SMART INFORMATION SYSTEM CAPABILITIES OF DIGITAL SUPPLY CHAIN BUSINESS MODELS

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ABSTRACT

This study explores how supply chain management (SCM) information system (IS) capabilities can lead to superior business performance, and what are the detailed capabilities and methods to master volatility and uncertainties in business environments. Key concepts in SC modelling have been identified for decreasing SC complexity and increasing SC agility and key methods for supply network planning and synchronisation for optimising business performance and objectives that are often contradicting at the same time. The study developed a best practice recommendation for profit-optimised SCM for companies with capital intensive and capacity constrained resources such as in the steel companies and others of the industry, and for managing their integration between SC domains and between technological and organisations' needs simultaneously. Finally, the study shows how Industry 4.0 innovations such as Smart Services and blockchain technology can provide new value potentials such as cross-organisational network effects and increased autonomy in SC ecosystems, and concludes with suggestions for further research in needed rules and semantics for SC ecosystem collaboration.

KEY WORDS

supply chain management, capabilities, artefacts, alignment, Industry 4.0

JEL CODES

M110, M150, O310, O320

1 INTRODUCTION

The research motivation: A holistic methodology and framework for developing dynamic capabilities for SCM IS in an ambidexterity way for fast alignment to business competitive strategy and context has been developed by previous research of the author (Nürk, 2019). However, the author asks which are the actual and detailed IS capabilities of the SC domains

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that provide companies with optimal and continuous business performance, and, how do they need ideally work together for continuous strategic fit? Hence, the present study focuses on these capabilities and their interaction for providing companies in the steel sector – as presenter of the process industry – with SCM IS best practice.

The research objectives: Based on increasing global competition and industry consolidation, businesses such as steel companies need to respond to environmental changes effectively and fast with their SCM IS processes. Hence, this study explored new knowledge and methods of SCM IS capabilities for dealing with such changing business conditions to be aligned with business strategy and between the domains of SCM. For this reason, a capability-based assessment model – that was developed by author's 2019 research – has been used at two steel companies for analysing the impact of IS capabilities of different SC domains on strategic fit in-depth. The present study summarises the qualitative findings of these industrial case studies and of a case study conducted at SAP SE (the author's employer), and synthesises these with possibilities of innovative digitalisation technology – such as proposed by the Industry 4.0 initiative – to a holistic best practice for dealing with SC dynamics and volatility in the most profitable manner. Finally, key concepts have been explored for reducing SC complexity and providing the required responsiveness to business dynamics with the available resources.

The research question and objective: For addressing the stated research aims, the following research question and main objective have been implemented:

- **RQ:** What are the IS capabilities of SC domains, and how do they work together for keeping strategically aligned and leading to superior business performance?
- **RO:** Explore IS capabilities of SC business models and how they interact to align SC domains to strategy provide superior business performance.

Contribution to current research trends in SCM: According to Patterson et al. (2003) and Monczka et al. (2015), most firms face challenging marketplace and are confronted with numerous contenders that are providing products and services fast, cheap and in high quality. For mastering the requirements from the market, they need robust supply chains and have to manage demand or production fluctuations efficiently and simultaneously. Hence, SC complexity from technological approaches needs to be controlled and synchronised with their management process. The present study explores key capabilities of the SC domains with a focus on their integration on different levels that help organisations to arrive at a simplified SC model and processes configuration, but, with high organisational integration. Finally, the study shows how Industry 4.0 innovations can be useful utilised in ecosystems of the sample industry.

The steel industry review: The modern steel industry originated in the 1850s in Britain and had grown with the world's industrial economy since then (Birch, 1969, pp. 412–413). Global steel production rose from merely 28 million tonnes (Mt) the beginning of the 20th century to 781 million tonnes (Mt) at the end (Mangum et al., 1996, p. 39). During this period, the consumption of steel increased at an average annual rate of 3.3%. Steel consumption increases as economies are growing and investments in infrastructure being placed. Hence, attention has shifted to the developing regions such as China, Brazil, India, and South Korea towards the end of last century (Egenhofer et al., 2013, p. 29). The global steel production peaked in 2007 with 1,343.5 Mt, with the following shares in Mt (IISI[1], 2008): (1) 489.0 in China; (2) 120.0 in Japan; (3) 97.2 in the USA; (4) 364.8 in Europe. The automotive and construction sectors are the largest steel customers, with significant impact on the demand for steel (Egenhofer et al., 2013, p. 28). According to Egenhofer et al. (2013, pp. 10–13), the steel business is characterised by the following:

1. *high capital needs and fixed cost* – producing steel requires expensive facilities that lead to

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high fixed costs, which needs a high capacity utilisation to reach the break-even point;
2. *scale economies and minimum efficient scale* – production cost per unit falls as the capacity of steel making resources increases, which leads to economies of scale;
3. *product substitutability* – steel is a commodity with common standards, except in highly specialised steel products for the automotive sector instance;
4. *barriers to entry and barriers to exit on the industry* – high capital requirements for new facilities and the resulting strong financial effort constituted a structural barrier to entry. The capital intensity is also the main barrier to exit as the investment in steel-making facilities cannot be converted into different usable, and the scaling back of the output volume is not always economical.;
5. *intra-sectoral competitive dynamics* – steel firms' demand curve is usually very elastic due to high substitutability of steel products of the equal category, which result in out-compelling competitors by price rather than by scaling back production.

The fact that variable costs are low and fixed costs are very high due to huge capital outlays leads to industry consolidations as producers with weaker financial positions in spite of the exit barriers are increasingly expelled from the industry as demand declines.

Structural changes in steel production: The steel industry has faced structural changes over the last decades due to increasing production in Asia together with the economic crises. Hence, production of crude steel moves from historical locations, such as the EU and the US, to Asia and has reached 1 billion tonnes in 2012 globally (Egenhofer et al., 2013, p. 29). This upward trend in Asia caused by increased internal consumption and by cheaper steel production, mostly in China, leads to a search for economies of scale by the members of the EU – as the second biggest player – and the North American steel industry. Many M&A of steel companies have taken place within the last decade, and the industry consolidation trend remains.

2 THEORETICAL BACKGROUND

For responding to environmental changes effectively, companies need to change their competitive strategy often to comply with new rules (Johnson et al., 2008, p. 3; McLaren et al., 2011, p. 909), whereas strategic alignment leads to greater business profitability (Avison et al., 2004, p. 224; Luftman et al., 1999, p. 9; Naylor et al., 1999, pp. 3–4; Porter, 1987, p. 7). Dynamic capabilities are potentials for innovative capacity enabling firms to respond to fast-changing business conditions by building, integrating and reconfiguring their internal and external competencies to sustain competitive advantage (Teece et al., 1997, pp. 511–516). Ideal levels needed from IS capabilities to support steel companies' competitive strategies at different levels have been identified by applying a strategic fit measurement model developed by a 2019 study of the author. To get a holistic and detailed view of IS capabilities' impact on strategic fit and business performance, different approaches of key researchers have been combined such as a profile deviation approach and a cross-domain approach to assess second-order effects across SC domains (Tallon, 2012; McLaren et al., 2011; Henderson et al., 1996). This study explores the IS capabilities of the SC domains in the steel industry and focus on how they need to interact together for reaching appropriate levels of fitness and deal with uncertainties and volatility most profitably.

SCM challenges in the steel industry: The literature suggests that there are several major SCM-related obstacles challenging the steel industry in reaching its business objectives: (1) increasing volatility and uncertainty in demand, which might lead to uncertainty in the supply of raw materials; (2) steadily increasing prices of raw materials, which lowers profits; and (3) the lack of visibility across the entire steel supply

chain (Xiong and Helo, 2008, p. 161). Therefore, a demand-driven solution design with extended visibility seems promising to provide enhanced business agility and predictability of demand for managing steel industry supply chains (Xiong and Helo, 2008, pp. 161, 167). Furthermore, raw material supply could be sustained through extensive relationship management with raw material vendors (Wang, 2011, pp. 3, 102; Lee et al., 2007, pp. 444–446). Moreover, firms in the steel industry need to deal with lean and agile manufacturing paradigms (Naylor et al., 1999, pp. 107–117) and coping with high market pressures, and to better integrate and synchronise their upstream and downstream processes at the same time. Increased visibility of changing business conditions such as Demand and Supply volatility helps steel companies to extend the visibility of the impact on supply chain activities as well (Xiong and Helo, 2008, pp. 160, 166). Hence, Analytics and Supply Chain Performance Management (SCPM) capabilities have been explored on their role for steel companies in truly understanding what has happened in the past, and for predictive planning (Sowar and Gromley, 2011, p. 2).

Supply Chain domains and their strategic significance: Empirical studies show evidence of the significance of SCM processes for business success in the steel industry such as the following: (i) new product development (Sadler, 2008, pp. 120–133); (ii) sales and operation planning (Zoryk, 2012, pp. 4–5); (iii) downstream SC optimization (Lichtenstein, 2012, p. 7; Sadler, 2008, p. 20); (iv) customer and supplier relationship management (Lichtenstein, 2012, p. 4; Elliott et al., 2013; Sadler, 2008, pp. 27, 56, 59, 76); (v) SC upstream efficiency (Lichtenstein, 2012, p. 6; Sadler, 2008, pp. 119, 127–133); and (vi) SCPM (Zoryk, 2012, pp. 7–8; Sowar and Gromley, 2011, pp. 2, 11). These findings lead to the question of how IS capabilities for SCM improve the strategic fit of firms in the steel industry. And, to what extent and in which aspects do they contribute to the strategic alignment? To investigate these questions and the contribution of the identified SCM processes to the strategic fit of firms in the steel industry, the related IS capabilities, and their level of support needs to be identified and analysed in detail. Hence, the present research explores the impact on the degree of strategic alignment – on different levels – of IS capabilities for (1) new product development (NPD), (2) SC planning, (3) SC operations and execution, (4) relationship management capabilities, and (5) supply chain performance management (SCPM).

The degree of strategic fit of SCM IS is expressed by the levels of support that IS capabilities for SCM offer for strategic fit, and the levels of functional integration of SCM processes. Moreover, IS capabilities for SCM have to investigate about their ideal levels and their actual implemented levels of support to strategic fit. According to Wu et al. (2006), SCM capabilities embody a firm's qualifications for effectively combining resources for creating and sustaining competitive advantages through knowledge integration from multiple sources and multiple partners across the supply chain (Wu et al., 2006, p. 502; Amit and Schoemaker, 1993; Grant, 1996, pp. 115–116). Because of its significance of SC integration to SC performance SC capabilities identified by leading SCM researchers (e.g. Simatupang et al., 2002, pp. 291–306; Wu et al., 2006, pp. 494–495), such as (1) *information sharing*, (2) *coordination*, (3) *activity integration*, and (4) *resource sharing* have been explored on their support for strategic fit.

IS capabilities' effects on the business process level and second-order effects along the supply chain: According to Tallon (2012), strategic alignment shows performance effects on the processes where alignment measurements have been allocated, but can also show second-order effects on the process level from spill-over effects upstream in the value chain (Tallon, 2012; pp. 9–11). Further insights into the performance yield of second-order effects on the process level are very valuable for executives for the reason to determine purposeful investments in the supply chain in a more focused way (Tallon, 2012, p. 12). Moreover, because of the complex interconnection of supply chains, misalignment at some stages could affect business performance at many other stages along the supply chain (Tallon, 2012, p. 9). Hence, increased strategic

alignment at the process level can create more meaningful information within each process and across domains, which could be shared across the supply chain. Hence, the impact of capabilities by second-order effects on business processes of other SCM domains have been explored.

Concepts of IS artefact: IS artefacts are viewed as a data repository, as functionality to support or as instruments for transferring information and supporting decision making (Strong and Volkoff, 2010, p. 749). Strong and Volkoff (2010, pp. 749–751) extend the theory of IS artefacts by the concepts of latent structures to consider three types of structures (1) *deep structure phenomena* – is described as scripts that represent the real-world systems: the "things," their "properties" and "states," and the "transformations" that alter those states; (2) *surface* – the IS facilities for user interaction; and (3) *physical structures* – the mapping of deep and surface structures onto the underlying physical technology (Strong and Volkoff, 2010, pp. 732–751). They conceptualising IS fit via misfits by the empirically visible events that help to reveal the underlying structure of the IS fit construct. They defined the two types *'coverage fit'* and *'enablement fit,'* which are both complex constructs, addressing the fit between the elements of a business software application and the addressed aspects of an organisation's operations. The differentiation of these two types is seen by the present study as very useful because the *SC design* as a key enabler of fit and needs to be provided by *enablement* through appropriate SC modelling, and cannot be purchased from vendors. The observed causes of misfit will be collected and grouped into six domains of misfit that correspond to concepts of ES artefact as follows: (1) functionality, (2) data, (3) usability, (4) role, (5) control and (6) organizational culture (Strong and Volkoff, 2010, pp. 737–745).

3 RESEARCH METHODOLOGY AND CASE STUDIES

The Qualitative research methodology: As this research was to explore new knowledge in-depth in SCM, a qualitative research methodology has been selected, which is open to considering facts and findings that were not expected at starting the research (Eisenhardt, 1989, pp. 533, 546; Bryman and Bell, 2003, pp. 424–516; Silva and Hirschheim, 2007, pp. 333–334; Kaplan and Duchon, 1988, pp. 574–583; Yin, 2009, pp. 25–46, 130–134). While case studies make it hard to generalise findings in SC integration, specifically if there is no clear theoretical framework supporting these, surveys incorporated only limited aspects of integration and fail to consider what actually happens in SC relationships and to address the context or business conditions (van Donk and van der Vaart, 2005, p. 32). Van Donk and van der Vaart (2005, p. 33) suggest the use of a multi-case study for research in integrative practice to bridge the gap between single case studies and surveys for developing knowledge in the field in its prevailing stage. Hence, three case studies were used as primary sources *'to use multiple sources of data'* for developing the final research theory.

Basic theory development based on secondary data: An exhaustive literature review has been conducted for identifying key concepts of the various SC domains for dealing with challenges the sample industry is facing. In referring to Yin's (2009, pp. 130–162) *logic models* for increasing case study evidence, the main building blocks of the research methodology are the literature review and synthesis – in order *'to rely on proven theoretical propositions'* that form the basis for the development of the research question and objective and the development of the research theory and methodological framework – in order *'to develop logic models.'* The plan with used methods and processes for the research phases is highlighted in Fig. 1. Moreover, the Fig. 1 shows the field studies in two stages with a first case study at SAP and two subsequent case studies at two steel companies A an B).

