 Learning Materials

Document: Module 1_Intro Supply Chain Management & Logistics.pptx

Module 1_Intro Supply Chain Management & Logistics.pptx covers the following topics of SCM: the definition of a SC, the stages within a SC, the structure of a SC network, the flows within a SC, and a process-oriented perspective.

2 Teaching Exercise 2: Service Designs & Resilience

This module examines risk and uncertainty in Supply Chains, and explains the concepts of the Ripple Effect and the Bullwhip Effect. In addition, real-world examples that have challenged Supply Chains are used to illustrate these phenomena. Finally, the chapter addresses the topic of Supply Chain Resilience.

To underscore the importance of this module, Knoppe (2024) identified that an individual short-term performance deficit (disturbance) can propagate through the global Supply Chain via the Ripple Effect (performance deficit negatively affects downstream processes and partners) and may escalate amplified by overreactions (Bullwhip Effect) into a long-term, unpredictable and very significant disruption of the Supply Chain. (Knoppe, 2024, pp. 96–97)

2.1 Risk and Uncertainties

Sources of problems in a Supply Chain include both risks and uncertainties. In the case of a risk, events occur with a known or estimable probability. For example, companies can analyze the risk of how much actual demand deviates from the forecasted demand by examining forecast errors. In the case of uncertainty, the probability of occurrence is unknown. Such events are significantly more difficult to incorporate into planning, tend to occur less frequently, but usually have a much greater impact than a quantifiable risk. Uncertainties include geopolitical, pandemic-related, or environmental events. (Knoppe, 2024, p. 96)

2.1.1 Global Pandemic: COVID-19

The rapid spread of the coronavirus had significant impacts on both social life and the economy. Measures such as restrictions on private life (e.g., limiting interpersonal contact), lockdowns, short-time work schemes, and disruptions in production and Supply Chains serve as illustrative examples. (Lerch et al., 2020)

The effects of COVID-19 on the SCM areas of procurement, production, and logistics are presented in the table 1.

Table 1: Effects of COVID-19 on Supply Chain Management Areas Procurement, Production, and Logistics Based on Kleemann & Frühbeis (2021)

Procurement	Production	Logistic
International procurement stop	Capacity utilization and overload	(Partially) closed goods traffic
Material and supply shortages	Short-term, complete production shutdown	Closed passenger traffic
Massive demand surges for specific products	Conversion of core production	Highly fluctuating demand in transportation
Production shutdowns at suppliers	Severe staff shortages	Difficult working conditions
Threat of supplier insolvencies		

Many companies primarily used their own internal data for demand and supply forecasting, rather than leveraging comprehensive end-to-end Supply Chain data. This reflected a limited adoption of information technology and automated systems in Supply Chain Management. Consequently, when the pandemic hit, companies struggled to predict demand and manage supply constraints, resulting in Supply Chain Disruptions. (Das et al., 2022, p. 250)

2.2 Ripple Effect

Global Supply Chains follow the principle of division of labor with the aim of increasing efficiency by carrying out individual production steps in the countries where they are most cost-effective. The intensive interconnection between companies across many different countries carries the disadvantage that shocks originating in one country can spread more rapidly worldwide. This phenomenon is known as the Ripple Effect. (Knoppe, 2024, p. 88)

2.2.1 Ripple Effect: Blockage of the Suez Canal

Triggered by strong winds and a sandstorm, combined with communication deficiencies on board and existing information asymmetries, the vessel Ever Given lost navigational control and became lodged sideways in the canal. (Fiolka, 2025) Hence, the Suez Canal was blocked from March 23 to March 29, 2021, which serves as a vital trade route connecting Europe and Asia. Numerous ships were backed up on both sides of the Suez Canal. Although the Ever Given was eventually refloated, the resulting traffic backlog persisted for nearly a week, despite more than 100 ships being allowed to pass through the canal each day, more than double the usual daily average of around 50 vessels. (Tran et al., 2025)

Figure 4: Blockage of the Suez Canal, Vessel Evergreen
Source: New York Times, online https://static01.nyt.com/newsgraphics/2021/07/01/suez-evergreen update/041c98002f5dc92941e63a577b4f4de202e27765/evergreen-locator-Artboard_1_copy.jpg

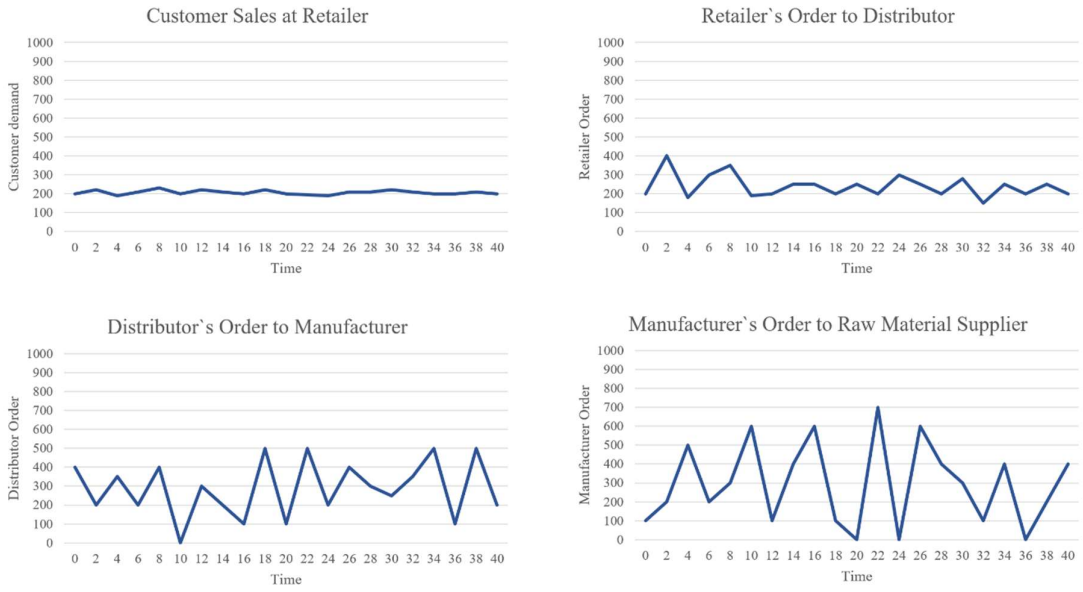
Furthermore, the coordination of cargo handling was overwhelmed by the simultaneous arrival of delayed ships, resulting in further significant delays in deliveries. Overall, many companies had to halt their production or services because the required goods were either on the Ever Given or on another ship stuck in the traffic jam caused by the blockage. The blockade was estimated to cost up to 9.1 billion dollars per day. (Fiolka, 2025)

Neither the occurrence of this event, nor the duration of the blockade, nor the resulting consequences could be reliably predicted in advance or integrated into further analyses with any degree of probability. (Knoppe, 2024, p. 96)

2.3 Bullwhip Effect

In the 1960s, Jay Wright Forrester discovered that demand fluctuations become increasingly amplified upstream in multi-tier Supply Chains, a phenomenon known as the Bullwhip Effect. Even minor variations in customer demand can lead to progressively larger order fluctuations at each stage of the SC. Figure 5 depicted this effect, showing order quantities ranging from 150–400 units at the retailer, to 0–500 units at the distributor, and ultimately 0–700 units at the manufacturer, despite actual customer demand remaining constant at approximately 200 units over the time period. (Scukanec et al., 2007a, p. 290)

Figure 5: Bullwhip
Based on Scukanec et al. (2007a)



One reason this effect occurs is when information is only passed along step by step through individual order quantities rather than by sharing end-customer demand data directly with all Supply Chain participants. (Sucky, 2022, pp. 24–25) Hence, each company places orders with its supplier based on its own individual forecast. Since orders must be processed and incur costs, demand across multiple periods may be consolidated into a single order. This increases both the order volume and the ordering interval. (Alicke, 2005, p. 106) Such bundling, as well as possible forward buying (purchasing now without current need due to expected future price increases), makes forecasting more difficult for the upstream Supply Chain stages. (Sucky, 2022, p. 30) Delayed reactions or the under- and overestimation of trends lead to overreactions, which then escalate and propagate to other Supply Chain participants. (Alicke, 2005, p. 102) These mechanisms are also reflected in the findings of Scukanec et al. (2007), who summarize the four principal drivers of the Bullwhip Effect as the updating of demand forecasting, the grouping of orders, price fluctuations, and re-distributions (rationing). (Scukanec et al., 2007b, p. 291)

The Bullwhip Effect has been observed, for example, at Procter & Gamble, Hewlett Packard and Barilla. (Sucky, 2022, p. 25)

"The Italian food company Barilla also observed that retail demand for Barilla-branded pasta in Italy showed little fluctuation. However, the orders placed by retailers with wholesalers varied over time. The fluctuations were even more pronounced in the orders that wholesalers placed with the pasta manufacturer." (Sucky, 2022, p. 25)

The reasons for the occurrence of the Bullwhip Effect are manifold. Several contributing factors can be identified in the areas of production, inventory and delivery capacity, as well as forecasting and

planning, ultimately resulting in economic inefficiency. Disruptions in production schedules can lead to delays and inconsistencies in the flow of goods, which in turn affect downstream supply chain activities. Furthermore, uncertainty in the production process, coupled with high production costs, can make it difficult for companies to respond flexibly to changes in demand. As a result, even small fluctuations in orders are often met with disproportionate adjustments, amplifying variability throughout the system. To mitigate uncertainties, companies often increase inventory levels. However, excessive stockpiling may result in operational inefficiencies, such as higher storage costs, increased coordination efforts, or prolonged capital commitment, without generating any actual added value. It may also lead to distorted demand signals. Variability in delivery capacities and a generally low service level further undermine the reliability of supply. These challenges are intensified by inaccurate forecasting and inadequate capacity planning, particularly when logistics processes remain reactive. Corrective measures such as expedited shipments or overtime labor entail significant additional costs. (Scukanec et al., 2007b, p. 290)

2.3.1 Geopolitical Event: Brexit

In 2020, the United Kingdom (UK) formally withdrew from the European Union (EU), ending 47 years of membership. (Österreich, 2025)

The EU unites and represents its member states in trade policy. As of 2023, it leads global trade in goods and services, holding a 16,1% share of world trade. (European Council, 2025) Furthermore, notable achievements of the EU include the establishment of free trade among member states, the adoption of the euro as a common currency to eliminate exchange rate costs and reduce currency fluctuations, the freedom to work anywhere within the EU, standardized customs and trade regulations, among others. (European Union, 2025)

The Brexit, the UK's exit from the EU, can be seen as a prominent example of a slowdown in international trade or even a reversal toward increasing protectionism. This event disrupted previously well-structured and reliably coordinated value chains, replacing them with volatility, uncertainty, complexity, and ambiguity. The ambiguity arises from the fact that while companies specializing in complex logistics solutions were able to benefit, others faced significant economic difficulties.

The effects of Brexit on the SCM areas of procurement, production, and logistics are presented in table 2.

