Neda Vitezić
Uwe Lebefromm

Production Controlling in the Digital Age

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PRODUCTION CONTROLLING IN THE DIGITAL AGE

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For the Publisher
Alen Host, Dean

Authors
Neda Vitezić, Full Professor
Uwe Lebefromm, Senior Lecturer

Editor
Neda Vitezić, Full Professor

Reviewers
Tina Vuko, Associate Professor
Tihomir Luković, Full Professor

Language Editor
Denisse Mandekić

Proofreader
Denisse Mandekić

Graphic design and prepress
Sanja Jovanović

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Neda Vitezić

Uwe Lebefromm

Production Controlling in the Digital Age

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and Business

Contents

PREFACE

The aim of this book is to present one of the most important parts of controlling – production – in its current 21st-century form – digitalization. Production is critical for the development of all societies and this is why measuring effects and overall company performance is of utmost importance. Digitalization is the current and future perspective embedded in almost every job and all segments of life. Controlling supports the management in the decision making process and is therefore not excluded from the impact of digitalized business processes.

This textbook is written for academic courses and practicing professionals. For the purpose of academic courses, the book is written as a core text for graduate and postgraduate students who want to acquire in-depth knowledge of the production controlling concept. For specialists like controllers, analysts, accountants, auditors, and other similar professions, the book provides an opportunity to apply their knowledge of the methodology that is to be used in strategic and operational process controlling. The five chapters of the textbook describe the essential approach to production controlling adapted to the needs of both students and professionals. Chapter 1 introduces the technological basis – Big Data. Cyber-physical systems are introduced for the purposes of business model creation and controlling. The introduction covers the impact of digitalization, and Chapter 2 describes the concrete concept of smart production, new forms and benefits of industrialization, business model in relation to smart production and economic dimension of Big Data, and the role of controllers. Chapter 3 discusses key performance indicators and a ratio system that can be used for controlling purposes. Chapter 4 deals with production process controlling starting with their components and determinants as success factors. Strategic and operational process controlling is described in detail by the methods and key performance indicators of value stream controlling. Production business model controlling is covered in the fifth chapter in which methodology is presented as a combination of process-oriented production controlling, supply chain controlling, and corporate controlling. Business model controlling methodology is based on innovation in production engineering and computer science, which calls for powerful IT business applications.

The beginning of this century was very dynamic. Rapid technological inventions, especially in IT, have been growing tremendously. What are the challenges of production controlling and what does it take to make it successful? The answers can be found in this textbook!

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Authors

September 2018

1. The Impact of Digitalization

Technological innovations bring possibilities and create a digital world. The impact of digitalization on the organizations' performance and business model creation is evident. "Digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business."[1]

The fourth industrial revolution will lead to modular networking of processes in industrial companies or factories. An intelligent factory consists of Internet-based production in which manufacturing facilities, products, materials, and tools communicate. Make to order (MTO) means production based on customer requirements. This generates costs for configuration of a wide range of product variants. On the other hand, globalization leads to high competition and pressure caused by rising costs which can only be solved by using high end technology. The vision of individualized products and services with manufacturing costs from batch production has become reality by pioneering development in manufacturing and information technology.

The search for and analysis of avoidable costs has lately focused on both technological competence and process competence. Process competence defines the ability to perceive complexity and guarantees that the process will result in suitable solutions and value added for the customer.

Digitalization is an ongoing process that will continue in the 21st century. However, it is also a tool for obtaining and handling information within the organization and its environment. The effects of digitalization are continuous and entail both opportunities and challenges for the controlling profession.

Controlling is a function that helps companies perform more efficiently and effectively in order to achieve the set goals and objectives. By using different analytical tools, controllers analyze various aspects of performance, coordinate plans between departments and make integrative conclusions suitable for decision making.