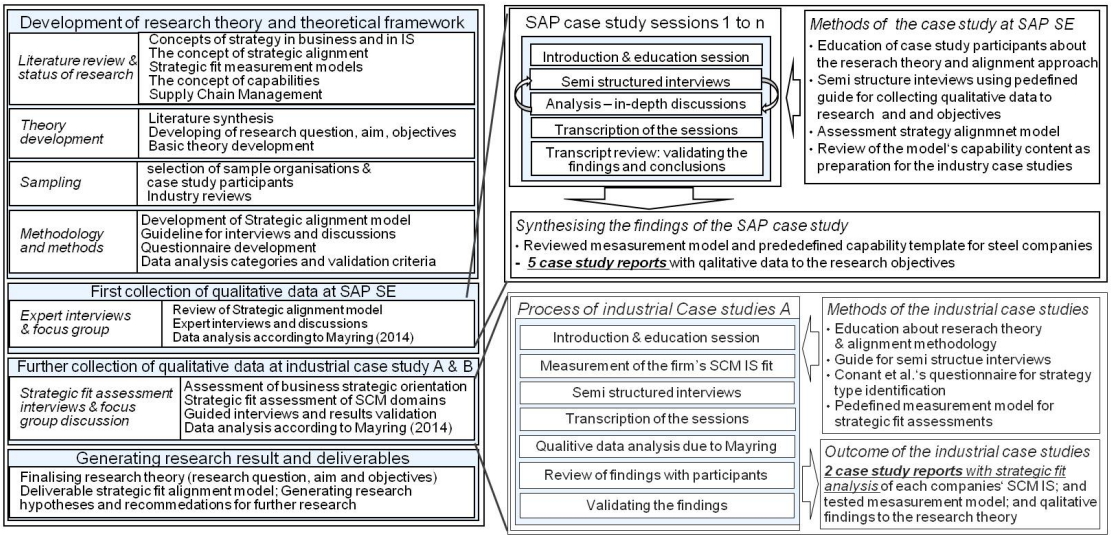

Fig. 1: The research design and plan; and the processes and outcomes of the case studies

Exploratory field study at SAP: An exhaustive case study at the author's employer SAP SE has been conducted as SAP is a leading vendor for SCM solutions and takes care of the steel sectors' challenges and needs. The approach provided rich information rather than using a single sample of a pilot case study that is typically used (Yin, 2009, p. 92). Session of sequences with each of 12 experts and semi-structured interviews have been used to identify IS capabilities required to point out the industry and organisation specific vital differentiators that are relevant for a strategic fit. Leading experts who developed SCM solutions for all manufacturing industries were involved, and, therefore, were able to assess the research theory regarding its generality and adaptability to other industries. For obtain a holistic picture of the factors influencing the research topic, these experts include: (1) Enterprise Architects whose work out IS architecture roadmaps; (2) Business Transformation Consulting and Business Process Consulting; (3) SAP Solution Management for the steel industry and the chemical industry; (4) SAP Product Management for SCM; and (4) SAP Industry Principals of the areas EMEA, North America, and Asia/India. All of them are very experienced, and have many years of experience in dealing with SCM processes (some of them more than 20 years) and have acted as manager for the development of SAP's SCM applications. In this role, the participants developed SCM solutions based on investigation and collaboration with steel firms and worked as trusted advisors for SCM implementations at these companies worldwide. Five reports (each between 8,000 and 18,000 words in length) have created as the outcome by transcribing each of 3 to 6 recorded interview sessions per participant and let them finally signed by the experts. These reports have served as raw data for the findings arrived. Additional experts from SAP have been consulted for spot interviews to digital innovations as follow up investigations.

The industrial case studies and the rationale for the sample selection: The case study organisations used from the steel industry are both global players based in Austria and Germany, with subsidiaries and international involvement around the globe. Moreover, both steel companies are engaged in both high-end product segments and low-end ones. The Austrian steel company is well known for highly innovative involvement in both collaborative product development concerning high-end products, and in driving IS innovations. In referring to Kuolikoff-Souviron and Harrison (2005, pp. 270–271), the present study goes for polar types in

Tab. 1: S&OP IS capabilities' support to fit at company A; deductive application of qualitative collected case study data for triangulation with strategic fit measurements of ideal level (to-be) and actual level (as-is), from Nürk (2019, p. 52)

IS capability	Ideal level	Actual level	Fit	Quotation or paraphrased quotation	Paraphrase	Paraphrase category B	Related KPIs
Demand planning	2.3	2.0	1.7	*"One of the most significant spill-over effects of demand prediction is the indirect, but the clear impact on resources balancing for productions of different segments. High levels of visibility in activity integration are the result contributing to smooth operations, SC synchronisation and coordination."* (PA1)	Demand prediction has an impact on well-utilised resources and indirectly on how well the activities are integrated for fulfilling the expected demand.	Enablement: The reached accuracy is a result of high SC modelling and configuration efforts in DP and S&OP.	1. Forecast accuracy 2. Profitability 3. OEE and plant utilisation 4. Delivery adherence 5. Material & resource availability 6. Transportations adherence
Demand review	2.2	1.9	1.7				
Demand alignment with operations	1.9	1.7	2.0				
Real-time visibility of demand changes across SC	2.6	2.1	2.2	*"Increased visibility of demand changes' impact on material flow has improved customer-order due-date adherence, reliability, and improved operational excellence as well."* (PA1)	Increased SC visibility improves operational excellence and delivery adherence.		
SC modelling	2.4	1.7	2.6	*"Simulation capabilities support strategic decisions, pro-activeness, risk mgmt. also, increase SC agility by better decisions."* (PA1)	Capabilities for modelling and simulating different business situations and contradicting objectives are vital drivers.		
Plan simulation	2.4	2.2	1.4				

sampling the highly innovative Austrian steel company (A), that offers high-end products to the automotive industry on the one hand, and in sampling the traditional German steel company (B) with a stable product portfolio for the packaging industry on the other hand. Hence, the polar type rationale is seen in the products the companies offer and the resulting different characteristics in their SCM processes. Both organisations are large steel producers and have to plan and synchronise their supply chains on a global scale. The industrial case studies have been conducted by streams of six sessions for each company using a guide for semi-structured interviews, the questionnaire (Conant et al., 1990) and the developed measurement model for assessing the competitive strategy types and the degree of strategic fit (Nürk, 2019, pp. 50–55). All sessions have been recorded by Skype capabilities so as there are available in mp4 video format for careful analysis. The team at both companies include the CIOs and IS strategists, the leads for manufacturing and sales and marketing. The questionnaire for determining the competitive strategy type was filled out by the companies' senior management. Reports have been created with 20,781 words in length for company A and 15,488 words for company B as the outcome by transcribing each of the interview session that have been recorded carefully and accurately and let these signed by the head of the group.

Strategic fit measurement between IS capabilities and high-order SC capabilities: The strategic fit measurement was to assess directly how the capabilities at different levels are aligned for transforming and executing the business processes following the business strategy. Therefore, strategic fit of SCM processes occurs through aligning assessed actual levels of capabilities to estimated ideal levels. Through this approach, IS capabilities identified have been grouped due to the structures of the SCM processes and subsequently to the organisations' SC domains (Nürk, 2019, pp. 46–55). In referring to previous research by McLaren et al. (2011), the overall measures as listed in Tab. 1 has been calculated using the Euclidean distance method and a Likert scale with the levels '3' for a high-level, '2' for a medium-level, and '1' for a low-level of support to the strategic fit of each capability.

Qualitative data analysis using content analysis: The rationale for the proposed *content analysis* is based on the complexity of SCM data and its interrelationships (Hsieh and Shannon, 2005, pp. 1281–1283) and the different interpretation of SCM terms in different contexts. The *deductive category application* was used by manually *fitting* interview data meaningful to predefined categories of IS capabilities for SCM and proving the plausibility by triangulating these against the quantitative measurements of strategic fit, as described in detail

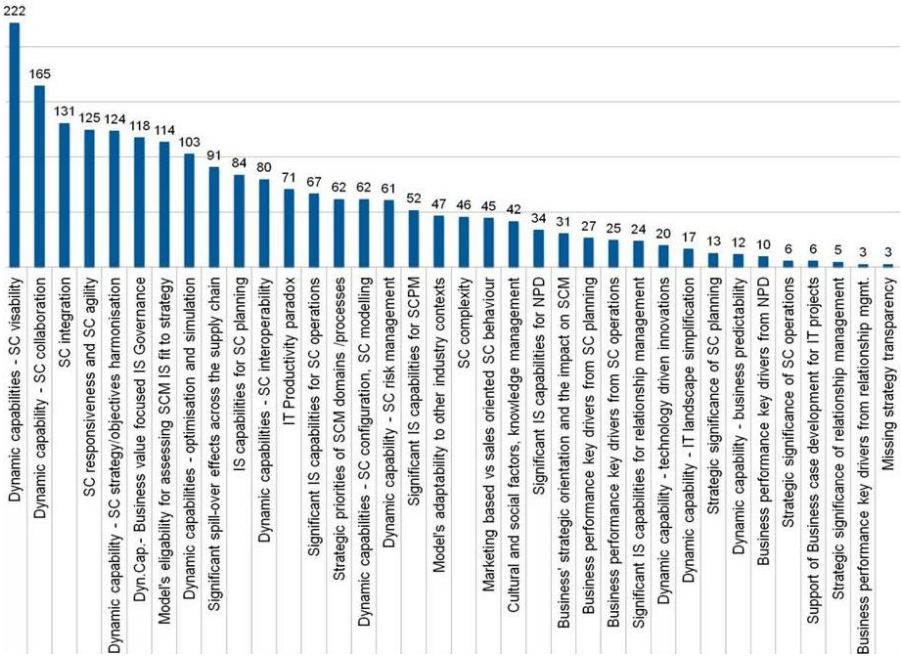

Fig. 2: Inductive format categories and their absolute frequency identified in the case study reports

in Nürk (2019, pp. 48–55) and highlighted in Tab. 1. The *inductive category formation* due to Mayring (2014) has been used for identifying further categories from the text content for developing in-depth findings to research objectives. For this reason, the online tool QCAmp for systematic text analysis based on the techniques of qualitative content, according to Mayring (2014) has been for used. For this reason, each transcribed case study report has been carefully reviewed to identify text passages that have a high relation to the research sub-objectives and assigned these to new categories. After new categories have been formulated, the selection criteria and rules have been established, and the reports have been repetitive review for identifying new relationships to these categories. Fig. 2 shows the categories that have been format as significant to research objectives and their absolute frequency within the reports collected at the SAP case study and the reports collected at the industrial case studies at steel companies A and B.

4 RESULTS AND DISCUSSION

Key capabilities for mastering SC dynamics and strategic alignment of SCM IS: For orchestrating IS capabilities of steel companies' SCM processes so as to moderate SC performance and antecedent capabilities of SC integration to deal with SC dynamics appropriately, the following key capabilities have been identified, (1) SC planning and optimisation capabilities, (2) SC simulation and visualisation capabilities and (3) SC design and SC modelling capabilities. The modelling of capability-patterns as yielded from strategic fit assessments have been identified as very useful for expressing needed levels for SC differentiation that can be used for IS configuration per companies' product segments. Moreover, such architectural artefacts with predefined organisational and technical configurations can increase SC agility in dynamic business environments significantly. Fig. 3 highlights a scenario where environ-

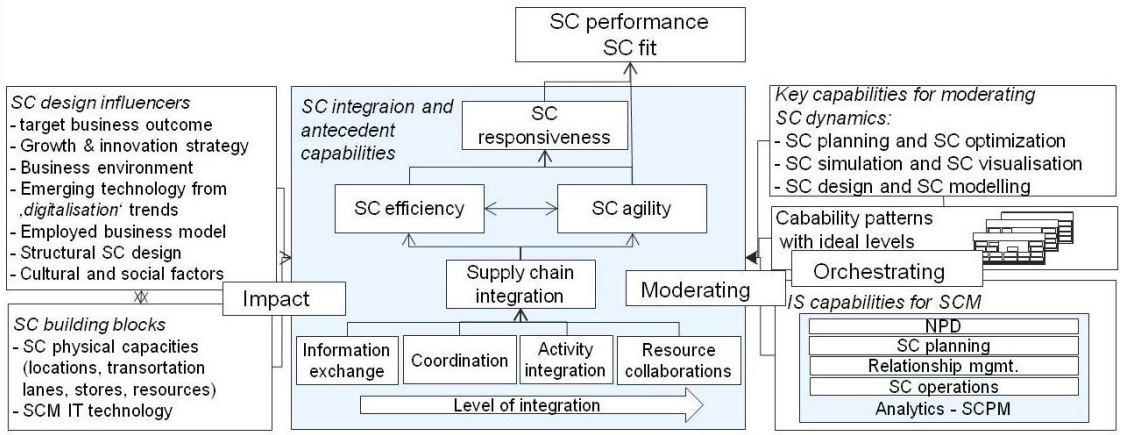

Fig. 3: The impact of SC moderating capabilities in SC performance (an author's view)

mental changes (left side) are affecting the levels of high-order SC capabilities needed for strategic fit (middle of the Fig. 3), and, how IS capabilities for SCM can be orchestrated by capability pattern (right side) dynamically for ideal levels of SCM IS fit.

Ambidexterity – balancing exploration and exploitation vs innovation and growth: Ambidexterity refers to a company's ability to balance exploration activities for variability creation with exploitation activities for variability reduction (Bledow et al., 2009) in a way to optimally acquire and assimilate new knowledge that can be exploited in innovations and will result ultimately in business performance. For this reason, the Portfolio Analysis provides a method for monitoring the proportion of products with a high market share but a low growth rate those come to the end of their life-cycle and need to be replaced by innovations. By this approach, companies can focus on reasonable effort for innovations to replace mature products in time. As a consequence, it provides valuable information for focused dynamic capability development for innovations that promises high-value potentials, and, therefore provides also initial information for the subsequent processes of segmentation, SC modelling and SC differentiation.

SC differentiation using customer and product segmentation: Following the above findings, a company's customer/product segment description can be enriched by information and characteristics useful for SC strategy and SC differentiation, which can be information about the value proposition, relationships, forecasting models and planning strategies and more. For this reason, the capability approach and the strategic fit measurement model that was developed by the author's previous research provide useful tools for bridging the business requirements to the IS capabilities as enablers and modelling theses as IS artefacts and dynamic capabilities. Finally, this information helps to differentiate the SC operating models such as for (1) Make-to-Stock (MTS) – producing stock-keeping units; (2) Make-to-Order (MTO) – where the same products are showing specific characteristic to customers; (3) Engineering-to-Order (ETO) – where the production or implementation procedure shows specific to customers and Assembly to order (ATO) – where the final production stage is configured to customer. By this approach, information that if interpreted together, can be combined by segments, which lead to coherence between portfolio strategy, marketing strategy and SC strategy.

4.1 The Impact of IS Capabilities for SC Planning to Strategic Fit

For safeguard SC profitability and SC performance, the levels of integration between demand management and supply management have been identified as the most strategically

relevant of steel companies in most cases. Sales & Operation Planning (S&OP) solutions help to determine business by predicting demand patterns that increase revenue and profit and provide plans to fulfil the demand in time and in a highly effective and reliable way; so as to satisfy the overall objectives such as service levels and profitability. Vice versa, the upstream and downstream processes have the highest impact on the S&OP domain by providing the entire SC capacity to fulfil the predicted demand with production and transportation resources. Their capacity is always constrained in nature, which limits production and presents a bottleneck. Such limitations by asset capacities have been identified as a key characteristic of the process industry and marketing-oriented businesses in general. This bottleneck also has a constraining impact on the sales figures and forecast to be realised. One of the main challenges that steel companies are facing is the complexity caused by the many constraints and dependencies need to be considered between processes and participants in planning supply chains.

Fig. 4 shows the high impact of the identified IS capabilities for SC planning onto all SC capabilities, including *second-order effects* on operational processes such as transportation. The high levels onto *coordination* and *activity-integration* show the significant impact of SC planning on operations by spill-over effects. Moreover, the figure shows the significance of IS capabilities for plan-modelling, optimisation and simulation for supporting business predictability and end-to-end visibility of supply chains. Furthermore, it shows the pattern of levels of support of the antecedent capabilities (ideal-levels) that would lead to ideal SC integration and ideal strategic fit. Finally, the right levels of support for the specific context can provide by IS capabilities for the antecedent capabilities of SC agility and SC responsiveness.

Value-based SCM has been evolved from cost and profit controlling to value-based management concepts to make the return on investment capital more transparent to the company and its shareholders (Kannegiesser, 2008, pp. 21–22). Indicators for measuring profitability were ratios between capital employed and the achieved business output such as Return on Assets (ROA) and Return on Capital Employed (ROCE), which have to provide meaningful analysis of profitability. According to Kaplan and Norton (1992, 2001), financial measures report the outcomes of past actions, but focusing on financial key indicators can promote behaviour towards short-term performance. Hence, they introduced the balanced scorecard and applied it with key measures driving financial performance.