Table 2: Effects of Brexit on Supply Chain Management Areas Procurement, Production, and Logistics Based on Kleemann & Frühbeis (2021)

Procurement	Production	Logistic
Increased customs and border formalities	Supply shortages	Complex transport route planning
Rising procurement costs	Low planning reliability	Overload at interfaces
Complicated sourcing strategies	Growing shortage of skilled labor	Longer waiting times
Increased buffer stocks		Warehouse overcapacity
Supplier failure risk		Unpredictable demand fluctuations
		Rising transportation costs

2.4 Resilience

Resilience is the capacity of a system to adapt rapidly and consistently in response to economic and environmental disturbances. A system is considered more resilient when disruptive factors have less influence and it can return to its normal state more quickly. (Kleemann & Frühbeis, 2021, p. 3)

Resilience, according to Wieland and Durach (2021), also entails the capacity of a Supply Chain to account for and respond to changes in its external environment. If the previously assumed normal state no longer reflects prevailing conditions, resilience requires the Supply Chain to adapt or transform accordingly, rather than striving to return to the obsolete normal state. (Wieland & Durach, 2021, pp. 317–318)

To enhance resilience, the synergy between agility (offering swift solutions but with instability) and robustness (providing stability at the cost of flexibility) plays a key role. (Kleemann & Frühbeis, 2021, p. 41)

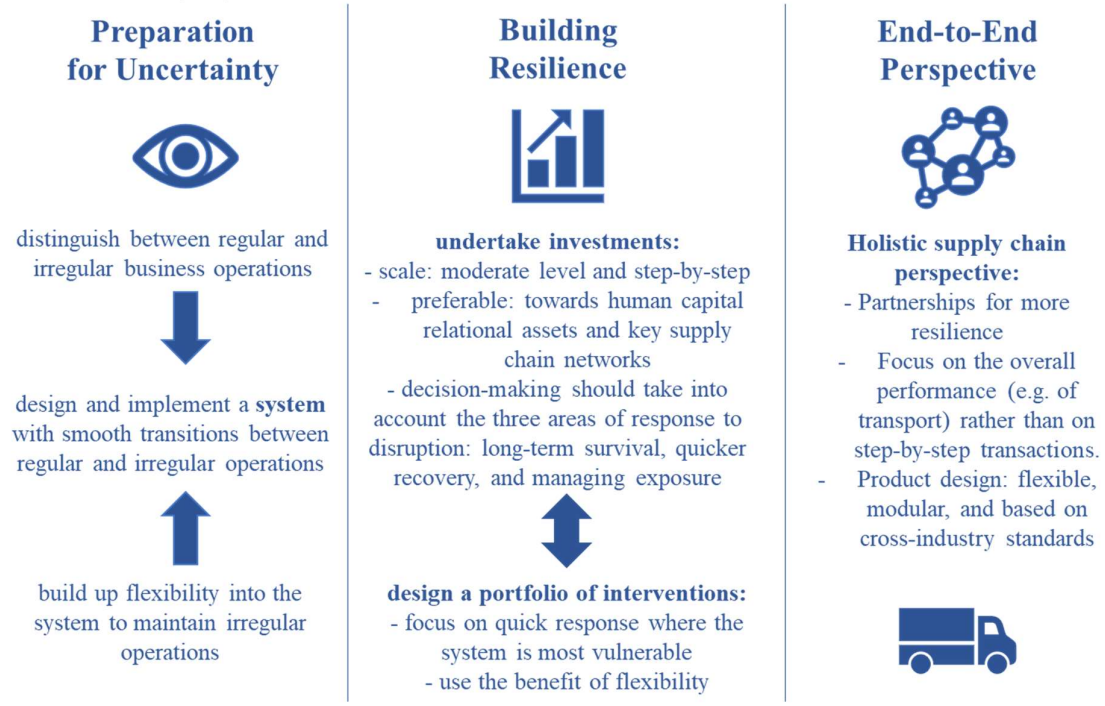
To find the right balance, the Triple R-Supply-Chain-Model, as presented in table 3, serves to visualize the implementation perspectives of resilient strategic content (in long-term), resilient tactics (in medium-term) and resilient operational measures (in short-term) across the areas of procurement, production, and logistics. Agility tends to focus on short-term effects, while robustness is geared toward long-term measures.(Kleemann & Frühbeis, 2021, pp. 19–40)

Table 3: Triple R-Supply-Chain-Model
Based on Kleemann & Frühbeis (2021)

Time horizon	Procurement	Production	Logistics
Strategy (long-term)	Acquisition and/or integration of suppliers Dual sourcing / backup suppliers Regional sourcing / reshoring Intensification of supplier relationships	In-house manufacturing / core production Nearshoring of production (Re-)design of the production network Adjustment of the production strategy	Expansion of the facility network Expansion of distribution channels Automation of physical activities Green logistics
Tactics (medium-term)	Green procurement / sourcing Supplier portfolio check Use of substitute goods Use of digitalization	Standardization of production factors Flexibilization of production facilities and processes Demand-oriented production planning Sustainable production processes / “green production”	Use of alternative modes of transport Use of alternative transport routes Cross-functional system integration Flexibilization of logistics spaces
Operations (short-term)	Supplier pulse check Raising employee awareness of risks Increase of reorder level / inventory disposition Use of classic (contractual) procurement levers	Agile (operational) production planning and control Digital work control Preventive occupational safety measures Remote operation and maintenance	Resource sharing Avoidance of empty runs (empty trips) Temporary capacity intensification Increased buffer stocks

To be immune to ongoing Supply Chain disruptions, it is crucial to prepare for uncertainty, build resilience, and adopt an end-to-end perspective on Supply Chain Management, as depicted in figure 6. (Eastwood, 2022)

Figure 6: Resilience-Model
Based on Eastwood (2022)



Ensuring resilience may entail significant costs. However, failure to invest in resilience measures can, in the worst-case scenario, result in a collapse of the entire Supply Chain. (Ivanov, 2023, p. 50) Investments in employees, relationships, and key supply networks are more useful than building hard capacity that is rarely used. (Eastwood, 2022)

Werner reveals that resilient Supply Chains pursue eight strategic factors: cost, time, quality, agility, service, innovation, information, and sustainability. (Werner, 2022, p. 46) He emphasizes that "for lasting resilience, it is essential that all processes in the Supply Chain are always transparent." (Werner, 2022, p. 43)

A key lever for strengthening resilience lies in the use of (digital) Information and Communication Technologies in Supply Chain Management. Das et al. (2022) note that "digital technologies are playing important role in supply chain resilience through high connectivity, accuracy and transparency." (Das et al., 2022, p. 251)

The importance of cross-company collaboration cannot be overstated. Network-wide collaboration, as Sardesai and Schreiber (2023) highlight, is indispensable in the context of resilience. Mutual trust forms the foundation for all collaboratively initiated measures. Cross-company data sharing, while ensuring data sovereignty through appropriate platforms, is a strong driver of resilience in networks, as disruptions can be detected and addressed at an early stage. This type of measure is closely linked to the areas of collaboration capability and visibility. (Sardesai & Schreiber, 2023, p. 46)

Li et al. (2023) demonstrate in an empirical study, based on hypothesis testing using structural equation modeling and conducted within the Chinese manufacturing sector, that both digitalization and collaboration among Supply Chain participants significantly enhance Supply Chain resilience. (Li et al., 2023, pp. 13–14)

2.5 Learning Materials

Document: Module 2_Bullwhip Effect.pptx

Module 2_Bullwhip Effect.pptx contains an explanation of the Bullwhip Effect, examines its impacts, and outlines strategies for its prevention.

Document: Module 3_Sourcing & Warehousing.pptx

Module 3_Sourcing & Warehousing.pptx addresses warehousing strategies, sourcing strategies, and procurement strategies, and includes a case example on Zara.

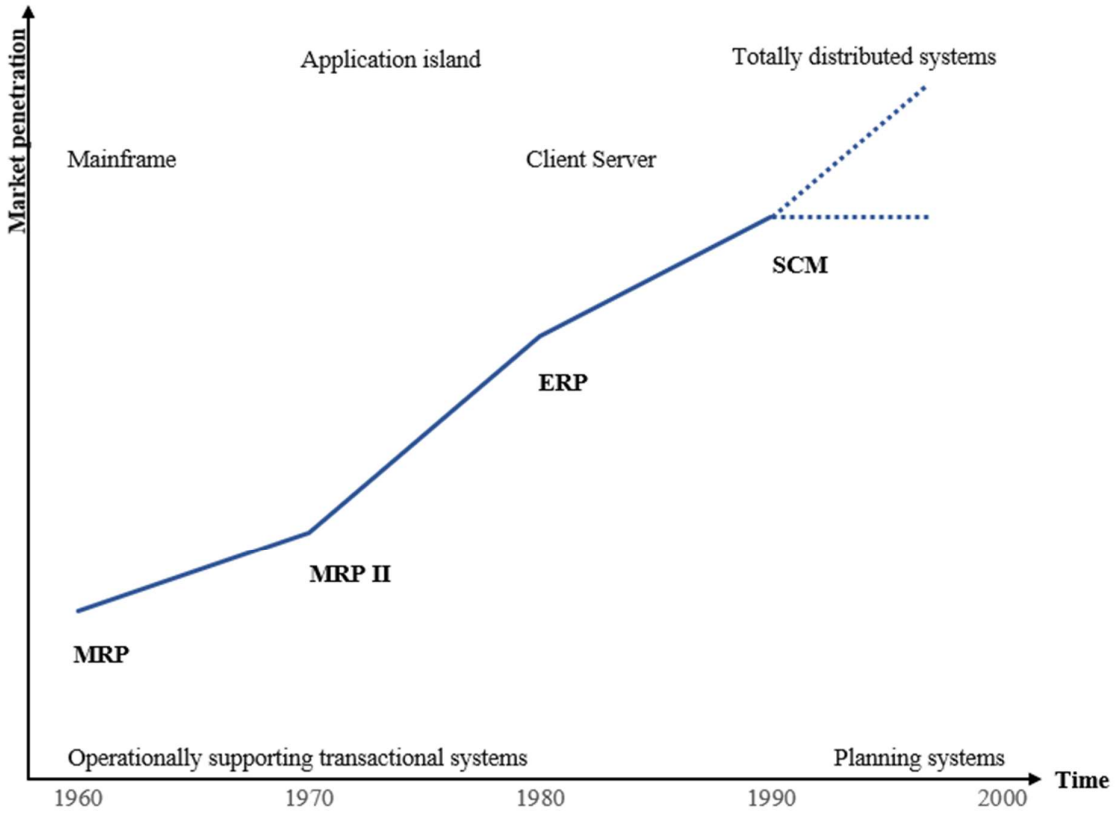
Document: Module 4_Service Designs & Value Co-Creation.pptx

Module 4_Service Designs & Value Co-Creation.pptx covers the fundamentals of service science, including its four streams, the concept of resilience as a service, and the aim of service science and value co-creation.