The role of controlling in the digital enviroment has been facing a challenge. Self-service business intelligence (SSBI) enables the employees in various departments to select data themselves. The controller's role of a gatekeeper in the controlling enviroment has become obsolete in the digital age, because in the past controlling was predominantly focused on data collection and processing, while nowadays employees can do it themselves. However, if anyone could select the data by self-service, every employee would select the data supporting their own argumentation. Data selection is in that case not objective, but subjective, and controllers' meetings will be postponed to set enterprise-related global data models and governance for data harmonization.

1 Gartner IT Glossary, http://www-it-glossary/Digitalization

The analysis of digitalization controlling has an additional role – to harmonize data in coordination with the IT department. Generally, data are signs adhering to a specific syntax. Data become information if they have a meaning for the recipient. Models make sections of reality less complex in order to make understanding of the context easier for model users. The data model definition is used to find out which data are needed and how they relate to each other. The data model must be specified by controlling in coordination with the IT department. Only strict governance can ensure harmonized data and enable the management to access decision-relevant data.

The future role of controlling is to derive meaningful conclusions from the selected data, which are now Big Data. Quantitative methods, i.e. mathematical-statistical methods, can be used to measure the correlation of the factors influencing the behavior of customers, to understand the development of market data and to predict the development of customer behavior and market data, provided that test results are successful.

The central task of data scientists is application of statistical methods using information technology. On the other hand, business interpretation and development of concepts in response to forecasting is a task of controlling.

Classic instruments of product cost controlling are based on classic costing and the focus is on production time cost as a part of the entire production process. Using sensors, data are made available every second through running production processes. Monitoring of the production processes takes place in real time. Thus, production controlling is always informed about the current state of production processes and can make timely decisions accordingly. Besides, the search for alternatives can be automated by self-learning systems when there is a problem in production. Therefore, the established production controlling needs to respond to this progress with new approaches.

1.1. The Technological Basis of Semi-Autonomous Organizational Units

Building a modular, flexible production structure is inconceivable without developments in the field of the information and communication technology, such as:

- Real-time data collection
- Short-term response to events
- Calculation and visualization of production process indicators
- Support of continuous improvement
- Steering, control and monitoring of the production in real time.

The following three chapters, chapter 1.1.1 to 1.1.3, provide an introduction to the main characteristics of the technology which is the basis for networked production units.

1.1.1. Internet, the Driver of Change in Communication and Cooperation

Technological progress has enabled a quick response of the organization regarding business combinations and collaborations.

Nowadays, the Internet enables the customer to find several potential vendors and distributors for the requested products in a short time. Small and medium-sized enterprises cannot rely on their product quality alone. The availability of defect-free products brings up the same question in each company: why should the customer buy only their products? The results of technological progress are increased expectations of the buyer's market in terms of product variety and manufacturers' flexibility.

Through the IOT (Internet of Things), the digital world is now additionally connected to the physical world. Techniques such as sensor technology and radio frequency identification enable the transformation of analog data into digital data and the resulting common electronic processing of the data, regardless of their origin. Therefore, the connection of business models to "Business Services" enables "Connected Business Models". This is the communication basis, not only among people, but also in human-machine communication. Development of the so-called "framework" enables communication of different technical systems at unimaginable speeds. The results of the study clearly show that the importance of transparency of global SCM[2] processes increases as well as the significance of operative production controlling.

1.1.2. The Revolutionary Approach of Cyber-Physical Systems

The enormous progress in sensor technology as well as information and communication technology enables the vision of a production environment in which production and logistics systems are organized by themselves, without human intervention.

The central elements are cyber-physical systems representing technological basis. These systems are distributed networked production units – intelligent objects that are linked in a web of data and services and controlled autonomously.[3]

2 SCM – Supply Chain Management

3 Fecht, N.: Industrie 4.0: die schöne neue Produktionswelt? Interview mit Prof. Dr. Thomas, Bauernhansel. 04/2013, availiable at www.openautomation.de/uploads/pics/o30421zsh_emo_industrie_4.pdf, 2013, p. 3.