Fig. 5 shows SCM value management concepts as part of a concise profit optimisation. There is a common view of the case study participants that effective financial management and financial performance measures are important prerequisites of operational performance management. Moreover, benchmarks in financial performance against competitors provide information to the firm's economic health in comparison to the industry average. SCM profitability depends on decisions in supply network planning and the levels of integration of the related processes. Moreover, as *'SC profitability'* is determined to a great extent by supply network planning decisions, high integration of cost control systems into S&OP processes has been identified as significant to support transparency in the planning of volumes and values. Concepts identified for managing value within the scope of SCM in the present study's target industry were examined in the subsequent sections in more depth.

Profit-focused supply chain planning: Asset utilisation in the most profitable way is highly important for steel companies as their production is very capital intensive. For this reason, transparency as to which products and which customers will bring the most profit will be highly important to secure margins. Subsequently, capabilities for reserving and allocating resources for highly-profitable orders were significant for steel companies. The conditions for profitable order placement were set in the S&OP processes, while sales order management will use these predefined conditions. Hence, forecast determination based on profit and service levels for product and customers presents a core objective of steel

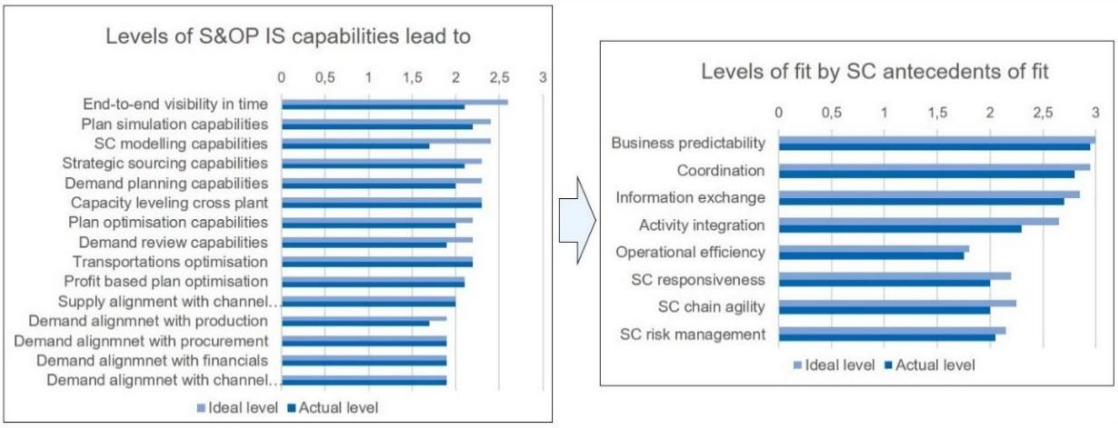

Fig. 4: Support of S&OP IS capabilities to the strategic fit of company A (figures from Nürk, 2019, p. 54)

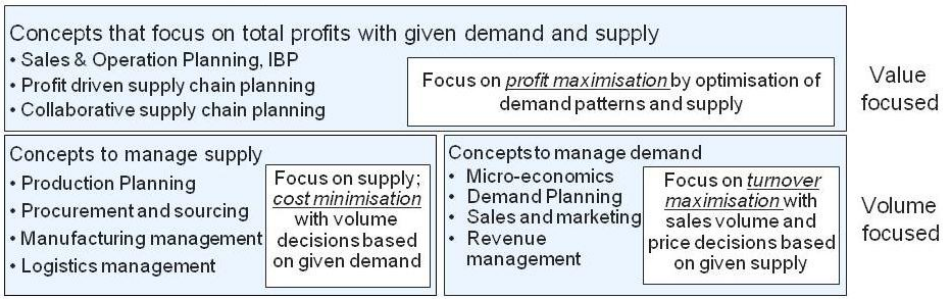

Fig. 5: Concepts in SCM for managing volumes & values (adapted from Kannegiesser, 2008)

companies' S&OP capabilities. At the highly innovative steel sample company, the most important objective of S&OP processes is to predict the most profitable plan that can be achieved with available and restricted resources. Moreover, long-term demand information for the expected product mix can be used for narrowing downtimes of important resources such as a blast furnace. Finally, sales-profit and resource-utilisation can be maximised at the same time using approaches such as the following:

1. forecast determination based on service levels and expected profit contribution;
2. forecast consensus based on business conditions and technical constraints;
3. sales allocation management based on consensus forecast and quotes of expected profit;
4. sales order acceptance management based on allocations and available supply.

The following S&OP capabilities were identified as key drivers for SC performance:

1. characteristic dependent demand planning; consider business rules in plan optimisation;
2. consider constraints and objectives in plan optimisation in a generic way;
3. increase plan profitability by demand prioritisation and finite capacity planning;
4. increase responsiveness to changing demand by alternative planning strategies such as plans with different product and demand mixes and capacity offers;
5. consider contradictory business objectives in plan optimisation;
6. ability to adapt plans to high demand as well as to low demand situations, which has been reported as important for steel companies for surviving.

The identified significance of supply alternative sourcing and consideration of transportation capacities show the necessity of highly

integrated S&OP processes to downstream processes such as sales order management and upstream processes such as production management. Finally, S&OP processes have to respond to fast-changing business conditions by quickly presenting new demand and supply situations in the most profitable way. High visibility of End-to-End processes and integrated collaboration capabilities are playing a major role in being responsive to changing market conditions. Hence, steel companies need extensive S&OP and Integrated Business Planning (IBP) capabilities for sustaining profit, such as the following:

1. extensive and highly integrated optimisation and simulation capabilities;
2. analytics capabilities for predicting demand and supply as reliably as possible;
3. collaboration capabilities for arriving at a consensus plan among stakeholders.

Profit optimisation versus delivery optimisation: S&OP processes have to deal with demand prediction and determination of raw material supply and resource capacity, and finally, the adjustment of all resources so far as possible with the ultimate market demand. For achieving the highest profit possible from the market demand, but, constrained by existing resource capacity and raw material supply, high integration of S&OP processes into operations processes of the downstream and upstream domain and finance, is needed for providing budgets based on the plan. Moreover, S&OP processes have to respond to rapidly changing business conditions by enabling planners to understand new demand situations as quickly as possible and integrating these into the supply plan in the most profitable way. Therefore, steel companies need extensive simulation capabilities for S&OP processes to be highly responsive to changing market conditions for sustainable business profit. As a result of these S&OP processes, a master plan as a reference is provided, which is aligned among the stakeholders involved and reflects the service levels and the planned profitability. Different levels of profitability for products and customers can be reflected in a master plan by this approach and can be selected most economically by subsequent sales processes. Using optimisation methods, the levels of profitability of demand positions are a criterion for selecting those in the master plan in case of restricted capacity. Hence, S&OP capabilities support steel companies in their long-term demand planning and supply planning by optimising the sales profit and the asset utilisation at the same time. The described approach helps to increase the profitability of the plan on the one hand and to decrease the complexity of the subsequent operational processes such as sales order management and production management on the other hand. The following core objectives of S&OP processes have been identified as significant in the case studies:

1. *Harmonise downstream and upstream processes* regarding the strategic objectives. For example, in many cases, the company uses the constrained S&OP plan to govern the acceptance process of sales orders concerning their profitability.
2. *From volume-based to profit-based decisions:* steel companies aim to shift from the pure volume-based demand and supply matching to a determination of the most profitable demand response. For this reason, they need to identify the best response opportunities and the required supply chain capabilities. For example, to get support on decisions such as *make or better buy* of subcontractor services – and for evaluating investments in new mills.
3. *One common plan for global synchronisation:* the increase in product proliferation and globalisation strategies of steel companies results in requirements of aggregation and scalability in S&OP processes. A key requirement identified from the case studies is that all information supporting business decisions shall be stored in *'one version of the truth'* to keep the global teams synchronised.

SC visibility versus SC complexity: Demand visibility is related to both of the defined IS fit types *'coverage'* by the implemented IS capabilities for Demand Planning and to a considerable extent to *'enablement'* through appropriate

modelling of hierarchical planning-data structures. Besides, *enablement* refers to modelling appropriate planning horizons and aggregation granularity and reflect the company's sales and distribution structure as well as the workflow design for the demand consensus process between the involved stakeholders. Moreover, demanding S&OP scenarios such as in the steel industry required planned customer-product combinations described by characteristics of being able to prefer combinations with high service levels or high-profit contribution by an optimiser. Such requirements in demand planning data show the dimensions and details that need to be modelled, but, also determine the extent of complexity that needs to be implied. Case study A shows that S&OP capabilities can significantly reduce the complexity of the SC operations processes through increased plan visibility, enabled by optimised master plans (Tab. 1, case study participant PA1).

The following characteristics of the steel companies' SC operation process show the requirement for extensive SC visibility and the complexity in SC modelling to provide these capabilities for a detailed End-to-End process perspective:

1. the manufacturing process is a continuous process rather than a discrete one;
2. the operations process is handled in most cases as a Make-to-Order process, and configured with quality and grade characteristics to customers' needs;
3. assets are capital intensive, and production capacities are restricted, and hence need to be utilised most effectively and profitably;
4. steel producers offer a wide variety of products and characteristics and face distinct fluctuations in profitability and demand.

The master plan acts as a mediator between demand management and supply management and supports sourcing decisions to meet customer's service level agreements and helps to fulfil companies' profitability objectives. It is based on aggregated production flow quantities, production capacities, and balances the cost of capacity and inventories against the master plan's profitability. Sales allocations for profitable product and customer combinations can be created based on the master plan, to reflect profitability and support reliable order processing. As a result, the master plan determines the supply options those constraint the demand. According to the case studies findings, demand-prediction and demand-alignment provide the foundation for balancing resource plans of the companies' plants, and therefore, has a significant impact in reducing the efforts for *'coordination'* and *'activity integration'* of operations' activities. Situations, where sales representatives cannot deliver promised products to customers because of capacity bottlenecks, are regularly recurring. Hence, demand prediction is seen as a capability with significant impact on delivery performance by spill-over effects from S&OP processes to operations and sales order fulfilment. Fig. 6 presents the levels of SCM and the positioning of Master planning, which needs to reflect the predicted incoming orders as accurate as possible as steel companies cannot change their technological processes in the short term.

The impact of SC planning capabilities on SC performance: Demand Planning capabilities enables segmenting customer and product combinations according to their profit contribution. S&OP-optimisation capabilities enable creating forecast plans by preferring demand of customer product combinations categorised as highly profitable, rather than combinations with lower profit. Hence, optimisation capabilities can support SCM processes so as to influence a steel firm's profit contribution positively, and decisions for the most profitable product mix and the most effective supply sourcing can be supported by S&OP planning capabilities. Moreover, strategic decisions on long-term sourcing of raw material and production capacities can be based on these processes. These decisions have a high impact on further product mix effectiveness and supply sourcing efficiency, and, therefore, on long-term profit. Based on that information, contracts for raw material can be negotiated with suppliers as early as possible. Particularly important supply sourcing decisions are those for high-end products for the automotive industry, which has to be produced onshore because

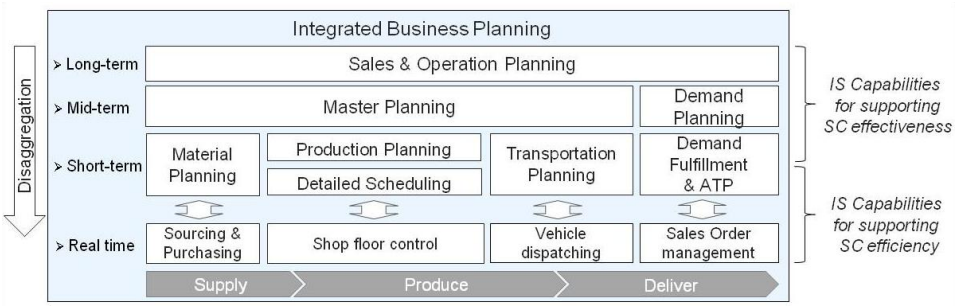

Fig. 6: The master plan for balancing demand & supply (adapted from Stadtler, 2005, p. 579; Meyr et al., 2002, p. 99)

of shorter distances to customers. Moreover, S&OP processes can deliver information about low-end products that are no longer profitable because of declining margins. Finally, production efficiency can be supported by S&OP processes by predetermined, effective patterns of orders schedules. Hence, optimisation and simulation methods are core capabilities for creating master plans.

Methods for plan optimisation in dynamic business: Master plan creation and *decision making* are supported in profit-oriented supply chain planning scenarios by different complementing methods, such as visualisation and analysis, *plan optimisation*, *simulations* and *plan references*.

The plan reference method: Reference models or in industry terms so-called *'best practice'* were used to support decisions by comparing with accepted good outcomes. The cases study has identified the following KPIs as the most important for steel companies: *'resource utilisation'* (in tones as a typical measure for steel companies; ROI), *'delivery reliability'*, *'inventory levels'*, and *'planning accuracy'* in volumes and demand patterns (Tab. 1). However, *demand patterns* represent an important instrument for steel companies for creating plans with different levels of profitability. Hence, modelling of demand patterns by comparing with good states in levels of profitability represents a key capability for profit-oriented supply chain planning.

The plan simulation method: Plans that reflect situations expected in the future can be created using simulation methods for supporting decisions. Simulations are prescriptive methods for supporting decisions in the planning of production and logistics. In the sample industry, simulation refers to creating variants of master plans using optimiser capabilities of SCM applications, to search for solutions in supply and demand that optimise profitability at a given resource capacity. However, uncertainty in profit-oriented SCM is a key motivation in other industries such as the automotive industry as well. It allows the comparison of different scenarios about demand volume and value to simulate capacity planning. SCM experts from SAP and participants of the industrial case studies rated *simulation capabilities* as significant for plans selections from different possible scenarios, based on expectations. Such *simulations* can support decisions concerning the overall SC strategy as well as decisions in SC planning and SC operations. The supported decisions relate mostly to demand and supply to reduce uncertainties and to provide alternated master plan variants for different situations in advance. Such simulated plan alternatives can reduce SC risk through increased awareness of the impact of possible environmental conditions on the plan results. The simulation method plays a key role in creating capability patterns, as architectural artefacts to increase SC responsiveness.

The plan optimisation method: Mathematical methods such as the *SIMPLEX* and *Branch & Bound* algorithms are used to solve optimisation problems in industrial operations for searching optimal results. Optimisation problems are characterised by a structure consisting of an objective function $H(X)$ to be maximised or to be minimised by varying the decision

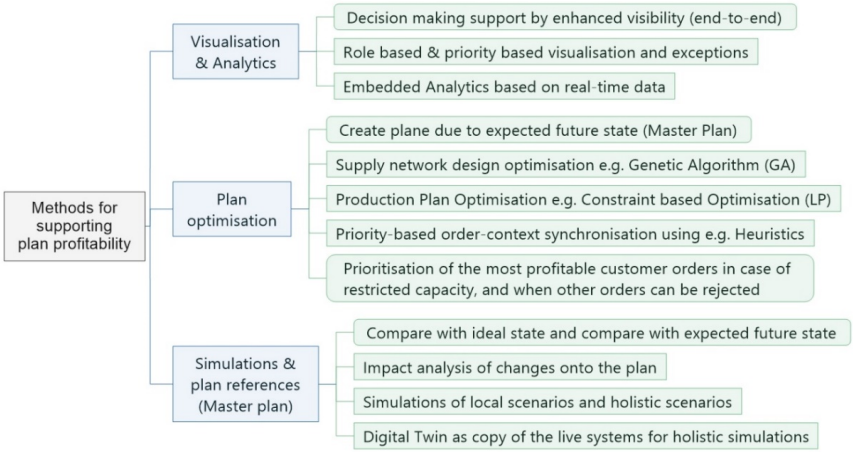

Fig. 7: Methods for supporting supply chain plan profitability

variable vector X, with X subject to a set of defined constraints θ leading to max (min) $H(X)$, $X \in \theta$ (Tekin and Sabuncuoğlu, 2004, p. 1067).[2] In contrast to local optimisation, global optimisation methods focus on finding global optima (minima or maxima) of an objective function f subject to the constraints S (Floudas et al., 2005, pp. 1185–1186). There is a consensus between the findings of the present case studies and the literature that a global value optimum should be reached in SCM scenarios instead of a local optimum (Floudas et al., 2005, pp. 1185–1186). Moreover, multiple-objective, instead of single-objective optimisation focuses on balancing multiple and competing objectives such as overall profit maximisation and further objectives of different stakeholders in the supply chain. Multi-objective optimisation requires evaluation and balancing of contradictory objectives such as customer's satisfaction versus one's profit. Modern SCM solutions use algorithms such as *Constraint Programming (CP)* for considering constraints in optimisation problems such as production scheduling (Kannegiesser, 2008, p. 57) and *Genetic Algorithms (GA)*[3] for large combinatorial problems such as in supply chain network design.