3 Teaching Exercise 3: Information and Communication Technologies in Supply Chain Management

In Supply Chain Management, three information systems can be fundamentally distinguished based on functional content and temporal development: MRP, ERP and APS (Sucky, 2022, p. 410) The abbreviation "MRP" stands for both "Material Requirements Planning as MRP1" and "Manufacturing Resource Planning as MRP2". Further explanations and differences between MRP1 and MRP2 are discussed in chapters 3.1 and 3.2. In German-speaking countries, these systems are referred to as PPS systems, which stands for production planning and control systems. PPS and MRP systems differ in name only. (Kurbel, 2021, p. 1) APS is considered a key technology in Supply Chain Management (SCM) as it operates across companies. (Sucky, 2022, p. 417)

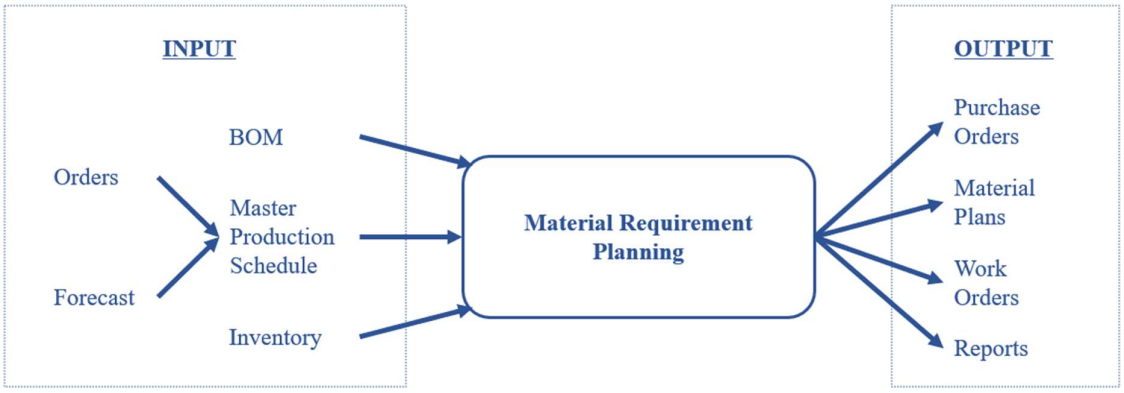
Figure 7: Market Penetration of operational support Systems
Based on Wannenwetsch & Nicolai (2004)



3.1 Material Requirement Planning (MRP1)

MRP1 is an early planning system with integrated information technology. As the name suggests the focus is on material requirements, from procurement to production. Most of the developments took place in the United States of America, for example the system PICS (Production Information and Control System) from IBM in year 1968. Thus, the MRP1 systems were geared towards the market conditions in the USA at that time, which generally tended towards high volume standardized production. (Kurbel, 2016, p. 41) The system was used for the calculation of materials and components required for production. (Sarferaz, 2023a, p. 4) Furthermore, MRP1 aids in quickly determining the required data from bills of materials. (Gronau, 2012, p. 38; 2021, p. 9) Production is initiated according to the time and quantity schedule or when inventory levels fall below the minimum required levels. (Kurbel, 2016, p. 41) The process flow in MRP1 is depicted in figure 8.

Figure 8: Process Flow in Material Requirement Planning
Based on Marker (2021)



However, if the specified material plan is not feasible due to capacity constraints, there is no feedback function for the production plan. (Sarferaz, 2023a, p. 4)

Therefore, MRP has evolved, and the following functions have been integrated:

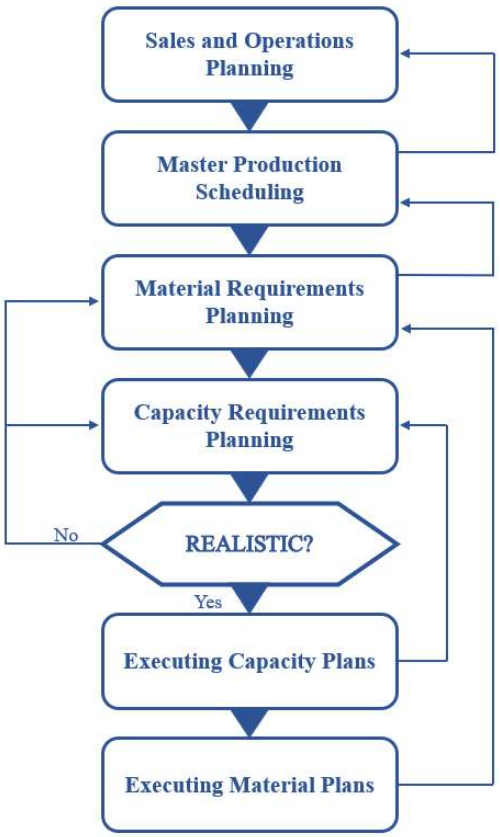
- ”procurement (purchasing)
- time management as an extension of quantity-oriented material management
- planning and control of production including workshop-oriented programming”

Through extensions of scheduling and capacity planning, it led to a transition from MRP1 to MRP2. (Gronau, 2012, p. 38, 2021, p. 9)

3.2 Manufacturing Resource Planning (MRP2)

The Manufacturing Resource Planning tool (MRP2) pursues the basic idea of achieving a "holistic market- and resource-oriented planning of sales, production, and inventory quantities", which is closely linked to the business plan and begins at the highest management level. (Kurbel, 2021, pp. 101–103) Other levels are "Sales Planning, Master Production Scheduling, Materials Requirements Planning and Purchasing Planning." (PlanetTogether, 2023) MRP2 plans with all resources required for production such as workers, equipment, machines, etc., and not just materials like MRP1. (Buma, 2021) Good predictability of capacity, lead times for orders, and processing times is a prerequisite. (Kurbel, 2019) Capacity planning makes it possible to determine whether the production programs are feasible with the available resources or whether corrective action is required. (Kurbel, 2021, p. 101) However, the timing of production is carried out independently of any capacity constraints, which makes it a sequential planning system, as depicted in figure 9. This sequential step-by-step execution can lead to over/under-capacities. (Hausladen, 2020, p. 129) Production capacity refers to the maximum amount of goods or services that a company can produce ideally using its available resources within a given time period. (Turovski, 2023) Undercapacity occurs when the demand exceeds the capacity. Overcapacity arises when the production capacity exceeds the demand. (Damilano, 2023)

Figure 9: Process Flow in Manufacturing Resource Planning Based on Kurbel (2021)



With MRP1, each department in a company attempted to map their workflows internally using their own software and database. As a result, the same data was recorded multiple times by different departments separately. Cross-departmental collaboration with production data was time-consuming and led to discrepancies. To overcome these challenges, MRP2 integrates a single unified database system. The advanced technology enables operational decision-making with data-based simulation methods (testing individual trading positions, forecasting best- and worst-case scenarios, etc.) without altering the data records in the database. However, the central information system only referred to production and closely involved departments such as accounting and finance, marketing and sales, procurement, and materials management. To include all departments in a company together and serve companies in different market sectors, the development of ERP followed. (Sarferaz, 2023b, p. 5)

3.3 Enterprise Resource Planning (ERP)

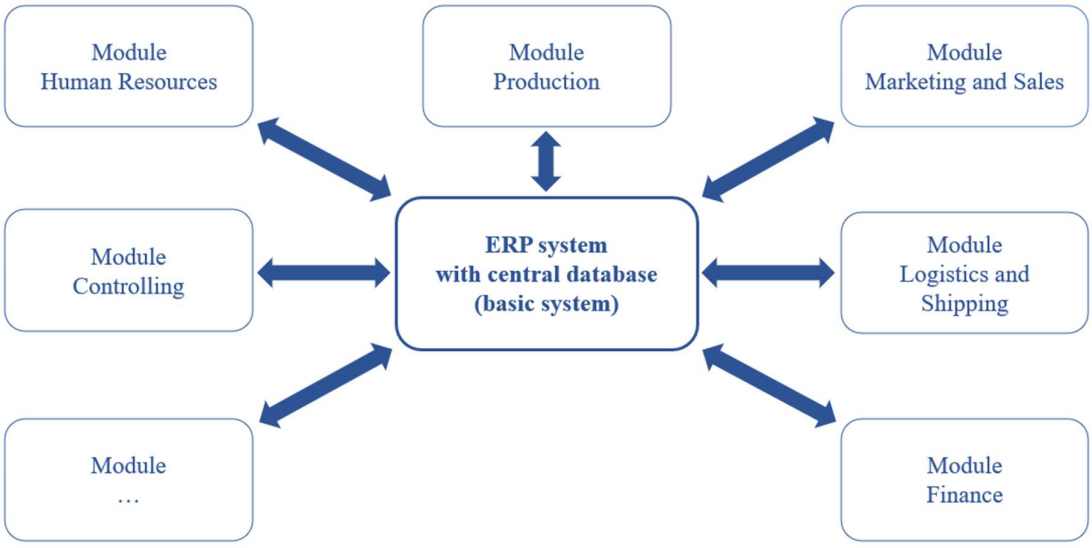
An ERP system manages all information necessary to conduct business processes regarding the resources of material, personnel, capacities, finances, and information. In contrast to special application systems such as for manufacturing, warehousing, accounting, personnel administration, an ERP system includes the management of at least three of the resources mentioned above. (Gronau, 2021, pp. 10–11)

Table 4: Assignment of Tasks to Resources in Enterprise Resource Planning
Based on Gronau (2021)

Task/modules	Resource
business Intelligence/Business Analytics	information
accounting	finance
salary and time registration	personal
production	capacity
customer relationship	customer
supplier	material
Warehouse management	material

The structure of the ERP system consists of the integration of various independent modules. Each module is self-contained and could also be operated as a stand-alone system. ERP is a standard application software because all modules access a unified database, as depicted in figure 10. (Wannenwetsch, 2021, p. 460)

Figure 10: Modules of an Enterprise Resource Planning System
Based on Sucky (2022)



The complete integration capability is an essential feature of ERP systems to flexibly add new modules with specific requirements. (Jahn, 2022) Different modules are used depending on the industry of the company. For example, storage and logistics do not play a role in an engineering service provider. (Gronau, 2021, p. 11) Furthermore, the entire ERP system is process-oriented, while the individual modules operate in a function-oriented manner. (Sucky, 2022, p. 415)

Documents such as customer orders, delivery notes, and invoices play a crucial role in ERP processes. They ensure that data is available to users in other departments with the appropriate access rights across functions and processes. Depending on the activity, these documents must be generated and stored in the database or viewed as a screen form. (Kurbel, 2016, p. 220)

The perfect ERP system enables a detailed insight into all roles within the company in real-time. (Jahn, 2022) However, the information flow between various companies was slow with the original ERP tools. Internal information improvement was the main feature until the late 1990s. Thus, the benefits were limited to the company. (Olson, 2014, p. 16)