This involves the virtual image of the real world of production supplemented by information. This virtual image can be found in the IT application system, revealing all possibilities of the participants in manufacturing – humans and machines.

Based on process information in a real and a virtual process, each participant and location (machine, transportation, storage...) can make decisions in the production process and communicate them to other participants. For example, if a tool recognizes its wear or loss, it orders its replacement via another tool supplier. The task of the sensors is to control the condition of the location. Actuating means handling systems such as tool-changing systems. Embedded systems are decentralized intelligence and make decisions based on process information.

The cyber-physical system (CPS) has impacts on the industrial production in technical, organizational, and business matters:

- Automation is possible for smaller series that enable consideration of a wide range of product variants.
- Flexibility continues to be the key factor of production work in the future.
- Each CPS has information on the entire production process and can therefore configure itself. Thus, the cost-intensive set-up time can be considerably shortened.
- Based on the embedded intelligence, the CPS can optimize itself. For example, the CPS is searching for the next optimal location based on the actual information on the production process.
- Interruptions in the production process could be cleared by searching for alternative strategies and their actualization in production orders.
- The production controlling has been transforming into a decentralized instrument for planning and controlling the production processes.
- The function-oriented production organization, historically defined by Taylor[4], is replaced by process organization, which strives for continuous improvement.

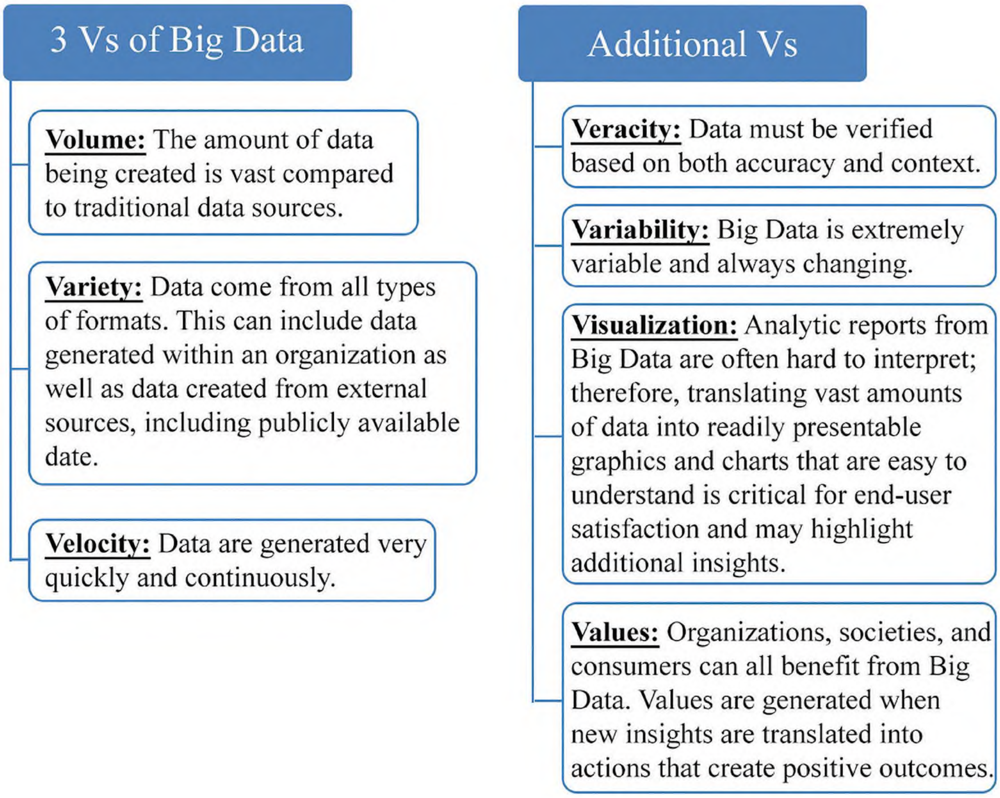
The road to autonomous, decentralized production structures has been outlined by the progress of production technologies, particularly for sensors and actuators. Ten Hompel and Henke detect: The extent of decentralization and self-organization of production processes increases with the complexity of logistic processes.