The plan analysis and visualisation methods: Analysis and visualisation methods provide capabilities for action-orientation, decision making by focused extraction, analysis and visualisation of data. These methods target increased the transparency of supply chain processes and an easy understanding of planning results. The methods introduced can be combined to support decision making. *Simulation-based optimisation* provides a prescriptive method for decision support (Kannegiesser, 2008, p. 58). SCM solutions provide comprehensive optimisation capabilities for creating consistent master plans. Such solutions are providing simulation capabilities for analysing effects of plan changes to End-to-End processes across SC networks, which covers transportation, manufacturing, and distribution processes, as well as stock, supply sourcing and procurement processes. Many steel companies are using such optimiser technology for their S&OP processes. Fig. 15 (in Annex) highlights examples of optimisation methods that were used in SC planning and SC operations on different levels.

[2]Since the simplex algorithm invention for LP problems by Dantzig in 1947, methods such as the branch & bound (Land and Doig, 1960) have been proposed for different mathematical programming models (Liu, 2011, pp. 22–33).

[3]GAs as meta-heuristics are commonly used to generate solutions in relying on bio-inspired operators such as mutation, crossover and selection. The GA is used by SCM applications for creating profit focused master plans.

4.2 The Impact of IS Capabilities for SC Operations to Strategic Fit

Key performance drivers of upstream and downstream processes: According to the experts' observation, there is a trend for steel fusion to be moved closer to the mines and the supply of ore, while the manufacturing of end products such as plate, tubes, and coils, and the associated differentiation stage relates to the customers' locations. As examples of such supply network setups, the steel plants of ThyssenKrupp in Brazil and ArcelorMittal in Mexico can be mentioned, where steel slabs are produced close to raw material supply in Latin America and transported to Europe and China for hot and cold rolling processes. A further example is the ThyssenKrupp cold rolling plant for stainless steel in Shanghai, where slabs were exported to Europe as semi-finished products. The primary objectives of this approach in placing the stages of product differentiation as close as possible to the market side are seen in enhanced responsiveness in case of demand changes and increased standardisation capabilities for raw material supply and semi-finished products. Managing such supply networks requires capabilities for planning and coordinating the transportation of semi-products from the steel fusion plants to the locations of finishing facilities synchronised to the local production, and finally, to external service centres for surface coating. For this reason, the following capabilities have been identified as significant key drivers of SC performance of steel companies' upstream and downstream processes:

1. *capabilities for plan optimisation* that can deal with technological constraints and with cost objectives for utilising capacities most effectively;
2. *capabilities for aligning plans with the actual sales demand product mix* to provide the right supply of material and resource capacity;
3. *capabilities for aligning supply,* such as material and capacity of production, transportation, and distribution resources with sales demand on a flexible basis;
4. *simulation capabilities* for reviewing plan reliability and profitability.

SC traceability by configurable production and batch valuation: High variability in steel grades wanted by customers is provided using product configuration capabilities. This variability needs to be propagated in most cases throughout the entire supply chain, from sales orders in batches of raw material. Hence, capabilities for handling batches with evaluating characteristics were prerequisites for tracing customer order positions onto raw material batches. Traceability capabilities were seen as highly relevant for return and complaint management as well as for tracking batches from suppliers throughout the supply chain until delivery to customers.

Fulfilment reliability and profitable order selection at the same time: Fast and reliable promising of sales demand and effective mapping of actual sales positions to supply as well as to allocations have been identified as significant. These are also core capabilities of the backlog management process of sample company B. Moreover, reliable demand fulfilment about delivery adherence is strongly impacted by sales order processing capabilities such as ATP[4] and CTP[5]. Steel companies use these capabilities in sales order processing to improve on-time delivery and reduce the opportunity losses by generating reliable quotes and finding the more feasible supply options. Finally, they help to increase profit by accepting orders with higher profit. Maintenance prediction for key resources has been regarded as significant for safeguarding the revenue sustainability by planning and scheduling with reliably available capacity.

Dynamic planning capabilities through innovative MRP concepts: In using production planning and scheduling capabilities, steel companies create detailed production plans for the short-term. The core objective is to create

[4] Available-To-Promise (ATP) is a business function that provide response to customer order requirements based on material availability to the requested quantity and due date.

[5] Capable-To-Promise (CTP) is a technique amending ATP taking existing inventory and the output of future period into consideration based on available production capacity and lead times of components.

highly effective production plans for the following criteria:

1. meet customer-demand reliably;
2. create order cycle times that are as short as possible;
3. consider available resource capacities and secure their effective utilisation;
4. reduce efforts for resource set-up and maintenance;
5. secure material availability and minimise inventory and work in progress.[6]

Dynamic MRP capabilities of a new generation of Enterprise Management Systems: As a result of the criteria above, a good plan shows contradictory objectives where involved parties need to compromise on a feasible approach. On the one hand, manufacturing lead times and inventory will be reduced; on the other hand, delivery performance to customers will be improved. MRP concepts of new Enterprise Management systems uses in-memory database technology, which enables companies to perform their overall planning run in very short time as the underlying database technology presents the company's full supply chain data model in the SCM IS working storage. Moreover, this approach provides real-time processing capabilities for planning and scheduling activities as well as enhanced end-to-end visibility of the supply chain. Moreover, in-memory database technology enables SC exception management and alert handling as well as supply chain analytics and reporting activities based on real-time supply chain data. The front-end applications of these Enterprise Management systems emphasises on user-centricity. The combination of the real-time data processing and user-role-centred front-end applications provides MRP planner with very high SC agility, SC responsiveness and SC visibility for priority and exceptions based MRP analysis.

Dynamic SC synchronisation – order scheduling and optimisation: A production schedule specifies the sequence of orders on given resources. For bottleneck resources, scheduling of orders needs to consider constraints such as finite capacity and fixed predefined sequences. The given master plan sets the frame for these planning and scheduling activities. By this approach, the plan is scheduled with a finite capacity to determine feasible dates for orders and activities in material availability can be considered at the same time. The production plan can be scheduled using optimisation capabilities or heuristics. The approach used depends on the objectives of the schedule: (1) when emphasising on scheduling single-order-contexts such as for Engineering-to-Order production (EtO) with focus on order priorities, a heuristic approach is preferred; (2) when contradictory scheduling objectives need to be considered in seeking an overall solution of a plan, an optimisation approach is preferred. The objective of an optimisation process is to find the best solution according to given objective functions and constraints. Moreover, the objective is to create a plan that satisfies the interests of stakeholders involved in the planning process by influencing the optimiser by setting the variables of the objective function such as virtual costs. Mathematical algorithms are selected based on the complexity of the scenario. An example for optimising the schedule of a production plan in minimising the control costs can show as follow:

$$\text{Objective function} =$$
$$= \text{minimise } (w_1 + w_2 + w_3 + w_4 + w_5),$$

where w_1 is total lead time, w_2 is setup time, setup cost, w_3 is max delay, w_4 is sum of delay and w_5 is production cost.

Constraints that determine the decision area for searching the optimal solution can be:

- C_1 availability of raw material and predecessor orders;
- C_2 capacity restrictions (finite capacity, shift models, downtimes);
- C_3 fixed patterns of order sequences, and more …

SC agility by preconfigured plan alternatives: The optimiser searches an initial solution and aims to optimise it by iterative approximation

[6]Work in progress (WIP): WIP is material on the shop floor or on the plant, in the process of transformation and therefore currently being worked on.

within an as geometrically defined convex polyhedron that describes the decision area defined by the planning constraints. Depending on the planning complexity – quantity and relationships of production-activities, cross-plant-dependencies, raw material and sales order relationships needed to be synchronised – such an optimiser run can take between minutes and hours, and the plan improvement time increases exponentially. As mentioned, the optimisation objective is not to reach an exact mathematical solution, but, rather plan the compromise the contradicting objectives of the stakeholder. The interviewed experts at SAP stated a needed timeframe of 1 to 3 months as an average in an implementation project for fine-tuning the optimisers weighting factors to reach such a compromised plan. Such a timeframe is not feasible in an ongoing business when business conditions were changing on short-term. For this reason, identifying needed plans and conditions in advance using simulation capabilities will help to identify configurations and predefine patterns as architectural artefacts to increase SC responsiveness.

Dynamic replenishment concepts: Besides the traditional MRP planning approaches of forecast-based planning (deterministic) and consumption-based planning (stochastic), there are innovative planning approaches for dealing with demand uncertainties and volatility of supply in a dynamic and agile way to safeguard supply chain resilience and demand fulfilment.

1. *Dynamic stock buffers and SC flow synchronisation:* High stock levels are needed when the lead time is higher as the delivery time accepted by customers, and for creating economies of scale. On the other side, a raw material stock is capital intensive and can run out of shelf-life in some cases and need huge space such as in the steel industry. Concepts such as Demand Driven replenishment offer dynamic ways to create stock buffers at strategic points within the supply chain for compensating volatility in demand and supply and enable a smooth production and resilient material flow at minimal stock levels. The concept of Demand Driven MRP is originated from the lean management concept Actively Synchronized Replenishment (ASR) and related to the Theory of Constraints (TOC). Such an approach safeguards work-in-process stock levelling for steel making process flow.

2. *Multi-Echelon inventory optimisation (MEIO):* While DDMPR focus on smooth production flow with minimal stock in assembly systems, MEIO aims to balance stock levels against promised customer service levels within multi-tier supply chains.

Both concepts aim to avoid bullwhip effects where depend demand rises within the supply chain by upward fluctuations due to planning procedures such as lot sizing and forecast errors.

SC synchronising and scheduling concepts of the process industry: Different industries with different manufacturing and material flow concepts are also using different order scheduling methods for synchronising their supply chains. Companies of the process industry such as chemical and pharmacy companies often use optimiser capabilities to create holistic plans for their make-to-stock production, synchronised as campaigns of orders for each product to minimise expensive and time-consuming resource setup efforts. Moreover, to create a continuous flow across product stages and resource networks. There are variations of this concept such as the sector-specific *'Block Planning'* and *'Coffin shape'* scheduling approach in the steel industry where the shape and sequence of orders for different products are clear predefined based on constraints of the process technology.

SC synchronising and scheduling concepts of the discrete manufacturing industry: Companies of the discrete industry with Make-to-Stock operating model uses holistic optimiser scheduling for order synchronisation as well. Companies with focus on Engineering-to-Order (ETO) approach prefer to use heuristics to schedule the customer-specific order contexts based on priorities and availability of raw material and resource capacity. Companies of the automotive industry focus on lean concepts to safeguard a continuous flow of the product mix at the assembly line that reflects exactly

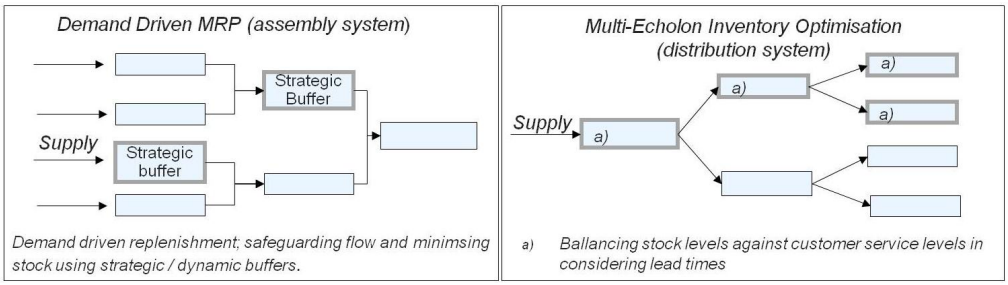

Fig. 8: Dynamic stock levelling in assembly and distribution scenarios (an author's view)

the rate of the demand. All dependent components, delivered from both internal and external suppliers, need to be provided Just-in-Time to the order flow at the assembly line.

Lean management versus continuous flow in the process industry: Companies in the discrete manufacturing industry primarily adopt lean management principles. The *production rate* in lean scenarios is determined by the *overall sale rate* of the product mix that is produced by the particular production lane. The production line is designed using lean principles such as *'Value stream mapping'* methodology and is equipped with lean methods such as *'Kanban cycles'* for material replenishment and methods such as *'rapid hunting cycles'* for labour force optimisation. Such scenarios require a reliable forecast of the model mix produced with a production line. Lean management principles play a minor role for steel companies and companies in the process industry. Instead of this, reliable schedules of continuous material flow with overlapping send-ahead quantities are important for these to safeguard the continuity of the technical processes.

Collaborative processes for safeguarding fulfilment: The following collaborative processes have been identified as significant for sharing information and resources in connected manufacturing ecosystems: (1) engineering change management such as phase-in processes for new products and phase-out processes collaboratively with engineering, manufacturing, suppliers and other related stakeholders; and (2) approval processes with suppliers for ensuring that they can deliver components that meet quality requirements and (3) quality data exchange between engineering, manufacturing, warehouse management and others. Finally, (4) collaborative equipment sharing and plant maintenance for ensuring services on-time and predict maintenance schedule reliable for factory capacity planning.

Overall Equipment Effectiveness for measuring productivity: The main KPI in the process industry called Operational Equipment Effectiveness (OEE) reflects the effectiveness of processes; covering qualitative measurements of the products in figuring out the process outcome. This KPI is particularly important in light of the high capital-intensive resource input in the sector. The OEE does not consider the profitability of the different products. As examined in previous sections, S&OP processes provide plans optimised on the profitability of the planned customer/product combinations. Hence, combinations with high contribution to profit can be preferred to realise in the case of restricted production capacity. Therefore, profitability can be managed on a master plan level using advanced S&OP planning capabilities. OEE management helps to transform the planed profitability most effectively by operational excellence.