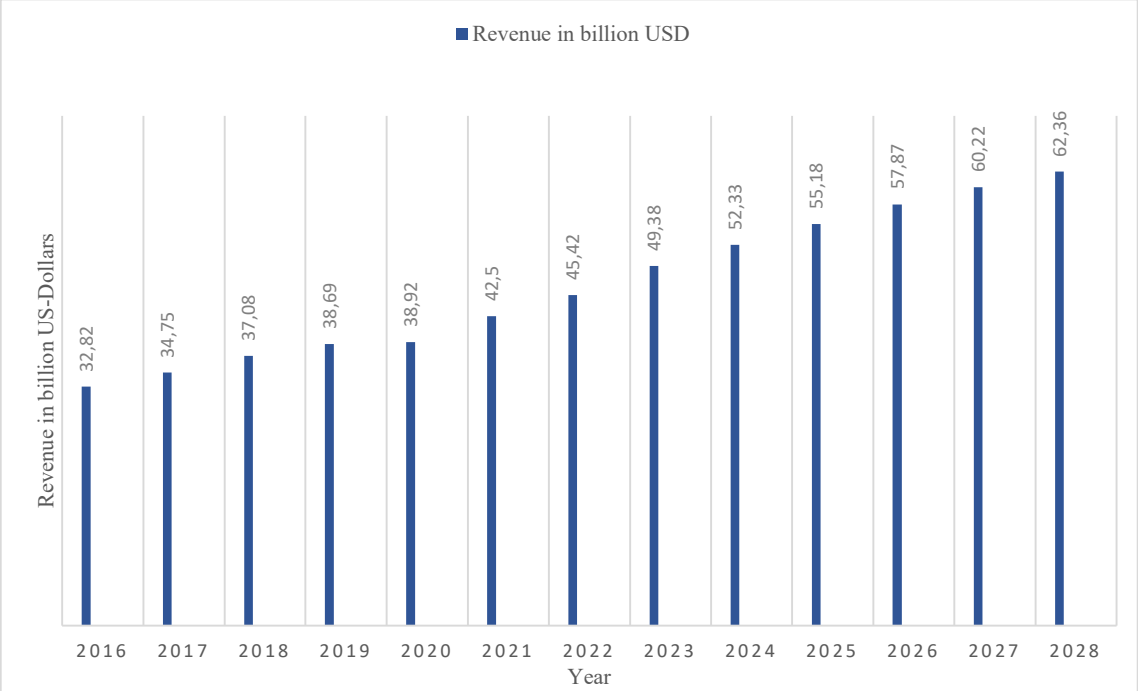
"Even if each company were to optimize its respective business processes with the help of an ERP system, it would not be guaranteed that better results could not be achieved if it were to coordinate its planning and control with other companies." (Kurbel, 2021, pp. 3–4)

Essentially, just as MRP and MRP2 systems only cover a partial area (production) within a company, ERP only covers the partial area (just one company) within a Supply Chain, instead of all participating companies. This leads to the approach of Supply Chain Management, which focuses on the entire Supply Chain in today's interconnected world. (Kurbel, 2016, p. 4)

3.4 Enterprise Resource Planning Market

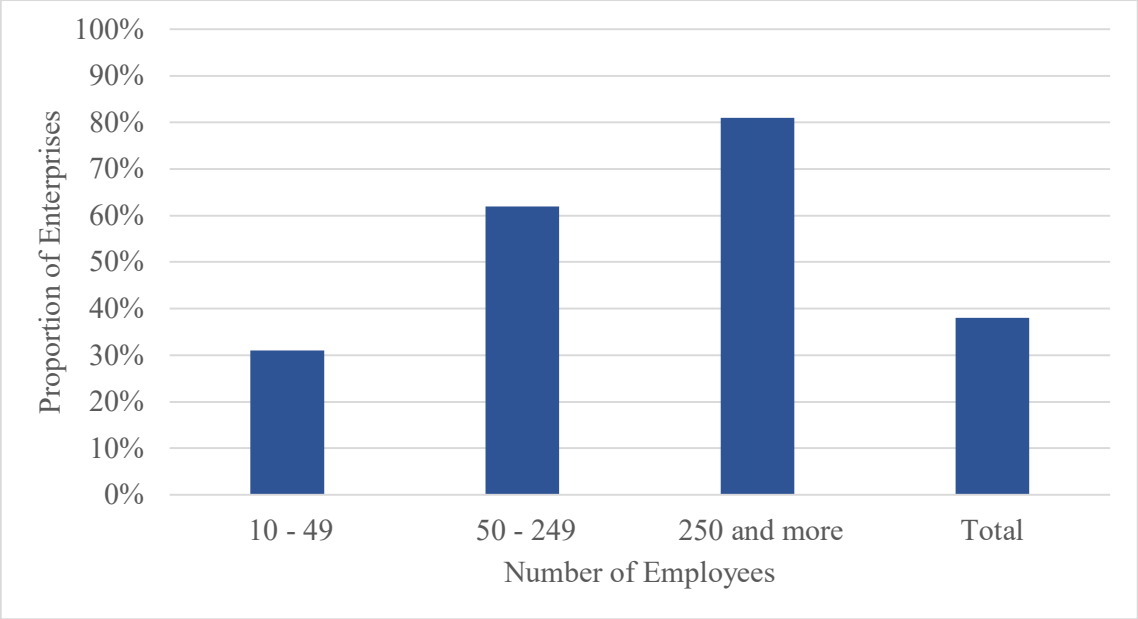
The global market volume of ERP systems was approximately 36 billion US dollars in 2018. (Sarferaz, 2023a, p. 18) A steady growth trend is forecasted for the coming years, as depicted in figure 11. (Statista, 2023)

Figure 11: Enterprise Resource Planning-Revenue - Global Forecast
Based on Statista (2023)



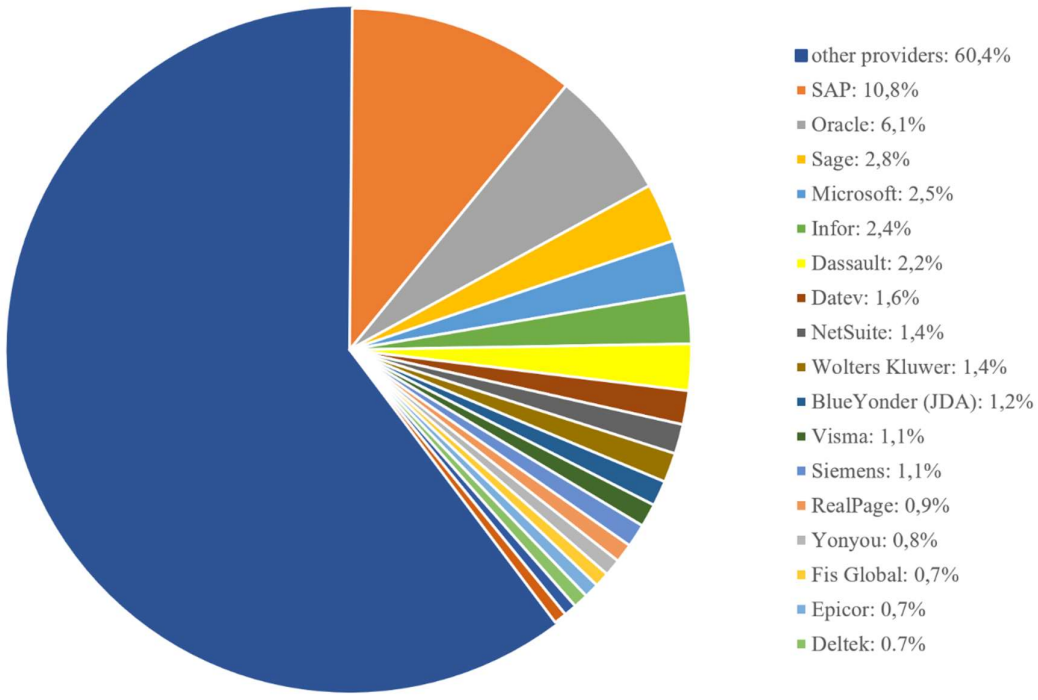
As presented by the Federal Statistical Office of Germany, 81 percent of the German companies with at least 250 employees use an organizational Enterprise Resource Planning system, as depicted in figure 12. (Statistisches Bundesamt, 2023)

Figure 12: Proportion of Companies in Germany using Enterprise Resource Planning Software, by Company Size in 2021
Based on Statistisches Bundesamt (2023)



In 2019, SAP was the global leader with 10,8 percent share in the ERP systems market, as depicted in figure 13, and also held the leading position in Europe, the Middle East and Africa. In North America, Oracle has the leading position. (Sarferaz, 2023a, p. 18)

Figure 13: Global Enterprise Resource Planning Market Share in 2019
Based on Sarferaz (2023a)



The market is a polypol market. For example, there are about 500 providers in Germany. In contrast, SAP had a market share of 56 percent in 2007. “The market share or the popularity of the provider are not the decisive criteria for choosing an ERP system. Rather, it is about the question of which solution

best meets the individual requirements." (Forterro Deutschland Abas GmbH, 2023) Selecting the most appropriate ERP system for an organization's specific needs remains a challenge. (Kurbel, 2021, pp. 335–336)

3.5 Advanced Planning and Scheduling System (APS)

In many companies, suppliers contribute most of a product's value. If an important component is not delivered or is delivered incorrectly, the entire Supply Chain can come to a standstill. The strength of a Supply Chain is determined by its weakest link, which is the weakest supplier in the chain. (Wannenwetsch, 2021, p. 499) Advanced Planning and Scheduling System, also known as Advanced Planning System or simply APS, supports cross-location and cross-company planning, control and monitoring of value-added processes. (Sucky, 2022, p. 417) Furthermore, APS systems are typically used to complement ERP systems rather than replace them. (Lamm, 2023) On the one hand, both systems can work alone. On the other hand, the best results are provided when they work together. (Technology Evaluation Centers Inc., 2022)

3.5.1 Features of Advanced Planning and Scheduling System

An APS system encompasses advanced modeling capabilities, a strong orientation towards bottlenecks, powerful algorithms, and support for complex data structures. It further integrates procurement, production, transport, and customer orders, along with interfaces to ERP systems and simulation functionalities. (Kurbel, 2016, pp. 438–439; 2021, p. 481)

The planning of a dynamic process is at the core, involving the mandatory evaluation of quality criteria derived from available information for a clearly defined upcoming period, accessible at every stage of the planning decision. (Mauergauz, 2016, p. 15)