4 Frederick Winslow Taylor (1856-1915) laid down the fundamental principles of large-scale manufacturing through assembly-line factories in his book 'Principles of Scientific Management' from 1911. He emphasized gaining maximum efficiency from both machines and workers, and maximization of profit for the benefit of both workers and management.
http://www.businessdictionary.com/definition/Taylorism.html

1.1.3. Big Data as Controllers Potential

Big Data is a term used for the collection of large and complex data sets that are almost impossible to process due to multiplicity, heterogeneity, and autonomy of the sources. Big Data includes information generated from social media, data from Internet-enabled devices (smartphones and tablets), machine data, videos, voice recordings, etc. Big Data are usually characterized by three Vs - *volume, variety, and velocity,* but there are four additional Vs that explain accuracy and reliability, variability, visualization and value, or cost-benefit of data collection:

Figure 1: The Vs of Big Data



Source: GTAG Understanding and Auditing Big Data, p. 9

In relation to the scope of Big Data for analytical purposes, it could be characterized as follows:[5]

- High volume of data that needs to be analyzed in detail.
- Data diversity where diversity is both a challenge and opportunity. Data could be structured in databases, semi-structured in log-files, and unstructured like text.
- Processing power and rapid availability due to temporarily validity, especially of process data.
- Quantitative methods for analysis and evaluation of data, calculating alternative scenarios and processing simulations.

Regarding the volume which can be used in a Big Data system, it is possible to use a line item instead of just aggregated data. Specialized Big Data systems are used for updating and processing the Big Data volume. It is clear that detailed data provide a much higher analytical potential than aggregated data to make actual data-based decisions.[6]

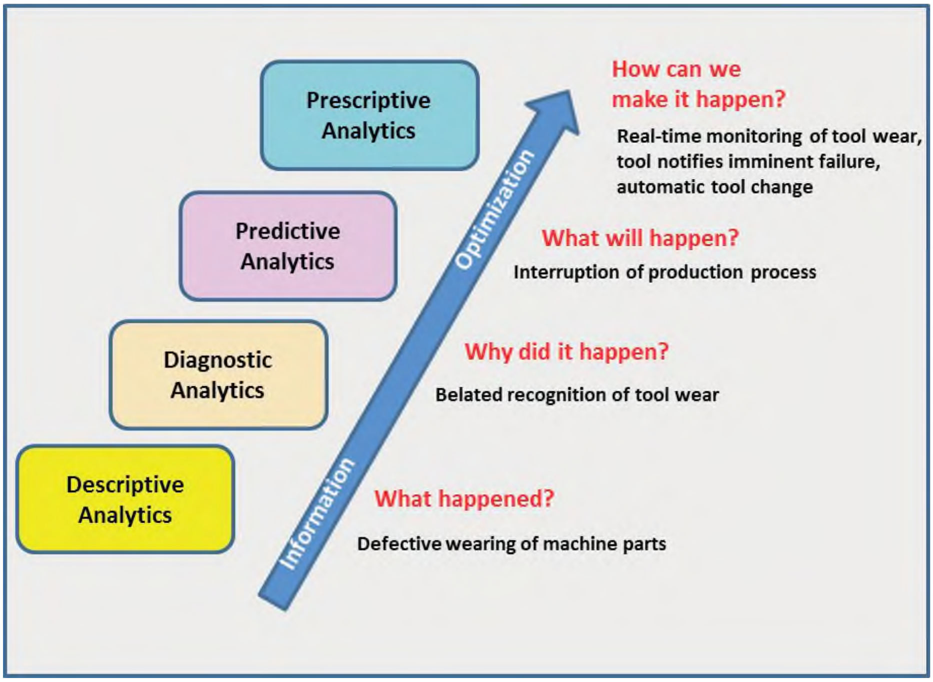
The question arises whether Big Data are more within the scope of tasks of the information technology department, whose aim is to provide data in a short time and accurately. In this regard, the predominant opinion is that the information technology assumes the role of enabler who provides the data using practical capacity of computer equipment and powerful organization of the IT department.