EDI processes for synchronising multiple-tier supply chains: Automotive companies are managing their extended supply chains usually fully automated. OEMs (original equipment manufacturers) and their suppliers are communicating messages between their IT systems by electronic data interchange (EDI). Fig. 10 provides an overview of a *Just-in-Sequence* EDI process and the message-exchange between an OEM and its tier suppliers. Multiple tier suppliers can enhance the process chain in practice. An OEM communicates the demand

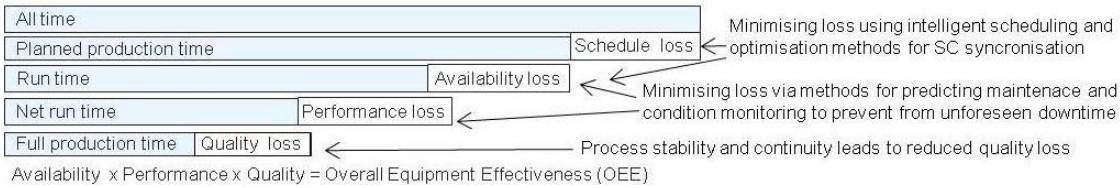

Fig. 9: The OEE as KPI for measuring effectiveness of processes and SCM methods (adapted from `oee.com`)

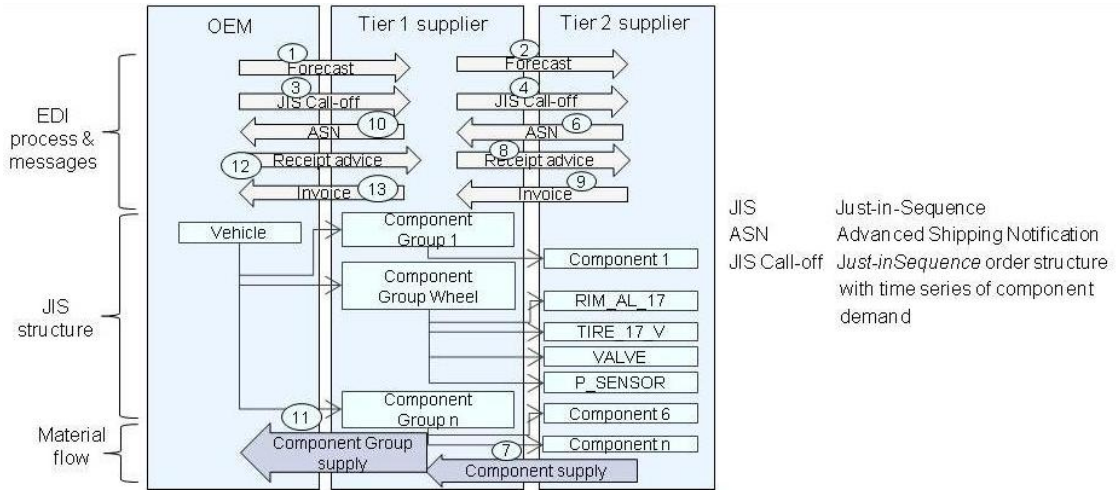

Fig. 10: Example of a multi-tier SC synchronisation process via EDI (an author's view)

for a specific part by a *forecast message* which provides the supplier a decision basis for calculating the own demands. *Just-in-sequence (JIS)* messages were used to communicate the component demand of complete BOM structures that are required for final assembly of cars configured by customers. The JIS-messages contain the sequences in which the parts must be delivered to the OEM's assembly line. With an Advanced Shipping Notification (ASN) that contains information such as used pallets, boxes, serial numbers, the supplier pre-informs the OEM about an upcoming delivery. The OEM confirms the receipt of the ASNs to the supplier by a functional acknowledgement, and as soon as the OEM proceeds the shipped goods, the supplier gets a receipt advice, which provides the basis for the credit note or an invoice message.

4.2.1 Value Potentials of SC Business Models from Industry 4.0 Innovations

SCM possibilities driven by the Internet of Things (IoT): The increasingly internet-based networking represents a major driver of change in the economy and society. The Internet of Things refers to a world in which uniquely identifiable objects and devices communicate and interact with each other. Previously non-interacting objects will get interoperable and digitally connected in global neural networks and virtually presented in the *'cloud'*. New possibilities emerge in all SC domains enabled by IoT solutions such as demand-signal-sensing from social networks to enhance planning and marketing capabilities. IoT devices such as for sensors have to connect with other IoT devices and in most cases cloud-based applications using the internet and IoT Platforms that provide the connectivity to manage the data that can come from hundreds of sensors. There are many IoT Platforms available that provide

deployment options with focus on services such as the following:

1. integrated machine learning for automating complex big data analytics;
2. predictive analytics and failure for increases uptime;
3. rules engine for message evaluation and alert monitoring;
4. automated sales orders creation and capturing potential opportunities;
5. marketing-notifies customers through texts directly on their devices.

Big data management refers to the IS trend of processing huge amounts of data to get appropriate data for faster decision making to increase business performance. The major proportion of new data is expected to be produced by machines talking to each other in automated scenarios. Hence, only a fraction amount of this data will be of real value in the marketplace. And even today, only a small proportion of the produced data have been explored for its value by analytics. Scalable data management and analytics systems allow fast and effective processing of *'big data'* to create *'smart data,'* from which new products and services can be created. Big data solutions accelerate decision-making to optimise business processes by generating meaningful information considering non-visible factors. Within the Industry 4.0 and Smart Service environments, big data analysis refers to the following components (adapted from Khan et al., 2017; Lee et al., 2014):

1. connection and sensing (networks, sensors, platform, cloud), Software as a Service (SaaS);
2. cyber-physical systems and self-learning Smart Services for SCM;
3. context and content (pattern, cross-context, correlation and sensemaking);
4. collaboration and sharing in supply chain ecosystems;
5. orchestration and customisation (alignment, personalisation, configuration and rules).

Autonomous systems are intelligent machines or group of machines those execute high-level tasks without being specifically programmed and without human control (Bekey, 2005). In comparison to automated systems that process predefined, engineered sequences of operations, autonomous systems can deal with unforeseen events (Tenorth and Beetz, 2013; Zühlke, 2008). These systems can deal with unforeseen events on an ad-hoc basis by flexible orchestrating their capabilities, which is also known as *sensomotoric skills*. This autonomy enables a system to respond quickly to unexpected events and varying environmental conditions intelligently and effectively without must to be reconfigured. The capability of autonomy enables the system to modify the course of actions and to react fast to variations in a production scenario based on local autonomous decisions without central replanning. Hence, autonomous systems are key enablers of flexibility industrial automation applications, and, are the basis of Cyber-Physical Systems. Moreover, simulations are an essential part of an autonomous system for looking forward to consequences of actions in particular situations enabling decisions between alternatives. CPSs enable intelligent technical objects those interact with each other in networks and via IoT. Embedded systems and online services can work together in the form of cyber-physical systems. Moreover, Smart Services are enabled by CPS and IoT. Hence, CPSs are an important contribution to the paradigm change to digital business models. Value chains of sectors, such as the automotive industry, energy-economy, and health-care, were expected to transform fundamentally based on these digital capabilities (SAP SE).

Basic components of CPS and challenges: Sensors were used to collect data from the physical system and from the environment, which is used for processing due to determine the further course of action in an autonomous process. Actors are receiving the information about the further course of action and are initiating activities required to govern the physical processes in a way to reach the business goals. *Modularity* is a major topic in industry 4.0 scenarios based on the various requirements for sensing and acting in different contexts and physical environments as well as *autonomy* as the key capability to deal with unexpected

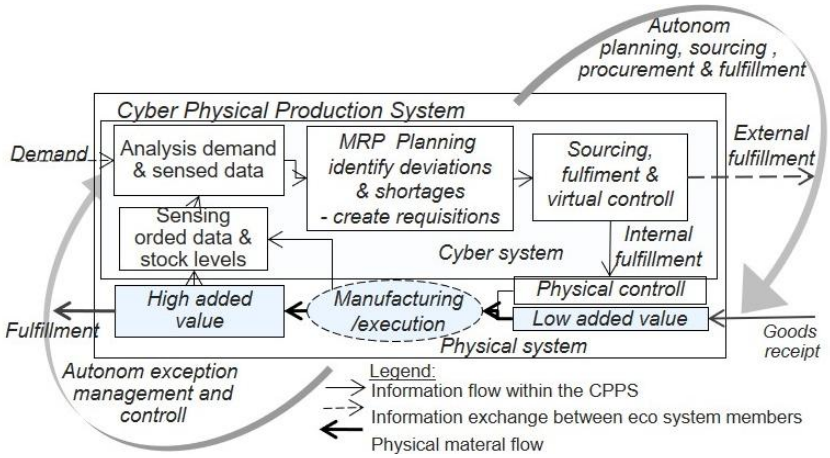

Fig. 11: Basic Cyber-Physical Production System (an author's view, encasing Trinh, 2016, p. 16)

exceptions in a reliable way. Among the present challenges and objectives of the research for CPS are *complexity reduction*, *development of controlling architectures*, *distributed sensor networks* and *compatibility standardisation of components for interaction and integration* among others (Geisberger and Broy, 2012). The concept of the CPS has been pushed forward by Acatec (Kagermann et al., 2013) using it for new digital production concepts such as Industry 4.0 scenarios with high levels of flexibility and autonomy along products and systems life-cycles. These concepts can lead to significantly increased competitiveness by new business models based on it.

A CPS for Production Management: In industry 4.0 scenarios, production systems and production units have to respond autonomously to new orders or unforeseen events by modifying order priorities and order sequence during operation on an ad-hoc basis, to name an example response. For mastering such situations, comprehensive and reliable knowledge about the current state of the production system, the further alternative possibilities and the system's capabilities is required. Moreover, high degrees of interoperability at the business process level and on technical levels are required for acting both partly and fully autonomously. Fig. 11 shows a basic CPS for production management. It demonstrates how the system can identify demand and sensed exceptions in manufacturing in an autonomous way and how it addresses these to planning and subsequently to internal and external fulfilment. A CPS can be a part of a CPS as well. Comprehensive, SC status information about processes and condition data of orders and resources can be gathered in a CPS by sensors. The processed data can be addressed via actors to initiate the physical actions as reasons to the initial status change. Each status change of supply chain data can be updated for members of the ecosystem in a reliable and trusted way using *blockchain* technology. Based on predefined rules, CPSs can interact in an autonomous way to identify unexpected demand and source potential suppliers within the ecosystem on an ad-hoc basis. The 'blockchain' concept, similar to a distributed ledger technology, shows promising for supporting SC processes based on CPSs. Moreover, the concept of Smart Contracts can support the autonomous application of predefined rules within an SC ecosystem.

Trusted SC collaboration through blockchain technology: International SC business partners require both improved document workflow and tracking visibility of goods transported across the globe. The blockchain approach supports a secure and transparent shared network and provides end-to-end visibility of status change to each participant on a real-time basis. A blockchain is a distributed database that maintains a continuously-growing list of records

secured from manipulation and modification. In referring to Morris (2016), Nakamoto (2008) and Popper (2016), Kim and Laskowski (2018) describe a blockchain as a distributed database that maintains a continuously-growing list of records secured from manipulation and modification, which consists of blocks with batches of individual transactions containing timestamps and a link to a previous block. Moreover, the used cryptographic technology *"offers a way for people who do not know or trust each other to create a record of who owns what that will compel the assent of everyone concerned… It is a way of making and preserving truths"* (Kim and Laskowski, 2018, pp. 18–22; The Economist Staff, 2015, p. 1). The approach provides improved business network's efficiency by increased visibility to all members of an ecosystem. Further benefits are significantly reduced settlement time and SC overhead costs and reduced risks of collusion and tampering based on full transparency to all actors and increased trust through shared processes and record keeping. Hence, the system inherent fraud prevention and reduced integration complexity result in reduced intermediation and increasing efficiency. Hence, the Blockchain technologies promise highly secure and immutable access to SC data and support digital SC scenarios in providing capabilities for trusted collaboration.

Value Drivers for the Blockchain technology in SCM are trust between ecosystem participants without central authority. Moreover, the data proceed and exchanged in the network consists of high quality and are up-to-date, consistent, accurate and in compliance with regulations and transparent to all peers with full history. The value created is transferred in real-time by this approach, which is expressed by the term *'exchange of digital assets.' Smart Contracts* assist process autonomy by providing system-enforced inter-company business rules. IoT devices are writing to smart contracts, which can provide real-time visibility of status information at each step of an enterprise entire supply chain. Such enhanced SC visibility provides tracking of goods across plants, distribution centres and retailers and real-time monitoring of stand-up and tear-down processes. These capabilities allow simplifying complex multi-party delivery systems and granular inventory tracking. Moreover, they potentially improve SC financing and insurance through enhanced tracing and verification capabilities. Neutral collaboration platforms for shared business data and business logic enable new consortium business models with trusted-multiple party scenarios with easy extension when new stakeholders will participate. The following characteristics having been identified in the SAP case study as indicators for potentials by a blockchain approach:

1. a multi-party scenario with three or more participants, preferably across companies and industries, e.g. consortia, and missing trust between members;
2. participants should be on eye level and multiple writers in the scenario;
3. a shared repository with a joint data model, semantics and standardisation;
4. need for transparency to reduce risks, avoid fraud, and to be compliant with regulations;
5. transfer of digital assets, which can be anything that comes in a binary format with the right to use such as digital documents, data, metadata, services, permissions and more.

Characteristics of Smart Services: Smart services are the core components of digital business models for generating value to businesses and customers and further ecosystem members. They are managed via platforms and are provided by internal and external service providers for orchestrating and operating the modular processes of ecosystems. They are interacting between sensors, systems and actors and are based on algorithms, and can adapt to changing contexts over time to sustain autonomous value creation in ecosystems by manufacturing systems and logistics. Cost of Smart Services is very limited as the marginal costs of digital value creation are nearly zero and can be distributed across the ecosystem that uses the service (Rifkin, 2015). The paradigm change from physical assets to digital assets reduces marginal costs significantly. Finally, Smart Services shift the focus from product ownership to their value-oriented usage.

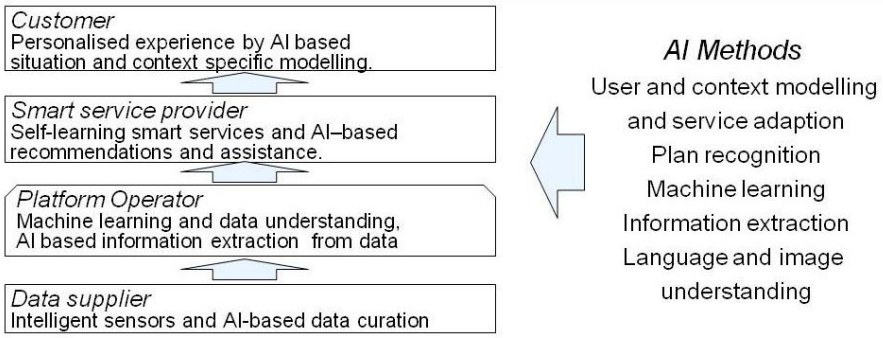

Fig. 12: Self-learning Smart Service architecture (Kagermann et al., 2013)

Potentials of Smart Services are such as the detection of deviations in processes and deriving measures as responses and autonomous processes by orchestrating predefined rules and flexibly combining with other services to adapt to environmental needs. Hence, they can increase process effectiveness and help avoiding waste and optimise resource usage, and solve unforeseen problems at an early stage. Their potential for external processes covers the digital interaction with customers, and to gather and analyse customer data on a large scale and individual perceptions to adapt the Smart Services to users needs. Such Artificial Intelligence (AI)-based approaches lead to self-learning services for selecting and meaningful interpreting collected data, which enable the extraction of context information that can be used for situational service adaption. Moreover, the reflection of acquired knowledge to different situations and contexts can lead to meta-knowledge meaningful for the business and customers. In sum, the potentials can lead to increasing innovative strength, turnover and profitability as well as increase customer loyalty and can provide a significant competitive differentiator. Fig. 19 (in Annex) highlights the building blocks for Smart Services modelling.

Digital-transformation of SC business models and opportunities: The following major areas were seen by SAP SE with significant value potentials from innovations and increased business process autonomy: (1) *Connected products* – with innovations in field service management and data-driven services based on real-time information from products. Moreover, sharing live insights on product usage, improving design and quality; (2) *Connected fleet* – tracking and managing fleets of cars, vans, buses, trucks, cranes, containers, land machines (with the integration of precision farming capabilities); (3) *Connected assets* – usage of statistical and machine learning capabilities, and physics-based models for operations and predictive maintenance and services. Moreover, leverage digital twins for simulating and analysing asset-performance and reducing risks; collaborating with ecosystem partners to share assets high efficiently; (4) *Digital Manufacturing* aims to increase the Overall Equipment Effectiveness (OEE) by vertical and horizontal integration of connected machines, robots and plant logistics, and, to reduce energy consumption and manage and predict quality.