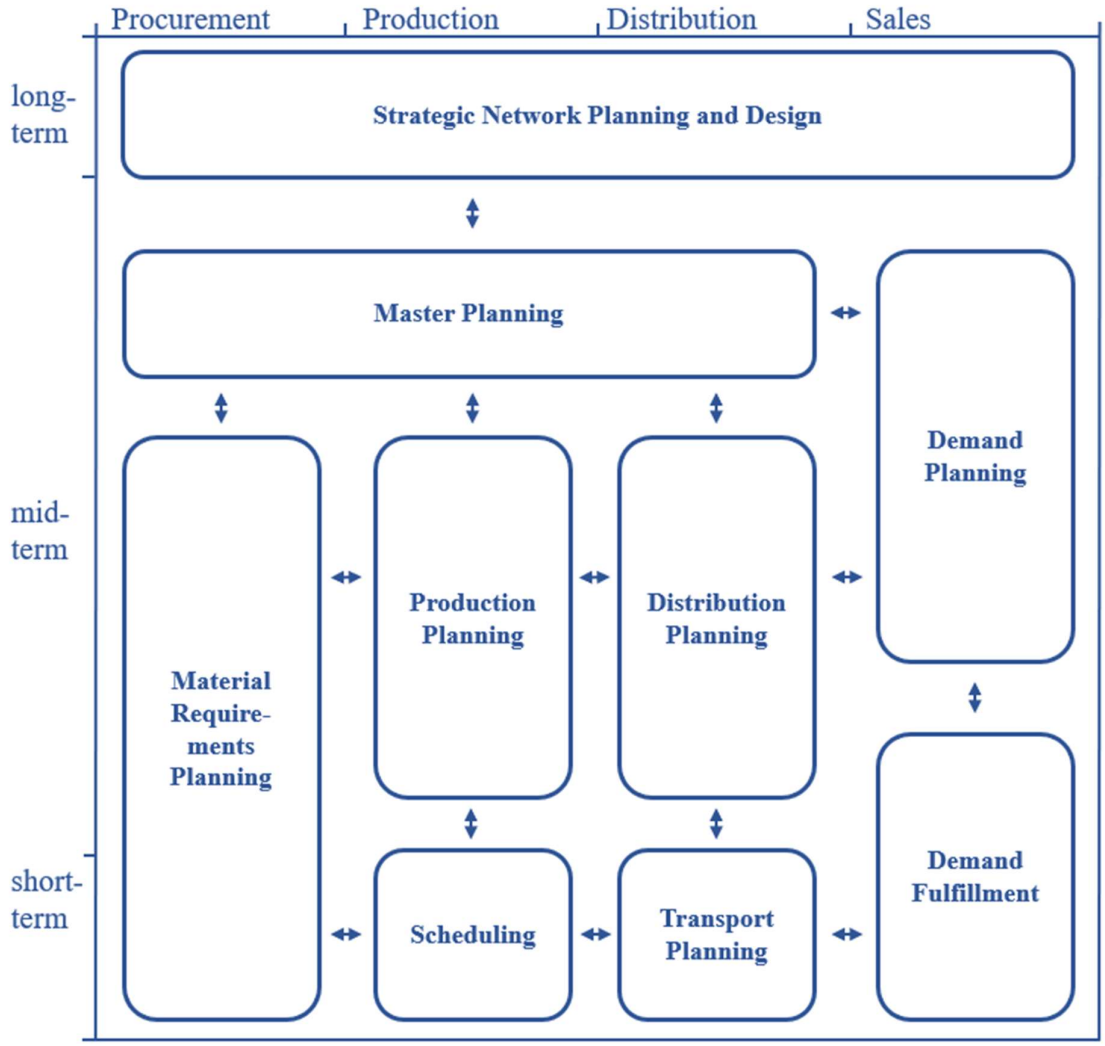
Integral Planning: Integral planning is the process of coordinating the entire Supply Chain. It can tackle internal Supply Chain issues (such as operating multiple production sites or distribution centers within a single company) and potentially encompass the entire Supply Chain. (De Santa-Eulalia et al., 2011, p. 173)

True Optimization: APS systems utilize cutting-edge analysis and Supply Chain optimization technology, including precise methods or heuristics, to execute planning and scheduling activities. The primary objective of optimization problems is to find solutions in a context of limited or constrained resources. Matching supply and demand are a critical aspect of most Supply Chain optimization problems, particularly when one or both are restricted.

The primary optimization techniques employed include mathematical programming (primarily linear and mixed integer programming), heuristics (including scheduling methods such as the theory of constraints or simulated annealing), and constraint programming. Other quantitative methods are also employed, such as forecasting and time series analysis, exhaustive enumeration, and scenario planning (what-if analysis and simulations). Additionally, other quantitative methods are used, including forecasting and time series analysis, exhaustive enumeration, and scenario planning (simulations and what-if analysis). (De Santa-Eulalia et al., 2011, p. 173)

Hierarchical Planning System: APS is responsible for planning and scheduling both Supply Chain and manufacturing efforts over long-term (strategic planning such as Supply Chain network design), intermediate-term (tactical planning such as optimizing the Supply Chain elements of production, distribution and inventory), and short-term (operational planning such as demand forecasts, daily production, inventory and logistics) time periods, as depicted in figure 14. (Greene, 2022, p. 40)

Figure 14: Supply Chain Matrix
Based on Kurbel (2021); Mönch et al. (2020); Sucky (2022)



As depicted in figure 14, an APS system is composed of nine components. These components are presented in the following sub-sections.

Strategic Network Planning and Design: In the realm of strategic network planning, the timeframe in question spans the long-term from three to ten years. (Sucky, 2022, p. 418). At the center of attention is the assembly of the supply chain and its network, which entails decision-making concerning location selection and target audience choice. (Kurbel, 2021, pp. 481–482)

Master Planning: Multi-site master planning coordinates the movement of materials in the Supply Chain and matches demand and capacity. It helps with the planning of the optimal use of production, distribution, and supply capacities for a mid-term period. The planning allocates demand (production and distribution quantities) to sites and resources to prevent bottlenecks. Therefore, it typically spans a full seasonal cycle or at least 12 months, divided into weekly or monthly intervals. (Cederborg & Rudberg, 2023, p. 4)

Material Requirements Planning: The main task of material requirement planning is to calculate the necessary quantities of secondary demand.(Kurbel, 2021, p. 101) Secondary demand refers the individual components (e.g. cords, rods and fabric) required to manufacture the final product, which represents the primary demand (e.g. a tent). (Blech, 2023)

Production Planning and Scheduling: The production planning module decides what materials or orders to produce, when, where, and how much. It also makes sure there is enough capacity and raw materials for the production plan. (Gronau, 2021, p. 264) “The time horizon considered is generally shorter than that for Master Planning, and the capacity constraints are more detailed.„ (Mönch et al., 2018, p. 5)

Distribution and Transport Planning: In network-oriented distribution planning, final product quantities are allocated in alignment with production and demand planning. Subsequently, these quantities are apportioned among individual customer orders within the framework of network-based transport planning, which encompasses elements such as the choice of transportation mode, loading planning, and route mapping. (Kurbel, 2021, p. 483)

Demand Planning: It is used to determine future demand quantities. (Kurbel, 2021, p. 482) “The term “planning’” can be misleading in this context, as the forecast of future developments based on observed time series merely provides information for planning and cannot be referred to as planning itself.” (Sucky, 2022, p. 419)

Demand Fulfillment: This process ensures timely delivery of customer orders. This involves checking the availability of goods in all warehouses and facilities and matching it with customer orders. If there is sufficient inventory, the order is shipped from the warehouse (Available-to-Promise, ATP). Otherwise, it determines whether a production order can be started or modified to meet the demand (Capable-to-Promise, CPT). If neither option is feasible, it looks for an alternative product to offer the customer. (Sucky, 2022, p. 419)

3.5.2 Benefits of using Advanced Planning and Scheduling System

Advanced Planning and Scheduling (APS) systems offer several advantages, including the ability to enhance customer service, streamline delivery times, reduce costs, optimize inventory, and increase precision in lead time and safety stock calculations. Their integration not only reduces throughput times but also improves resource utilization by refining the sequencing for efficient setups and changeovers. Moreover, APS systems are characterized by their capability to balance trade-offs between conflicting objectives, thereby addressing challenges inherent in contemporary business dynamics, such as striking the delicate balance between mass customization and cost reduction. (Greene, 2022, pp. 39–40)

Forward and backward scheduling are also supported by APS. Forward scheduling informs customers of the earliest possible delivery date from the order date, whereas backward scheduling calculates the latest possible production start date based on the completion deadline to ensure timely delivery. (Dynaprog AG, 2023)

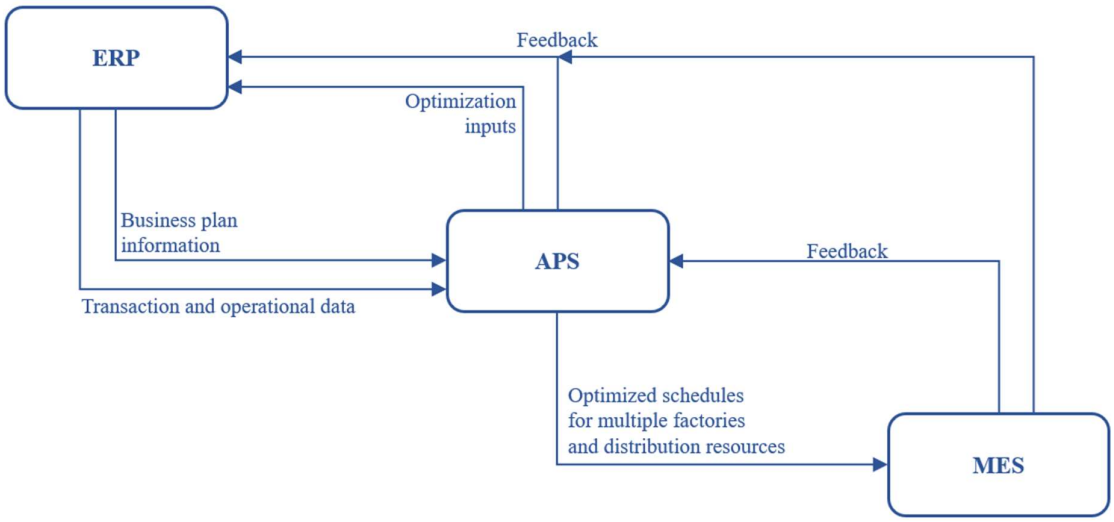
By simultaneously considering and simulating relevant planning variables, APS systems gain an advantage over the classical PPS. This results in a shorter planning cycle and better and faster outcomes compared to sequential PPS systems, which must revise their demand plans after elaboration due to capacity constraints. (Hausladen, 2020, p. 131)

3.6 Advanced Planning and Scheduling System in Combination with Enterprise Resource Planning System and Manufacturing Execution System

ERP manages the resources and the basic activities and transactions of a company, such as orders, material requirements, accounting, logistics and human resources. APS handles the constraints by accessing the information in the ERP database, such as order size, due date, available capacity, setup time, etc., to determine different scenarios and solutions and return (synchronize) this output in real time to the ERP system. The output includes equipment loading, equipment utilization, line utilization, order release time, and order start/finish time. In addition, the ERP database is connected to the Manufacturing Execution System (MES). MES is responsible for executing, monitoring, and controlling the processes on the shop floor. It serves to detect and analyze the current constraints such as machine capacity, efficiency, and changeover times. By integrating the systems, multiple touchpoints are analyzed and the

decision-making of the production planning, scheduling and control is adapted flexibly and responsively to the actual demand with automatic data transfer in real time. (Greene, 2022, p. 41) The process flow is depicted in figure 15.

Figure 15: Process Flow, Advanced Planning and Scheduling System in Combination with Enterprise Resource Planning (and Manufacturing Execution System)
Based on Greene (2022)



3.7 Analyzing the Information Technology Providers

The representative logistics software providers are capable of supporting all modes of transport with their software solutions, as presented in table 5.

Table 5: Competition Overview
Based on the Homepages of the Companies

Company	IT-System	Mode of Transport				
		Road Traffic	Rail Transport	Shipping Traffic	Air Transport	Combined Transport
SAP AG	SAP S/4HANA	YES	YES	YES	YES	YES
Soloplan GmbH	CarLo	YES	YES	YES	YES	YES
Oracle	Oracle Fusion Cloud ERP	YES	YES	YES	YES	YES
proLogistik Transportation GmbH	pLG Product Suite	YES	YES	YES	YES	YES
Axians	LBase	YES	YES	YES	YES	YES

The SAP S/4HANA includes shipping and air transport in contrast to the SAP IT system TP VS. Soloplan introduced the add-on CarLo in AIR&SEA in 2016 as a comprehensive solution for managing multimodal transportation. A dedicated add-on for rail transport is not explicitly provided on Soloplan's homepage. However, timetable information can nevertheless be stored in the master data and linked to partial routes in road transport. (Presseservice, 2012) Oracle rebranded G-Log, which already supported all modes of transport, as Oracle Transportation Management in 2006. (Martens, 2006) It is now part of Oracle Fusion Cloud ERP. The company proLogistik Transportation GmbH emerged from the merger of active logistics and cargo support Group since January 14, 2025. The IT system of active logistics TMS supported all modes of transport except shipping traffic. The pLG Product Suite of proLogistik

Transportation GmbH now supports shipping traffic. Air transport is not explicitly mentioned on the homepage. However, since it was already included in the IT system of active logistics, it can be assumed that it continues to be supported. Axians is the international ICT brand of VINCI Energies S.A. The IT-System LBase, developed by Transflow GmbH, is still in use. Transflow GmbH was renamed Imtech ICT Austria and was subsequently rebranded as Axians ICT Austria in 2015. Table 6 provides an overview of the companies' homepages.

Table 6: Homepages of the Companies

Company	Homepages
SAP	https://www.sap.com/austria/about/company.html
Soloplan GmbH	https://www.soloplan.de/ueber-soloplan/
Oracle	https://www.oracle.com/corporate/
proLogistik Transportation GmbH	https://www.prologistik.com/en/about-us/group/
Axians	https://www.axians.at/das-sind-wir/standorte-netzwerk/

3.7.1 Number of Employees at Information Technology Providers

The number of employees at the companies, as reported on their respective homepages, together with the percentage changes between 2006 and 2025, is presented in table 7.

Table 7: Company Comparison based on the Number of Employees Based on the Homepages of the Companies

Company	Employees (year 2006)	Employees (year 2025)	Percentage changes
SAP	53.000	109.000	+ 106 %
Soloplan GmbH	60	270	+ 350 %
Oracle	56.133	160.000	+ 185 %
proLogistik Transportation GmbH	240	800	+ 233 %
Axians	60	16.000	+ 26.566 %

At each of the selected companies, the number of employees has increased by an average of at least 3.88% per year (=106 percentage changes within 19 years). However, it should be noted that proLogistik Transportation GmbH and Axians should be considered separately due to the corporate restructuring. For the year 2006, the number of employees for proLogistik Transportation GmbH was taken only from active logistics, while for Axians it was taken from Transflow GmbH.

3.7.2 Turnover at Information Technology Providers

The turnover of the companies, as reported on their respective homepages, together with the percentage changes between 2006 and 2024, is presented in table 8.

Table 8: Turnover Overview
Based on the Homepages of the Companies

Company	Turnover (year 2006)	Turnover (year 2024)	Percentage changes
SAP	€ 10,3 Billions	€ 34 Billions	+ 329 %
Soloplan GmbH	€ 3,9 Millions	€ 30 Millions	+ 768 %
Oracle	€ 14,38 Billions	€ 53 Billions	+ 368 %
proLogistik Transportation GmbH	N/A	€ 100 Millions	N/A
Axians	€ 3,5 Millions	€ 3,6 Billions	+ 102.757 %

The turnover data from 2024 is used as it represents the most recent and precise figures available. SAP and Oracle recorded an increase in turnover of over 300% within 18 years, corresponding to an average annual growth rate of approximately 8%. Soloplan GmbH exhibited an even more substantial growth of 768%, rising from €3.9 million to €30 million in turnover. Due to corporate restructuring, as previously outlined, proLogistik Transportation GmbH and Axians must be considered separately. There are no revenue figures available for active logistics and cargo support Group from 2006, prior to their integration into proLogistik Transportation GmbH. For Axians, the revenue of Transflow GmbH was taken into account for the year 2006, whereas for 2024 the revenue of Axians as the international ICT brand of VINCI Energies S.A., according to the company's homepage, was considered. The revenue of Axians ICT Austria is estimated to range between 10 and 50 million USD. (LeadIQ, 2025)

3.8 Learning Materials

Document: Module 6a_Information & Communication Technologies.pptx

Module 6a_Information & Communication Technologies.pptx examines the development of information systems, including MRP I, MRP II, and ERP systems from an internal perspective; APS from an orchestrating perspective; ECR and VMI from an integrative perspective; and the concepts of the digital product passport and digital material passport.

Document: Module 6b_WebX & Internet.pptx

Module 6b_WebX & Internet.pptx covers the definition and fundaments of the internet, its interrelation with technology, services, and applications; explores the concept of WebX, Intranet and Extranet; and examines current trends in cloud computing and edge computing.

4 Teaching Exercise 4: Simulation of Information in a Supply Chain: Beer Distribution Game

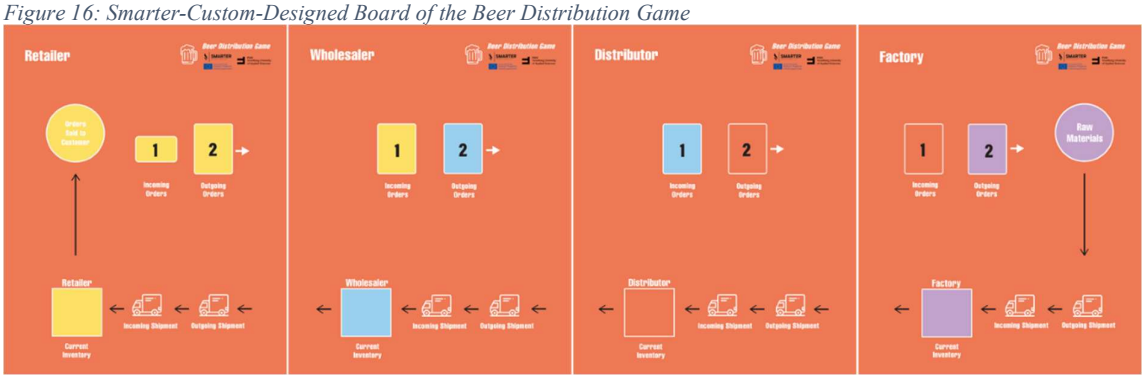
The Beer Distribution Game (BDG) is a management simulation developed in the 1960s at the MIT Sloan School of Management by Jay Wright Forrester, who also identified the Bullwhip Effect. The game was designed to illustrate the impact of information asymmetries and delayed communication processes in systems such as a Supply Chain. (Dizikes, 2012) In its gameplay, participants take on various roles, including retailer, wholesaler, distributor, and manufacturer, within a Supply Chain with the task to fulfil the incoming orders of beer. The objective is to minimize the overall costs of the Supply Chain through efficient management of inventory and order quantities, while also optimizing one´s own position within the Supply Chain. (Riemer, 2019)

The Supply Chain in the BDG is simplified in comparison to real SC. There are no price fluctuations of the goods (beer), no capacity constraints, no labor problems, and, in principle, no material shortages, as the factory can theoretically order an unlimited supply of goods from its supplier. Furthermore, the SC is structured as a linear chain in the game, meaning that each player has exactly one supplier and one customer, rather than operating within a SC network. The logistics of beer distribution are passed downstream from upstream in the Supply Chain, and the information flow of demand orders is passed from downstream to upstream of the Supply Chain. Since the participants only secretly transmit the order quantities to the nearest player and no further communication is allowed, attention is usually focused solely on one's own situation. This results in overreactions to demand fluctuations, leading to supply chain related phenomena, such as the bullwhip effect and costs inefficiency. (Sterman, 2020)

4.1 Smarter-Custom-Designed Board and Settings

The key advantage of the Smarter-custom-designed board is its ability to support two different game modes. On the one hand, it enables a separate game version of the Beer Distribution Game in which each player, role such as the wholesaler, is isolated from the others, and the only flow of information occurs through order quantities. On the other hand, it can also be played as a collaborative game version, where players are positioned next to one another, has full visibility of the material flow, and can communicate and collaborate directly with all other players in the Supply Chain. All other game boards known to us are limited to a single mode of play. The Smarter-custom-designed board consists of four fields, each representing the individual role in the supply chain, see figure 16. The term “role” is used synonymously for a stage and/or a player, such as Retailer, Wholesaler, Distributor, or Factory, within the Supply Chain. Each role within the game can be assigned to up to four participants.

Figure 16: Smarter-Custom-Designed Board of the Beer Distribution Game



The circles labeled “Raw Materials” in the Factory field and “Orders sold to the Customer” in the Retailer field are managed by the game master or helpers to complete the Supply Chain. Apart from the assigned roles, the four fields are otherwise identical. The flow of information in the Supply Chain is represented by the fields “Incoming Orders” and “Outgoing Orders”. The flow of goods (beer) is represented by the fields “Incoming Shipment”, “Outgoing Shipment”, and “Current Inventory”. In

contrast, the flow of finance is excluded to maintain simplicity. The following sub-sections provide a detailed explanation of the fields “Incoming Orders”, “Outgoing Orders”, “Incoming Shipment”, “Outgoing Shipment”, and “Current Inventory”, followed by a more in-depth examination of the flow of goods and the flow of information.

Incoming Orders: The card placed on this field indicates how much goods the downstream stage has ordered.

Outgoing Orders: Please write your desired order quantity on the outgoing order card placed on this field, as soon as the game master gives the corresponding instruction.

Incoming Shipment: According to the game master’s instructions, the goods are moved from the “Outgoing Shipment” field to the “Incoming Shipment” field, or from the “Incoming Shipment” field to the “Current Inventory” field.

Outgoing Shipment: According to the game master’s instructions, the goods are moved from the “Current Inventory” field of the upstream stage to the “Outgoing Shipment” field of the downstream stage, or from the “Outgoing Shipment” field to the “Incoming Shipment” field within the same stage.