Platform driven steel business – sensing and condition monitoring: More than 50,000 sensors can be implemented for monitoring SC end-to-end processes at a steel plant (Sagermann, 2019). They collect data such as quality characteristics and machine and environmental conditions of the factory. These data are continuously communicated to the SCM live system and can be communicated to a Digital Twin as well for doing trend analysis, simulations and predictions of an unacceptable trend by extrapolating deviations. Such insight can trigger an investigation and changes in the physical manufacturing process. Steel plants such as the sample companies produce 1.5 million tonnes of steel to fulfil 10,000 customer orders per year, delivering 70,000 coils. Considering the figures of downtime based on a hot strip spindle

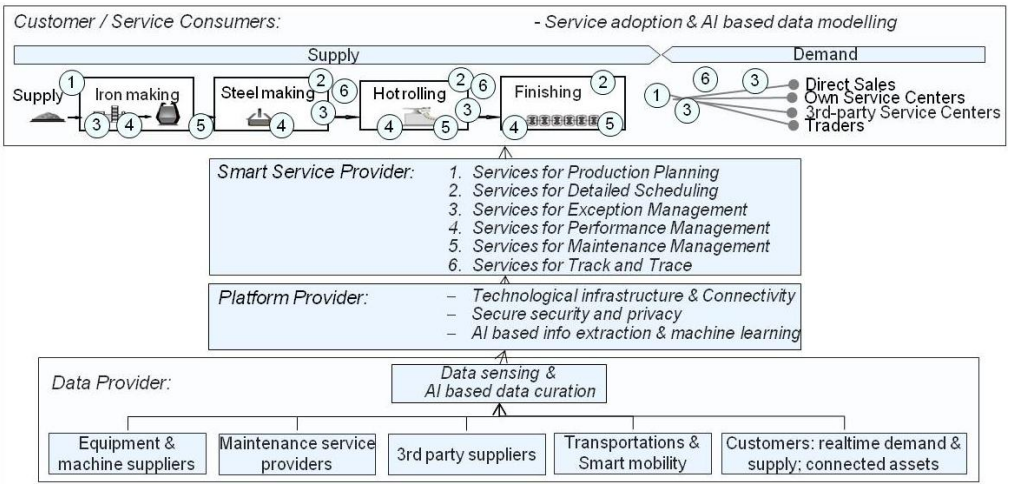

Fig. 13: Layers of a Smart SC business model (an author's view, adapted from Kagermann et al., 2013)

failure will result in EUR 3.7 Million for three days of repair work. This example demonstrates the high value that condition monitoring can provide to steel companies for preventing from such cases.

4.3 The Impact of Relationship Management IS Capabilities onto Fit

Objectives and capabilities of relationship management: Steel companies have a few large customers, such as automotive suppliers and construction companies, and few vendors for raw material such as mining companies. Therefore, the maintenance and care of these relationships have been identified by the case studies as essential for steel companies' survival and for securing sustainable long-term success. Hence, a much tighter relationship with strategic customers is required for firms in the steel industry in comparison with other sectors, such as the consumer industry. There are two categories of strategically relevant suppliers identified for steel companies: (1) suppliers of direct materials such as scrap and ore for iron production; and (2) suppliers of indirect material, such as technical equipment. Moreover, customers sometimes sell back scrap as input for further steel production.

Collaboration is embedded in SC processes: As seen in the assessment result of all SC domains, collaboration presents an integrated part of these SC processes. Moreover, SC integration antecedent such as *coordination* and *information exchange* plays a significant role in relationship management and SC processes of all domains. On the one hand, SCM IS independent qualities such as *partnership*, *trust* and *commitment* play a significant role in relationship management and in balance score cart system to control relationships. On the other hand, there is a common view by the participants that customer satisfaction and trust as a basis for good partnership relates to a high extent to qualities resulting from good SCM practices such as reliable order delivery to promised dates, which has finally, a significant impact on the market share from the long-term perspective. Collaboration is seen a company's ultimate core capability, providing benefits such as revenue enhancement, flexibility and cost reduction, but, levels of collaboration have not reached as aimed so far (Fawcett and Magnan, 2001; Wognum and Faber, 2002). Based on the impact from qualities of good SCM practice, the experts identified the S&OP domain with the highest impact on relationship management. Long-term plans, as the basis of relationship management, are determined using S&OP processes. Hence, customer and supplier

relationships need to be stabilised for securing sales volume and raw material supply.

SC performance effects of relationship management: The case study participants were of the view that there is no dedicated customer service process, but rather a focus on (1) delivery-quality, (2) support and provisioning of equipment, spare parts and services, and (3) finally, in product support. The assessment at company B shows that relationship capital with customers can be released in exceptional situations to safeguard the short-term performance by enabling agile collaboration with customers and supplier, and long-term performance through customer retention. As identified at company 'A,' steel producers of high-end products often were involved in the NPD process of their customers. Through such pre-investments in collaborative R&D processes, customer satisfaction and retention could be significantly increased by fast delivery of high quality as technical constraints were aligned before the order. Finally, nearly all efforts in relationships are seen by the experts as having an impact on business performance at other places in the supply chain. For example, capabilities placed in supply relationship growth will help positive effecting downstream and upstream by increasing availability of raw material for production, which will result in better delivery adherence. Supplier relationship management will result in improved inventory levels. These improved inventory levels will have a positive effect for just-in-time (JIT) production and adherence to delivery dates and will finally result, finally, in better customer relationships.

4.4 The Impact of IS Capabilities for NPD to Strategic Fit

Ambidexterity – balancing exploration and exploitation for NPD: In NPD, exploration refers to the new knowledge acquisition useful for developing breakthrough technologies and for innovative diversification. Moreover, it covers all skills, methods and tools used to organise and support this learning process. This learning process follows the organisational assimilation of the acquired knowledge and the merge with the exploitation process (Ahuja and Katija, 2001) where the deposited knowledge will be exhausted to provide the company value from new products and services. Ambidexterity refers to a company's ability to balance exploration and exploitation in this process considering a company's structure, context, domains and organisational dimensions in a congruent way. Bernal et al. (2016, p. 9) cite Lewin et al. (1999, pp. 536–539) in stating that exploration and exploitation are moderated by environmental dynamism and competitiveness. Jansen et al. (2006) reported that exploration activities show more effective in dynamic environments, and exploitative innovations are more beneficial in competitive environments.

Simultaneous exploration and exploitation for constraint NPD: As innovation drivers of NPD processes have been identified the provision of pioneering products to the steel companies themselves – upstream innovation – and to their customers, such as automotive suppliers-downstream innovation. Moreover, NPD in the steel industry emphasises two main processes: (1) the development of new steel products, which focuses on the development of new steel grades with improved characteristics and qualities; and (2) subsequently in the development of new production technologies to create these new steel grades in an effective and efficient way. Finally, the production of the newly developed products will be established by implementing the equipment needed and aligning the processes. Steel companies need to balance knowledge exploration for new products and the exploitation by producing these appropriate with existing process technology in a closed and simultaneous way because the constraining factors for new products are implemented in the organisation and their asses. Hence, they need to consider in NPD a company's structure and resource capabilities, the domain capacities and contextual constraints in a congruent way of developing new products.

Innovation focus of steel companies: Although steel business is a mature one, it needs to be continuously innovative to survive by designing new products but also by driving innovations for production processes.

Moreover, steel companies are also impacted by governmental considerations such as requirements regarding CO_2 certificates and for reducing energy consumption, which leads to enhanced efforts in NPD. Because of their positioning in the high-end product segment, sample organisation A's NPD strengths have an important impact on their business success. R&D objectives, such as weight reduction of products by innovative design, represent a very high value for automotive producers. Weight reduction goes hand in hand with reduced security, which needs to be compensated by the increased quality of the steel used, through improving its grades and characteristics. As a result, high-grade steel is needed, which leads to more complex production processes.

Business potentials enabled by collaborative product development: For obtaining first-hand information about their customer's needs, sample company A has placed engineers in their customers' organisations. Collaborative product development with customers, vendors and external laboratories enables first-hand information to increase responsiveness to new requirements from the market and can help in proactive resource alignment and external activity integration. By this approach, the exploration process, including information collection and assimilation has been moved as close as possible to the customer where the demand and technical requirements were created. Besides, many cases where an innovative recommendation has been provided to the customer in the design phase that result in winning activities of the overall supply chain stages. As an example, was reported to provide the customer surfaced finished sheet that must not sub-contracted after mechanical transformation for this reason. Moreover, information exchange with Government agencies regarding compliance criteria has become a hot topic for steel companies. Collaborative management of new development projects, technical document management and phase-in and phase-out management are the focus of the discrete manufacturing industry. Collaborative development of new substances using a common *'specification database'* in compliance with regulations of customers' countries Governances plays a major role in the process industry.

IS capabilities for collaborative Product Development have to cover requirements for integrated governance of the development project of different business domains such as mechanical engineering, electronic engineering and more and more software engineering. According to SAP SCM Product Management, in developing Smart Business models, companies' focus in R&D moves from products to services. NPD IS capabilities have to manage their overall life-cycle collaboratively, from idea development, design, production, service and maintenance until the rejection and replacement. Hence, capabilities for workflow management for status and document management for developers, partners and stakeholders as well as buy-off and release management, and finally, life-cycle management covering phase-in and phase-out activities become more important for innovative NPD. Case study findings show that first-order effects of IS capabilities for NPD occurring faster in developing new products and speed up innovation as a result. A key implication is improving speed to market by supporting the development and faster testing of new products and new types of steel. Moreover, NPD capabilities enable steel companies to react adequately to the innovation requirements from the market. For this reason, collaboration and information exchange by a common database to all related parties in the NPD process can result in speed up innovations, improved quality of the developments and reduced sources of errors and misconceptions as important spill-over effects of R&D and NPD processes.

4.5 The Impact of IS Capabilities for SCPM & Analytics to Strategic Fit

IS capabilities for Supply Chain Performance Measurement: According to the SCM experts from SAP, the most common SCPM-objectives are the definition, modelling, and application of KPIs for real-time monitoring of SC processes to increase plan-efficiency and accuracy, and, finally, to increase the visibility of the actual

value flow. Also, Supply Chain Analytics is observed as a hot topic to understand SC key drivers and KPIs more clearly about the companies' overall objectives. SCPM helps companies to reach transparency on the supply chain situation and helps to sharpen the focus on critical SC processes to be responsive to unforeseen situations coming from the market. Moreover, SCPM helps companies in mastering their SC processes by identifying weaknesses within and initiating appropriate measurements as a response to these. SCPM IS solutions provide capabilities to align SC planning and SC operational processes with financial objectives. Moreover, exceptions in the supply chain can be identified in time, followed up with root cause analysis and linked to SC risk management activities. KPI management for SC performance and SC risk prediction have been identified as highly important for steel companies as well as the definition of KPIs for SC objects on a generic basis.

Business value by improving the business predictability: Based on their support of the prediction of new business more quickly and more accurately, the interviewed business transformation principals observed a significant impact of Analytics and SCPM on the business value regarding shareholder value and market capitalisation. They see accuracy in prediction of business performance by determining the future quantity and value flow on business forecasting as an important driver of trust from company's shareholders and therefore can impact the overall market capitalisation by positively. Such predictions require the ability to consider internal and external aspects in planning and budgeting and to link to reporting capabilities for material and value flow. As a result, such capabilities can increase a company's value significantly.

SCPM at different levels: Business-wide unified SCPM engagements have been identified as core activities of leading international steel companies such as ArcelorMittal and Gerdau. The following activities were identified with high priority for SC performance optimisation:

1. provide business-wide harmonised reporting structures;
2. monitor SC performance and SC risk regularly;
3. manage exceptions to respond in real-time to critical SC events.

Critical SC KPIs and real-time exception management: The following KPIs have been identified as a core for safeguarding steel companies' SC performance: (1) cost and profitability on certain levels, such as plant, product, and planner; (2) on-time delivery performance; (3) asset utilisation and *'overall equipment effectiveness'* (OEE); (4) inventory turnover and days in inventory; (5) reduction of revenue loss due to stock-outs. Exception management capabilities for identifying deviations of these KPIs and causes and roots of critical SC events in real-time have been identified as particularly important. The practice of SCPM on different levels and the global harmonisation of the related reporting structures and processes have been identified as key activities of strategic alignment at global steel companies such as ArcelorMittal and Gerdau for supporting overall business performance (Beeby, 2014; Legrand, 2014).

Adoptions and global harmonisation of Performance Management: Performance improvements through aligning SC processes with strategy goes hand in hand at global steel companies with the alignment of business structures and reporting structures. Optimisation of global SC performance rather than the local SC performance needs to be addressed using common KPIs and aligned shared incentives for the parties involved in a global supply network. According to ArcelorMittal's CIO Legrand (2014), the following activities are used for harmonising business and reporting structures: (1) develop *'components for reuse'* for all SC processes to increase speed in scaling up SC models and in alignment activities; (2) *'integrate'* SC processes with resource maintenance (RM) and human resource management (HRM) when setting up new global plants; and finally (3) *'standardise'* and *'automate'* SC processes (Legrand, 2014, pp. 8–19). The following key points have been identified as significant for SCPM effectiveness: (1) align SC objectives, KPIs, and incentives of involved parties on

a global scale; (2) align reporting structures across subsidiaries (vertical and horizontal); (3) establish a central, single source of truth of data for the global enterprise; (4) provide global access to that data by technologies such as CLOUD computing (Legrand, 2014, pp. 8–19).

Identified performance potentials from SCPM harmonisation: Harmonised reporting structures contribute to increasing end-to-end visibility and are supporting global business process alignment. Hence, it supports adoption and scaling out of technical and organisational developed capabilities that improve effectiveness and efficiency. Finally, harmonisation of reporting structures provides enhanced benchmarking capabilities and accuracy and can result in better alignment of local and global SC strategy and their improvement by sensemaking effects.

Embedded Analytics for real-time operations insight: Embedded analytics provides capabilities for modelling and performing analysis based on the real-time operational data of business applications databases. By this approach, analytical views, and reports can be modelled as needed by business users' roles. Moreover, analytical Queries and KPIs can be performed with high precision and speed based on operational data not limited on predefined aggregates, which were replicated (pulled) from business application databases to a Business Intelligence (BI) or Business Warehouse (BW) system. Enhanced reporting capabilities and machine learning capabilities can be realised based on the embedded analytics solutions. Cloud applications allow access global of real-time data for analysing and benchmarking different plants and work centres performance and provide global monitoring by digital boardrooms for the following reasons: (1) *SCPM* using analysis of manufacturing KPIs, comparing with target figures and alerting in case of exceptions; (2) *Benchmarking* and comparison of plants and nodes using OEE key figures; (3) *Order status information* such as actual cycle time, start on time; (4) *Conformance and non-conformance information monitoring* for identifying scrap and yield and related Root Cause Analysis; (5) *Condition monitoring:* defining machine models with sensor sub-subscriptions for monitoring e.g. Indicating resource down situations, and (6) *Predictive Quality from manufacturing insights:* selective investigation of machine data to build and operate predictive quality models, e.g. data stratification analysing contribution such as of machine and process parameters and material characteristics based on segmentation.

4.6 Interoperability and EAM Principles as Catalysts of SC Dynamics

SC interoperability has been identified with significant impact on SC integration and SC dynamics. There are various definitions of SC interoperability in the literature such as the *"ability of interaction between enterprises"* (IDEAS, 2003) and the *"ability of a system or a product to work with other systems or products without special effort on the part of the customer"* (IEEE, 2016). Technical, organisational and operations has been identified as the most common types of interoperability by Ford et al. (2009), but, the meanings of SC interoperability need to be defined according to the context (Palfrey and Gasser, 2012), and its multidimensional nature in regard of used technology for communications and the involved organisations and individuals should be considered (Chalyvidis et al., 2013). The 2007 ATHENA Interoperability Framework defines the following useful categories (Berre et al., 2007, pp. 14–15):

1. *data interoperability* – for information sharing by business applications in heterogeneous IS landscapes, considering different data models, conceptual schemas and data structures;
2. *services interoperability* – concerns about identifying and composing functions of various applications by solving syntactic and semantic differences;
3. *processes interoperability* – aims to link various processes for smooth work;
4. *business interoperability* – refers to harmonised work within and between companies, despite different modes of decision-making, culture, commercial methods and legislation.