Current Inventory: Record your current stock level. According to the game master’s instructions, goods are either received at the “Incoming Shipment” field or delivered to the downstream stage at the “Outgoing Shipment” field.

Figure 17: Beer Coins as Flow of Goods

Flow of Goods/Material/Beer: As the name of the game suggests, the flow of goods focuses on beer. For this purpose, we created around 300 coins with a beer design, each coin represents one beer, see figure 17. The coins were made from wood scraps using a laser cutter. To keep things simple, we disregard the fact that the goods are not actually beer from the raw materials stage up to the factory, as well as we focus only on the main product beer and not on by-products such as the bottle, label and packaging materials. Furthermore, the beer coins received by the customer are returned to the “Raw Material” stage by an assistant or the game master, in order to maintain the circulation of coins with in the game. In contrast to the simplified game mechanics, real-world supply chains must consider logistical challenges such as the return of bottles and other reverse logistics processes.

Flow of Information: The flow of information is facilitated through the use of order cards. Therefore, a stack of predefined customer order cards was created, each specifying a fixed order quantity and sequence. The Retailer may only reveal the top card upon instruction from the game master. In addition, for each role assigned to participants, two reusable order cards were prepared. These cards can be filled out with a dry-erase marker by the players with the desired outgoing order quantity. By using the pre-labeled and pre-positioned order cards prepared during game setup, and by following the game master’s instructions, the game ensures that the cards remain in continuous circulation throughout play. This gives the Smarter-BDG-design the advantage that order cards can be reused as often as desired and, unlike in other game designs, do not need to be discarded after a single use.

Game Setup: As a player, please skip the Game setup. As a game master and as a helper, please follow the instructions of the document to prepare the game: Beer_Game_Setup & Instruction.xlsx.

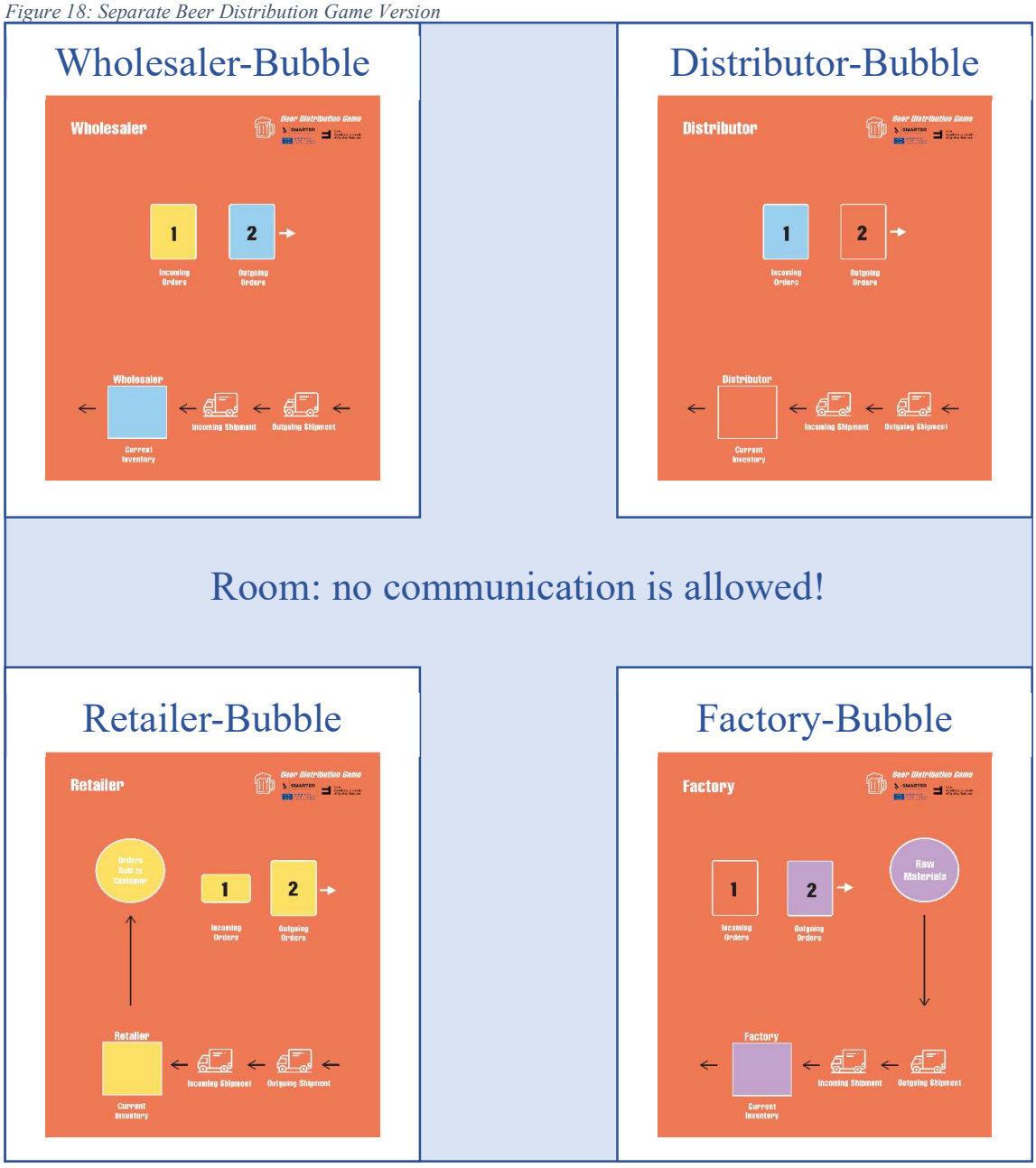
Game Play and Recommendation: As a player, please follow the step-by-step instructions provided by the game master. Additional information is available in the two different versions of the game: separate BDG version and collaborative BDG Version, and also in the Learning Material, documents Beer_Game_Handouts.xlsx and Beer_Game.pptx. Only the game master and the helpers are allowed to get further information in the document: Beer_Game_Setup & Instruction.xlsx.

Our recommendation is to first play the Beer Distribution Game using the separate version and only afterwards switch to the collaborative version as a contrast. However, if there is not enough time to play both versions, our Smarter-custom-designed board allows for a flexible decision on which version to play. The following sections explain the two versions in more detail.

4.2 Separate Beer Distribution Game Version

In the separate BDG version, every of the four stages is stationed far away from each other and only communication within the stage-bubble is allowed, as depicted in figure 18.

Figure 18: Separate Beer Distribution Game Version



The only possible information exchange with another stage is via order cards. Helpers, three additional coaches, are the only connections between the stages and ensure a secret information flow and material flow. Each coach is assigned to one specific connection between one pair of stages: retailer and wholesaler, wholesaler and distributor, and distributor and factory. The coaches deliver the order cards faced down, as secret information flow, to the next upstream stage. The upstream stage must wait for the game master's instruction before revealing the incoming order card to determine the requested quantity. The goods (beers), which are placed in a custom-designed transport box as depicted in figure 19 and specifically created for the separate

Figure 19: Transport Box

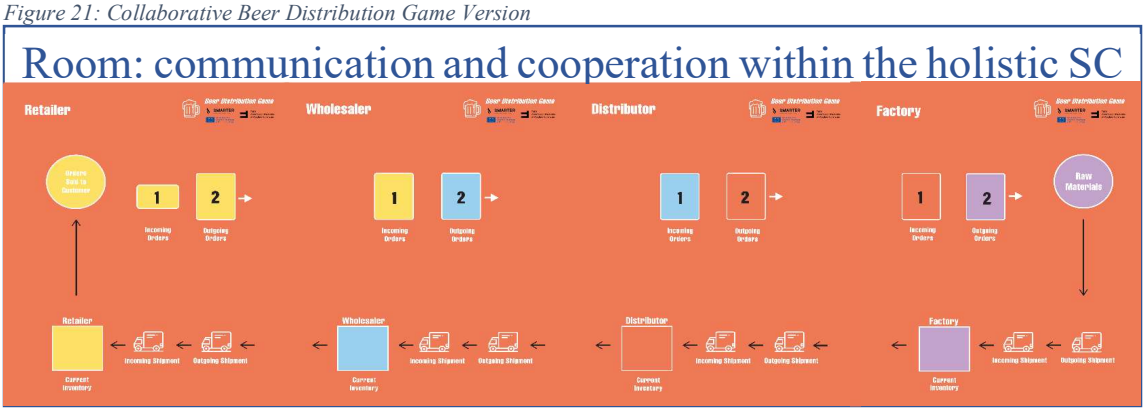
BDG version, are delivered to the next downstream stage by the assigned coach. The downstream stage cannot see the amount of incoming goods until the request comes to open the transport box. The advantages of this game version are the physical separation of the stages, as is most often the case in real-world supply chains, improved role focus, and increased information asymmetry. In figure 20, images of the separate BDG version during the Smarter week in Carlow, Ireland, are shown, illustrating the isolation and lack of information flow between the players.

Figure 20: Isolation - no Information Flow between the Players

4.3 Collaborative Beer Distribution Game Version

In the collaborative BDG version, the four stages (Retailer, Wholesaler, Distributor, and Factory) are arranged sequentially, one next to the other, as depicted in figure 21.

Figure 21: Collaborative Beer Distribution Game Version



Communication between all stages is allowed, this enables the exchange of information in real time and allows strategies for the entire Supply Chain to be discussed and defined collaboratively. Moreover, no transport boxes are needed, which makes the material flow (inventory and movement of coins) in the holistic Supply Chain transparent and reduces the steps to put the coins in the transport box and to put the coins out of the transport box. Furthermore, the outgoing shipment, represented by the beer coins, as well as the outgoing order card are passed directly from the players to the next stage. Helpers are no longer required as intermediaries between the stages. Aside from these changes, the game principle remains the same as in the separate game version. The advantages of the collaborative game version are its simple setup, better oversight for the game master, and increased dynamics, as all roles are allowed to communicate with each other. In figure 22, images of the collaborative BDG version during the Smarter week in Carlow, Ireland, are shown.

Figure 22: Collaborative Beer Distribution Game during the Smarter Week

4.4 Learning Materials

Document: Module 5_Transport Logistics.pptx

Module 5_Transport Logistics.pptx addresses the definition of transport logistics, differentiates between intralogistics and extralogistics, and examines business transformation in this context.

Document: ISL_Paper.docx

ISL_Paper.docx builds on the BDG during the Smarter Week in Ireland and addresses the shift from materialism to dualism. Thanks to the implementation of both game versions, along with the completion of the questionnaire from the document Beer_Game_Questionary.docx for each version, differences in the participants' well-being, learning aspect, insights and perspectives between the game versions could be recorded an evaluated. For example, in the first played separate BDG version, 8 out of 17 answers were "Learning and understanding of the SC" to the question "What are your key insights in playing the Beer Distribution Game", while only 2 out of 16 answers were given in the collaborative BDG version. Instead, the leading answers in the collaborative BDG version to the same question were "Information and communication" and "Collaboration and coordination", each mentioned 7 times.

Document: Beer_Game_Setup & Instruction.xlsx

The Beer_Game_Setup & Instruction.xlsx assists the game master and its helper in preparing the game depending the version. It also contains a complete list of all materials and items required for the BDG, and instructions during the BDG.

Document: Beer_Game_Reporting & Financial Controll.xlsx

The document Beer_Game_Reporting & Financial Controll.xlsx is used for each stage to support reporting and financial control during the game.

Document: Beer_Game_Handouts Collaborative Version.xlsx

In the document Beer_Game_Handouts Collaborative Version.xlsx, each stage serves as a guide for the participants by outlining the steps to be carried out according to the game master's instructions in the collaborative version.

Document: Beer_Game_Handouts Separate Version.xlsx

In the document Beer_Game_Handouts Separate Version.xlsx, each stage serves as a guide for the participants by outlining the steps to be carried out according to the game master's instructions in the separate version.

Document: Beer_Game.pptx

The document Beer_Game.pptx serves as an introduction and test for the BDG. It illustrates the basic process of how orders and goods (beer) are moved during the game. Furthermore, it explains how to complete document Beer_Game_Reporting & Financial Controll.xlsx.

Document: Beer_Game_Clock.pptx

The Beer Game Clock limits the time players have to complete the steps instructed by the game master. The steps are divided into morning, afternoon, and evening (each 45 seconds) and Relax (30 seconds). The document Beer_Game_Clock.pptx is used during both game versions.

Document: Beer_Game_Transport Box Design.docx

The document Beer_Game_Transport Box Design.docx serves as a design template for the transport boxes in the separate BDG version.

Document: Beer_Game_Questionary.docx

Each participant played both game versions during the Smarter Week and, after completing each version, was asked to fill out the Beer Game Questionary in order to better assess and compare the players' impressions of the two versions. Further information and findings can be found in the ISL_Paper.docx.

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6 Appendix

6.1 Use Case Report Lukas: Working at Gebrüder Weiss GmbH

I have worked for more than four years at Gebrüder Weiss GmbH, an international transport and logistics company. My team was responsible for managing loading equipment such as euro pallets and box pallets, which had a price of around 20€ per euro pallet and 80€ per box pallet as of 2021. During the COVID-19 pandemic and the beginning of the Russian attack against Ukraine, prices rose significantly, this had a significant effect on the Supply Chain. Please refer to the attached articles from international and national sources for further information.

Europaletten werden teurer - eurotransport

The Ukraine war is hurting Europe's pallet supply, and Russia's army may be feeling the squeeze too | Euronews

Paletten-Logistik: Steigende Holzpreise sind eine Herausforderung (internationales-verkehrswesen.de)

Preise für Paletten explodieren - ooe.ORF.at

Industry group warns pallet prices up 400% amid shortage | Supply Chain Dive

Supply Chain Latest: Prices for Wooden Shipping Pallets Are Soaring - Bloomberg

Wooden Pallet Prices to Decline in Europe in 2023 (beroeinc.com)

Navigating Pallet Price Trends For 2023 - Reusable Packaging News (packagingrevolution.net)

Pallets as Loading Equipment

Due to their standardized dimensions (1200 mm × 800 mm) and structural characteristics, pallets facilitate efficient transport, handling, and storage processes, while also contributing significantly to transport safety.

Further research substantiates that digitalization is also advancing in the area of loading equipment. On January 1, 2024, the EPAL Euro pallet QR was introduced, marking each individual pallet with a unique QR code on the two right-hand corner blocks. (Österreichische Verkehrszeitung, 2024, p. 4) This offers shippers the opportunity to link information about the current goods to the load carrier. (Lebensmittel Zeitung, 2024) The consignee receives this information via scanner and can also collect location-related key figures on storage duration, circulation and process times. (European Pallet Association e.V., 2025)

Pallet System

"More than 650 million EPAL Euro pallets and 20 million EPAL box pallets are in circulation and form the basis of the largest exchange system the world has ever seen between users in the supply chain." (European Pallet Association e.V., 2023)

Belgium, the Netherlands, Luxembourg, Germany, and Austria are exchange countries within the European pallet pool. This is a deposit system which means that if one or more Euro pallets or grid boxes have been used as loading aids, they should be exchanged 1 to 1.

However, there a several reasons, why directly change is not always possible or wanted:

- Receiver has no Euro pallets in the warehouse or only with too bad quality
- Truck needs an empty loading space for the next tour
- Sender and/or Receiver have a pallet-account
- Receiver have bought the pallets with the goods directly from sender,
  no change was intended here.

The truck driver is responsible for documenting the loading equipment with both the sender and receiver. This documentation should include information about the equipment's condition before transportation and whether it has been exchanged between the sender and receiver.

If the change was not implemented as planned, we have identified solutions to balance the load carriers afterwards. In the best case, we were able to book the differences directly on a pallet account.

The persistent contact with our business partners and the collection of data were essential for providing our departments and other branches with necessary information. This helped us avoid extra transportation of empty loading goods and reduce costs. Furthermore, the ERP programs CIEL, OPAL and SAP have supported us.

ICT in Use

Overall, we have used CIEL more than any other. CIEL helps with searching and controlling shipments and the handling is very simple. For example, all users in company can search for shipments by entering the name or address of the sender or consignee in the search field and then all transports within the last months appear sorted by date. Once you find the delivery you are looking for, you can view more details such as notes of scanned documents and whether the pallets have been changed or not. Furthermore, the key-ids of all business partners are stored in CIEL. It is like a databank.

OPAL was the booking system for pallets and box pallets. We have pallet accounts with several business partners with whom we often carry out transports. With the data from CIEL, we can control when we have a transport and check the papers in the online archive (CMR and pallet bon) as well as what happened with the loading equipment. If we could not exchange all pallets during collections, we credit it to the account. If the consignee could not exchange them during delivery, then we charge it to their account. Every month we send the balance to our business partners for confirmation. The advantages of pallet accounts are that the exchange does not have to be done physically for every transport and the compensation can be made as needed". In addition, OPAL shows an overview of the pallets and box pallets balance of all accounts. Every GW-branch has worked separately, but in OPAL it is possible to check with whom the other branches have an account and how the balance is. If one branch had a credit with a business partner and we owed pallets there, we could arrange a transfer booking via OPAL.

If a freight forwarder has owed us at least one full load of empty pallets (561 pallets), we could request them and have them sent to us at their convenience. Sometimes they preferred us to invoice these loading aids. For this we used SAP for example. With the key-id which we got from CIEL we could choice the respective receiver. Attached is the link from SAP on how to create an invoice or a credit note. The guide includes information on taxes and dates that you should be aware of. The booking department is notified by the SAP software that an invoice has been created and verifies its accuracy. If the invoice is not paid within the standard period, they will provide us with feedback to initiate a payment reminder.

6.2 Enterprise Resource Planning Providers

6.2.1 SAP AG

SAP AG is the world's largest producer of business software. The ERP system of the same name, SAP, initiated an "ERP system technology revolution" when it was founded in 1971. SAP is active in every industry and has ventured into the logistics and services sector with the industry solution SCM (Supply Chain Management) TP VS. This software is relatively new on the market and meaningful results for this product were difficult or impossible to find.

Employees:	51200
Market:	Worldwide
Turnover 2006:	10.3 billion euros
Name of the IT solution:	SCM (Supply Chain Management) TP VS
Installations 2006:	not specified
Total installations:	not specified

Specialized logistics solutions:

This software is designed for ...

Road transport:	YES
Sea freight:	YES
Inland waterway transport:	NO - Next release
Rail transport:	YES
Air freight:	NO - Next release
Multiple zones:	YES

Specialty: 100% compatible with the other SAP programs

6.2.2 SOLOPLAN

Soloplan GmbH is a leading software company in Germany for the haulage and logistics industry. The company was founded in 1991 and has completed around 2,200 installations as of 2006. Its main market is in Austria, Germany, and Switzerland, although it also supplies non-German-speaking countries with its software solution.

Employees:	60
Market:	Europe
Turnover:	approx. 3.9 million
Name of the IT solution:	CarLo®
Installations in 2006:	Not specified
Total installations:	approx. 2,200

Specialized logistics solutions:

This software is designed for ...

Road transport:	YES
Sea freight:	NO
Inland waterway transport: NO	
Rail transport:	NO
Air freight:	NO
Multiple zones:	YES

Note: This software is programmed to be "rigid" (inflexible), making it very difficult to incorporate changes and customized requests.

6.2.3 ORACLE

Oracle is the world's largest producer of databases. Specialized software solutions are the exception rather than the rule. Nevertheless, Oracle has ventured into the haulage industry with G-Log.

Employees:	Not specified
Market:	Worldwide
Turnover 2006:	14.38 billion USD
Implementations 2006:	46
Total implementations:	187

Specialized logistics solutions:

This software is designed for ...

Road transport:	YES
Sea freight:	YES
Inland waterway transport:	YES
Rail transport:	YES
Air freight:	YES
Multiple zones:	YES

Specialty: Oracle is a provider of databases. It can be assumed that the G-Log software product is 100% compatible with the database.

6.2.4 ACTIVE LOGISTICS GMBH

Employees:	250
Market:	Germany, Switzerland, Austria
Turnover 2006:	not specified
IT solution:	Transport Management System (TMS)
Implementations 2006:	85
Total implementations:	not specified

Specialized logistics solutions:

This software is designed for ...

Road transport:	YES
Sea freight:	YES
Inland waterway transport:	NO
Rail transport:	YES
Air freight:	YES
Multiple zones:	YES

Assessment of the Competition

Technical

The almost limitless applicability of the Logic Interpreter gives Transflow a significant advantage. Almost all areas of work can be mapped using IT technology. Another advantage is the co-operation with strategic investor and parent company ILS GmbH. This means that group-wide IT expertise can be utilized.

Size

The main advantages here are SAP and Oracle, which are not only the largest companies in terms of personnel but also in terms of turnover. However, their products are not specialized in the freight forwarding and logistics market.

Specialization of the Product

Transflow can again capitalise on this advantage. Any type of transport can be mapped with LBase. Oracle is another provider of seamless transport planning. Oracle is more specialized in the database market.

Barriers to Market Entry

SAP, the world's largest provider of ERP systems, is attempting to enter the logistics market with its SCM TP VS product. Due to the existing company organization, the size of the company and the high inflow of capital, this attempt should be taken seriously in the market for freight forwarding and logistics software. Further new entries seem impossible without long-term investors.

Special Forms of Competition

VisionFlow GmbH is a company founded in 2003 and based in Dornbirn. The founders of this company are former employees and managers of Transflow GmbH. This company has since been acquired by its competitor Acitve Logistics GmbH.

Employees:	5
Turnover:	not specified
Name of the IT solution:	best expertise in LBase
	Active Logistics - TMS
Installations 2006:	none
Total installations:	none

Notes:

VisionFlow can draw on the best LBase know-how

Main risk for the company Transflow is the loss of existing customers, who switch to VisionFlow.