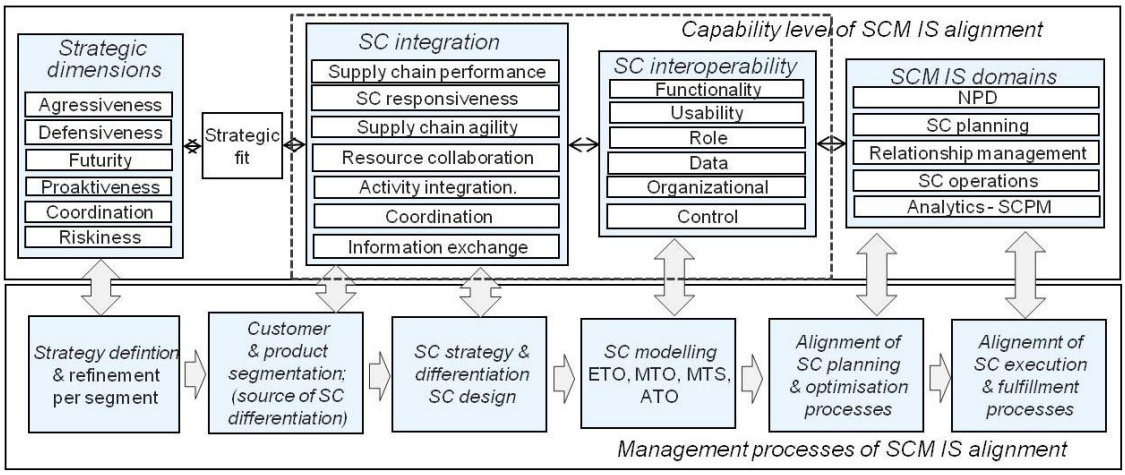

Fig. 14: SC integration levels needed to fit enabled by apposite SC interoperability (an author's view)

5. *conceptual compatibility* of methods, rules, syntactic and semantic;
6. *organisational compatibility* of companies and their structures, persons and authorities;
7. *technological compatibility* of communication between business partners.

SC interoperability as an enabler of SC integration: There are different interpretations of the concepts of SC integration and SC interoperability in the literature. The present research draws on the view that *interoperability* at various levels between involved systems provides the prerequisite of good SC integration. Integration is broadly used recognised in SCM (e.g. Bagchi et al., 2005; Childerhouse and Towill, 2011, pp. 7458–7460; van de Ven and Drazin, 1985; Rai et al., 2006, p. 237) and in strategic alignment and business-IT alignment (e.g. Avison et al., 2004, pp. 224–225; Henderson and Venkatraman, 1990, p. 11; Ward, 2011, pp. 30–31; Broadbent and Weill, 1997, pp. 79–81, 89). Both integration and interoperability are seen as systemic concepts, while interoperability has been recognised as autonomous, and, a provider of compatibility between systems and therefore integration capabilities such as coordination and collaboration (Chen et al., 2009). Chalyvidis et al. (2013) provide a useful view for designing supply chains with architecting a *'System to System'* (StS), with a focus on orchestrating and subsequently managing the identified interfaces between the business partners. Encasing this view and enhancing it with the identified interoperability categories, Fig. 14 highlights the present study's concept of *systems-to-systems* interoperability as an enabler of SC integration.

The following EAM Principles have a positive impact in interoperability on several levels when adopted by IS Governance to an organisations specific needs and priorities (Source: SAP):

1. *Enterprise Commonality* and controlled technological diversity to minimise the cost of maintenance and connectivity and promotes reuse of existing investments.
2. *Enterprise Alignment* by prioritised investments as opposed to the business view. Keep visibility of initiatives and change activities to balance conflicting strategic priorities.
3. *Manage data across organisation* accurately and timely based on a single source of data shared across the enterprise for effective and consistent decision making.
4. *Solutions should be scalable* for dealing with volatility in business volumetric.
5. *The flexibility of business processes, applications and technology* should be aligned with the organisation's requirement. However, it comes at a price and should be focus on processes that differentiate an organisation from its competition.

6. *Buy solutions in preference to build them* benefits companies by reducing the time-to-implementation of new assets and technical risk and increase system stability.

7. *Manage and control the implementation of new IS solutions* using a defined life-cycle for careful system selection, proof-of-concept and pilot stages to reduce implementation risks and do not randomly increase complexity or inconsistency of the technology footprints.

8. *Outsource stable and non-differentiating services* with an agreed set of SLAs to third-party vendors that may handle the operation more efficiently. Enterprises may then focus resources on extending differentiating architectures providing added value to strategy.

5 CONCLUSION

For maximize companies' performance, it is not enough simply to coordinate the activities of different functional areas across a supply chain (Danese et al., 2013), but, rather the intra- and inter-organisational activities need to be integrated (Fazli and Amin Afshar, 2014, p. 349), which is also underpinned by a study of Sukati et al. (2012) about the positive impact of SC integration on competitive advantage. The present study explores SCM IS capabilities as key performance enablers and how they need to be integrated ideally between technological and organisational domains and between external and internal parties. While the author's 2019 study provides a comprehensive framework for dynamic SCM IS alignment using high-order SC capabilities for mediating integration of antecedent capabilities (as shown by Fig. 3), the present study contributes a coherent methodology for managing key SC objectives and SCM IS capabilities with a focus on integration between SC domains and between technological and organisations' management. In referring to Battisti et al. (2014) and Monczka et al. (2015), the study's concept contributes to complementary management of technological and organisational innovations and simultaneous adoption. Besides, the present study contributes to detailed methods for designing, modelling, planning and synchronising SCM IS in the most simplified and profitable way. Moreover, the study provides organisations with a guide for utilising SCM IS capabilities following businesses strategy and organisational needs in a prioritised way. Finally, the study shows how Industry 4.0 innovations such as Smart Services (Kagermann et al., 2013) and blockchain technology (Kim and Laskowski, 2018) can provide new value potentials such as cross-organisational network effects (Rifkin, 2015) and increased autonomy.

The study demonstrates a holistic approach for SC integration and profit optimisation considering spillover effects and antecedent capabilities across all SC domains. It focuses on integration and not on functional features in detail, such as the various forecast-based planning methods and consumption-based planning procedures as they are well known. However, innovative approaches such as dynamic replenishment methods have considered by the study. In practice, many companies expect stock reduction and availability from highly sophisticated planning methods and syncronised orders from complex algorithms of scheduling heuristics. But, many SCM projects fail as the needed integration levels between the domains are not given, and the right priorities are not reflected by the processes and capabilities. In referring to the theory of constraints (TOC), the present study focus on integration for balancing levels of fit and capabilities across domains.

The impact of SC dynamics on the complexity on steel companies' SCM: Complexity implied in SCM IS has been identified as the major concern of steel companies against the implementation of these solutions. Hidden interdependencies and functional changes can lead to unpredictable side-effects within the

supply network. Moreover, SCM processes are often automated and balanced against the known business situation but failed in cases of changes. Therefore, configurations of SCM IS are often not robust against a massive change in business conditions and process targets are partly conflicting, but highly related to each other. For that reason, the SC design and SC modelling have been identified as the most significant practices for managing SC dynamic and SC complexity that steel companies are facing, and for dealing with contradicting objectives and balance long-term business objectives against short-term targets.

Key capabilities for managing SC dynamics and SC complexity: The overall SC profitability and the transparency to identify the impact of environmental changes have been identified as key business objectives. Hence, key capabilities for managing SC performance in dynamic business environments and concepts to respond fast and agile have been identified as the following:

1. *SC design and SC modelling:* manage ambidexterity between innovation innovations and segmentation with SC differentiation and SC strategy using capability patterns as artefacts;
2. *SC planning and profit optimised Master plans* for the supply network;
3. *SC simulation* and *visualisation* for predicting bottlenecks and priority management;
4. *DC from IS Governance by EAM:* preconfigure architectural artefacts for projected business situations to increase SC agility;
5. *DC accelerators:* promote (1) a collective view on objectives and a common direction of actions by organisational learning; and (2) principles of EAM and interoperability.

Trends that lead to increasing complexity in SCM and IS capabilities for dealing with these: The individual characteristics customers want from steel companies' products have a direct impact into the complexity of the SC planning processes by characteristic dependent demand differentiation, while the quality from the upstream process flow is difficult to predict precisely. As a result, there is a high interdependency between characteristics-driven profit-based planning processes and the characteristic-based matching sales orders, manufactured orders and forecast consumption. Moreover, as steel companies are facing restrictions of their production resources' overall capacity and capacity shortages caused by periodic maintenance activities, fast capacity increase often cannot be provided. With infinite capacity, demand could be fulfilled by never exceeding capacity, and order acceptance can be based on comparing marginal profit with marginal costs (Hintsches et al., 2010, p. 177). But, based on described implications, steel companies were confronted with the challenge of optimising their sales order acceptance when demand exceeds the production capacities and need to select orders that contribute the most profit. For supporting these sales order acceptance processes, sophisticated S&OP solutions are necessary, which provide managers with *Master plans* that prioritise the most profitable products and customers in case of finite resource capacity. *Master plans* represent ideal states regarding profit contribution, resource utilisation and customer service level fulfilment. SC planning solutions such as S&OP and IBP can consider profit contributions in plan creation and provide collaboration capabilities for reaching plan consensus between stakeholders. For dealing with the high variety of SC objectives, planning on different levels of aggregation and granularity is often managed by different IS applications as grown in the past that are connected by interfaces. As a consequence, the IS applications does cover the company's business limited from a local point of view and information originated in different areas cannot be leveraged throughout because of missing transparency. Hence, *end-to-end visibility* and the clear definition and harmonisation of *SC overall objectives* and alignment of the local objectives to the overall ones have been identified with high priority as prerequisites for managing supply chains performance-oriented. Optimisation and scheduling methods can synchronise companies' extended supply network in considering process technological sequencing

characteristics and availability of raw material flow and transportations. *SC design complexity* can be reduced by combining lean supply chain with agile supply chains that can be flexible and priority-based management. Besides, innovative, dynamic replenishment methods such as DDMRP can be used in assembly and distribution systems for adapting to volatility from raw material supply, service levels and lead time. Key concepts for SCPM and Analytics has been identified for monitoring the overall SC objectives on the corporate level and aligning local SC objectives; local managers can be highly effective supported by *Embedded Analytics capabilities* focusing on business role-specific data insight. Finally, capabilities and methods for collaborative NPD and relationship management processes have been identified for supporting cross-organisational ambidexterity. Fig. 20 (in Annex) provides an overview of the key capabilities for mastering SC dynamics.

Profits increase by improved transparency and methods for dealing with volatility: A 2013 review on SC complexity drivers by Serdarasan underpins the positive impact of improved SC integration, SC visibility and data synchronisation onto reduction of complexity from dynamics (Serdarasan, 2013, pp. 533–540). According to the present study's findings, unnecessary complexity implied by missing transparency and contradicting SC objectives can be reduced by harmonised SC objectives and SC business applications that focus on priority and exception management. Moreover, end-to-end visibility and appropriate levels of differentiation and the right levels of aggregation for the SC processes have a significant impact on SC integration. On the one hand, too less visibility in SC processes can lead to un-appropriate fulfilment result from missing details in planning and in missing SC agility in SC operations. On the other hand, too much detail in SC modelling can lead to unnecessary SC complexity with bad business process performance as a result of a difficult appliance and suffering IT performance. SCM concepts for dealing with volatility are summarised in Tab. 2 (in Annex).

SC interoperability as an enabler of SC integration and SC dynamics: The right level of SC integration for providing appropriate SC dynamics, as a response to environmental changes, can be managed continuously by EAM. Fig. 18 (in Annex) provides a best practice for dynamic SCM IS alignment, and Fig. 17 (in Annex) shows examples of interoperability of SCM IS on different layers. Types of IS misfit according to Strong and Volkoff (2010, pp. 732–751) – (1) *functionality*, (2) *data*, (3) *usability*, (4) *role*, (5) *control* and (6) *organizational culture with the dimensions coverage and enablement* – have been identified as very useful for defining SCM IS artefacts by expressing SC interoperability to reach the right context-specific SC integration.

Key performance drivers of SC operations: Profitability can be predicted by SC planning, but, operations have to transform the plan to yield the profits. Therefore, supply chain end-to-end visibility needs to be provided to the extent needed for tracking and tracing priority and exception-based SCM. The following methods have been identified as performance drivers of upstream and downstream processes: Business-role-centred MRP analysis based on real-time data, exceptions and priorities and decision support by simulation capabilities help to arrive on well-founded planning solutions by estimating the impact of alternative decisions more reliable. Combining lean and agile supply chains using customer order decoupling points (CODP) separates supply chains in highly efficient parts that can provide operational excellence and parts that focus on flexibility, differentiation and responsiveness to customers' needs. SCPM solutions provide managers with analysis for monitoring operational excellence by KPIs such as the OEE. Business-application specific Embedded Analytics capabilities offer in-depth investigation on process efficiency and output quality and reliable prediction of resource maintenance for safeguarding the OEE.

New value from smart technology for SC ecosystems such as platform capabilities and self-learning Smart Services are increasing the autonomy of SCM and improve synchronisation of supply chains and can deal ad-hoc with unforeseen events and exceptions. Data

replication technologies such as the blockchain approach foster trust in autonomous collaboration between SC ecosystems members through increasing transparency and reliability of SC statuses by nearly real-time SC synchronisation. Transforming principles of interoperability and EAM serve compatibility, scalability, and reusability and are core drivers of demand-side network effects to provide increased business value at declining marginal costs at the same time. The artificial intelligence (AI) methods and use cases introduced by the study are providing key components for designing collaborative, digital SC business models. New value potentials arise from a cross-context 'big view' in business modelling as values potentials are expected to come from scaling effects and spill-over effects and network effects across SC ecosystems. Following the *'zero marginal cost'* paradigm uncovered by Rifkin (2015), development efforts for such IoT connected Smart Services, and digital products will converge nearly zero at significantly increasing opportunities for creating business value at the same time.

Recommendation for a further research avenue: Recommendation for a further research avenue: Aligning business rules and configuration schemas for collaboration with partners have been identified as a present gap in steel companies' extended supply network. Norms such as ICLASS exist, but, need to be developed and aligned further to industry-specific taxonomies and semantics. Such developments can enhance standardised EDI processes for multiple-tier supply chain synchronisation by customer-specific configurations. Moreover, these can lead to enhanced autonomy and increase trust in collaborative SC processes such as demand identification, supply sourcing and order fulfilment. Finally, these developments will provide companies with further opportunities for machine learning use cases across different contexts.

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7 ANNEX

Concepts in SCM for dealing with dynamics and volatility: Tab. 2 summarises the SC concepts for dealing with business dynamics and volatility on different levels of aggregation.

Tab. 2: Concepts in SCM for dealing with volatility in demand and supply (an author's view)

Level & horizon	SCM Processes	Business objectives	Sources of volatility	Concepts for dealing with volatility
Sales & Operation Planning Long-term ~ 12–24 month	Predict the optimal plan for demand and supply at known sources of change and volatility	Prediction of business, supply, margin and profit; Longterm alignment of resource base and supply; financial planning	Market demand; customer behaviour and perceptions; supply availability, macro-economic impact.	Optimisation methods such as the Genetic Algorithm for optimal matching demand & supply; recognition of predefined master plans
Production Planning mid-term days to months	MRP planning & analysis; Finite capacity planning; Optimisation & synchronisation	Provide a plan for optimal fulfilment of customer orders, stock reduction; order lead time minimisation and resource utilisation.	Unsteady Sales order demand; Volatility of supply, transportation and resource capacity	MRP planning concept, heuristics and optimisation (e.g. Simplex and Line Programming) concepts for optimal, iterative order synchronisation
Production Execution actual & near-term	Manufacturing and Continuous Processes: MTE, MTO and MTS	Continuous flow order sequence and optimal supply and fulfilment, OEE optimisation	Unsteady supply of components (delivery time and delivery quantity)	Dynamic Replenishment: DDMRP (assembly); Multi-echelon (distribution) Balancing service levels against stock levels
Shop-floor management near-time and ad-hoc	Order management on production resource on time and in sequence.	Continuous production flow; just-in-time supply and delivery; OEE optimisation	Unforeseen tool breakdown and other exceptions; unforeseen demand and supply situation.	Autonomous systems for dealing with unforeseen exceptions and addressing these to useful actions (e.g. CPS, I.4.0, blockchain)

Methods and examples of SC optimisation

Processes	Examlpes of SC optimisation methods	Coverage / enablement
Integrated Business Planning	1. Shape a common demand signal from different internal & external sources using Big Data methods 2. Create a Master plan for the extended supply chain based on consensus demand, supply restrictions and optimized profit contribution by technology such as Line Programming (LP) and Genetic algorithm	1. High levels of coverage by available optimiser technology 2. Very high levels of enablement requird for SC modeling of planning data structures and process configuration
MRP	Create a detailed production & supply plan for given demand and mostly at finat capacity (to-be plan)	High levels of coverage through provide functional IT capabilities
Detailed Scheduling & optimisation	1. Create a holistic plan using *optimiser (LP) technology* and synchronise the most effective order sequence for fulfillment, considering finite capacity and weighted constraints such as setup optimisation and due date adherence and more. 2. Optimal order sequencing using *heuristics for* single order contexts, considering different algorythm for different synchronisation goals such as priorities for backorder processing.	Very high levels of enablement. required from SC modeling for: 1. high acuracy needed for order data and resource data; 2. (2) clear knowledge about plan objectives and their reflection in weighting data like in setup matrix 3. Clear consensus between stakeholders about plan objectives
Shop floor optimisation ME systems	1. Create detail order sequence for each resource using heuristics technology 2. Block-planning methodology in the steel industry: create order sequence by a predefined sequence pattern that fits the process technology.	1. Very high levels of enablement needed for concise plan integration between ME system and core Enterprise Systems.

Fig. 15: Methods of SC optimisation and examples per layer (an author's view)

Examples for SC visibility and dimensions on different levels

Processes	Examlpes of significant visbility requirements	Data, characterisrics
Demand Signal Management	1. Understand the market using Big Data and IoT technology for analysing consumer data and social data 2. transforming unstructurd data into structured information using qualitative content analysis (e.g. summative coading)	Unstructured data to Meaningful inform. • Brand / Product • Location/Region • Time…
Integrated Business Planning	1. Create a consensus forecast and a common view for alignment with stakeholders 2. Understand demand impact onto the extended supply chain 3. Create and understand the most profitable Master plan from it	Aggregated time series 1. Customer/region 2. Location, resources 3. Profit contribution ...
MRP	• Create and understand the optimal order plan for fullfilment	Detailed order data
Detailed Scheduling & optimisation	1. Optimise and synchronise the most effective order sequence for fulfillment by finite and constrained based scheduling 2. Understand the impact of demand and supply changes and define actions based on priorities and exceptions	1. Detailed order sequence 2. Resource based data 3. Priority based data
NPD & Project Management	1. Understand the needs for innovation from the market 2. Provide a common database with customer and suppliers for collaborative development 3. Understand the impact of innovations into planning, execution 4. In Engineering-to-Order: Understand the impact of changes from customer in into project management and SC execution	1. Master data management 2. Engineering change Management 3. Engineering data base
Production execution	1. Role based order execution and monitoring of order backlog 2. Understand priority and changes and decide for actions.	1. Order backlog 2. Resources mgmt.
SRM, sourcing & procurement	1. Understand long-term and short –term requirements for procurement in balancing promised customer service levels against effective stock levels	1. Stock data 2. History data 3. Demand insight
CRM, sales & distribution	1. Understand the order backlog and have knowledge about opportunities in the market 2. Understand customers' value propositions from the own offer	1. Opportunity data 2. Demand & history 3. sales & supply data
Shop floor control	1. Operations transaction control, and operations analytics 2. Insights in distributed manufacturing ; predicted quality 3. Predictive maintenance; IoT technology for asset inside	1. Operational Analytics based on transactional data

Fig. 16: SC visibility at different levels of SCM and examples (an author's view)

Layers and examples of SC interoperability		
Layer	Examlpes of interoperability requirements and methods	Concepts / standards
Strategic	1. Align business strategy and corporate strategy with vision 2. Harmonise strategy by adoption and scaling out 3. Align business model and capabilities to strategy	1. Business model canvas 2. Strategic alignment
Operational	1. Business application and process interoperability: 1. OData for application integration on UI level 2. API standard for application integration on programme level 2. Business data interoperability for collaborative SC processes: 1. Interoperability of product structures and configurations 2. Electronically data sharing for forecasts, scheduling agreements, supply and delivery notifications (ASN) , JIT, JIS 3. Tracking and tracing using (1) RFID technology and sensors data on the status of the material and (2) batch configuration 4. Data interoperability for collaborative NPD processes 3. Methods and data interoperability for SCPM: 1. SCOR model for SCPM and benchmarkling 4. Blockchain & distributed ledgers or cyber planning cycles	1. OData as layer for common SC object definitions on UI level 2. ODET, VDA Norms for JIT, ASN, JIS (automotive) 3. EBOM, VDAFS, Eclass, IDoc 4. BAPI, BADI 5. KPI structures and business metrics 6. Hyperledger
Infrastructure technology	1. Bridging system boundaries using processes interfaces and Data Base interfaces 2. Open source operating systems and SW development 3. H ANA Cloud Intergration (HCI) for integrting local business application with cloud solutions	1. HCI interface 2. Open Source Cloud Computing 3. Governance service standards such as ITIL

Fig. 17: Layers of SC interoperability and examples (an author's view)

Best practice for dynamic SCM IS alignment by EAM	
EAM domain	Best Practice activities
SCM IS fit assessment	1.Continuously assess strategic fit of SCM IS accross the supply chain for all SC doamins 2.Continuoulsly assessed needed and expected levels to fit the competitive strategy
Architecture development (absorptive capacity)	1.Artefacts for business architecture were designed for all SC domains based on identified SC capabilities and needed levels to strategic fit (as-is and to-be). 2.Artefacts for application and IT architecture were designed for all SC domains based on identified IS capabilities for SCM and needed levels to strategic fit (as-is and to-be). 3.Context specific artefacts were designed for different expected business situations, and organised by useful strategic differentiators such as product secments. 4.Clearly capability description by objectives and required organisational and technical setup. 5.Different *'views'* of the artefacts were linked to stakeholders needs 6.The Artefacts cover all domains – business, application, data, technology and governance.
EA process (exploitation)	1.Continuously measure and review as-is levels of implemented capabilities and compare with ideal levels (to-be) needed to fit competitive strategy 2.In case of deviations, review catalog of available artefact on capability to fit startegy. 3.Initiate implementation of selected artefact (technical and organisational transformation) 4.Initiate capability definitition e.g by prototyping if approriate capabilies is not available----
Stakeholder involvement	1.Executive management and LoB participate in promoting and optimizing EA processes 2.Stakeholders actively support the architecture review process and promote the approach
Architecture communication	1.SC objectives are understood by stakeholders and are up to date 2.There is a process for collecting feedback and is used for continuous improvements. 3.Architecture models where maintained in one central repository. 4.Senior management use EA views to decide and demonstrate key decisions
Architecture governance	1.EA standards and guidelines are linked to IT and business strategy and vision 2.IT strategy has been clearly defined and linked to business and SC strategy 3.EA models and capability patterns are linked to business drivers and SC objectives 4.EA Governance team has senior executive sponsorship and key stakeholders participate 5.Ideally, all planned IT acquisition and purchases where guided and governed by EA 6.EA compliance KPIs where defined and tracked and regularly communicated. 7.Common definitions, standards, applications and systems exists and were govern 8.Architecture models and artefacts were developed based on common taxonomy

Fig. 18: Best practice for SCM IS EAM (an author's view, adopting SAP best practise for EAM)

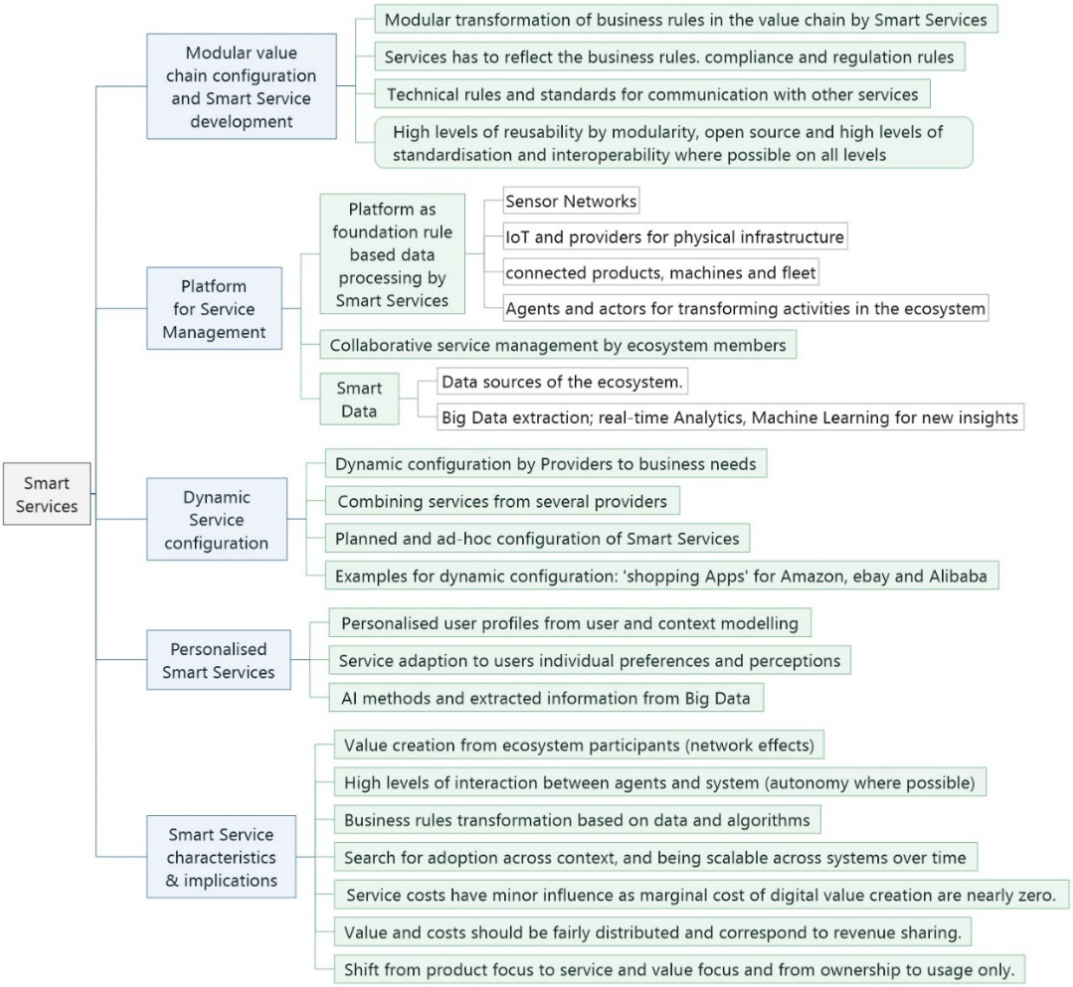

Fig. 19: Building blocks of Smart Services modelling (an author's view, source adopted from Smart Service Welt, Kagermann et al., 2013)

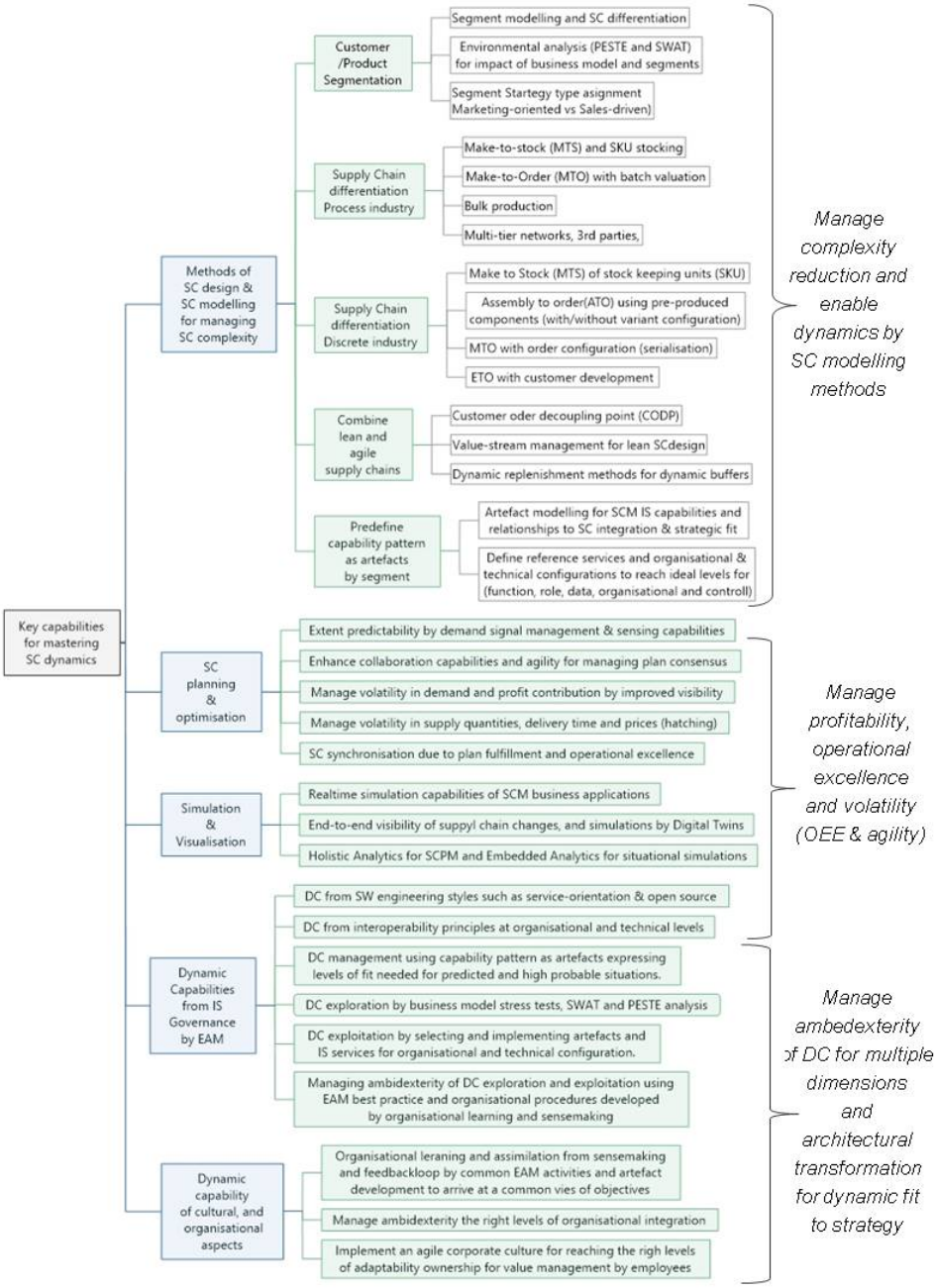

Fig. 20: Key capabilities for mastering SC dynamics and SC complexity (an author's view)

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