Due to great possibilities of Big Data, the analytics methods are changing from descriptive to prescriptive:

5 McKinsey: Chief Marketing and Sales Officer Forum – Big Data, analytics and the future of marketing and sales, 2013, p. 16.

6 Bakhshaliyeva, N., *et al.*: SAP Predictive Analytics, Bonn, 2017.

Figure 2: Prescriptive analytics as a value-driving instrument for production controlling



Source: Modified from Bakhshaliyeva *et al.*, 2017, p. 59.

The role of controlling is processing and analyzing data and providing the most realistic information for the decision-making process. Therefore, the scope of tasks of "Business Analytics" is defined through Big Data in a new dimension.

The opportunities based on the Big Data technology promise a quantum leap in production controlling. The possibility to simulate future scenarios becomes a reality. The classic role of controlling in the descriptive and analytic analysis will be complemented with predictive and prescriptive analysis. If previous business can be mapped with sufficient accuracy using a mathematical-statistical model, the model provides a very good basis for the development of alternative scenarios and the associated forecasting.

In the past, controlling was focused on data collection and processing. Nowadays, application solutions take over. Controlling has more time to interpret the data and create concepts for a business plan. Time required for data collection and processing can now be used for strategy, planning, and consulting activities.

The technical implementation of the example illustrated in Figure 2 is not only possible in the case of automated enterprise asset management. Big Data contribute to the optimization of the supply chain of networked companies within cooperative planning, forecasting, and replenishment (CPFR).

1.1.4. Controlling as a Sub-System

The goals of controlling are derived from strategic corporate objectives. The controlling system is a sub-system of the company's guidance and management system. The coordination and support of the planning and control system using the computer science system are one of the essential task scopes in controlling.

Therefore, the scope of tasks in area of controlling is development and design of the controlling system on the one hand, and continuous coordination and reconciliation of all organizational sub-systems in the company on the other hand. The fourth industrial revolution generates increasing dynamics in the company and its environment.

Big Data will have considerable influence on controlling in the future. A huge impact on methods, instruments, skills and organizations is to be expected that will consequently redefine the entire world of controlling. Controlling has **two main roles:**

- **Managerial** – an advisory role that helps the management organize, direct and control the activities that will achieve the set goals.
- **Reporting** – coordination of a series of data and information from different sources and their unification into meaningful contents essential for business decision making.

Horváth notes that controlling in a company system coordination mechanism can be distinguished according to system-building and system coupling of coordination.[7] The system-design function leads to generating new sub-systems with special consideration of the interface problem matter. By contrast, the system-coupling function includes ensuring the cooperation of various sub-systems at a given system landscape.

Horváth refers to various forms of human communication and conflict resolution. Today, the communication has progressed to human – machine communication. Therefore, investigation of the controlling system with its integration in the current state of the information technology is essential.

Due to technological changes, controllers have undergone a very successful transformation from registrars to business partners. This should be the strategic focus of the controlling function. The new role of controllers allows closer collaboration with the management on a wider range of topics.

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7 Horváth, P., Gleich, R., Seiter M.: Controlling. 13th Edition. Vahlen, Stuttgart, 2015, p. 332.

1.2. From Big Data to Business Model

The widespread use of the term 'business model' started with the development of personal computers and spreadsheets. There are many definitions and views of this term. Peter Drucker (1994) defined the term as "assumptions about what a company gets paid for" — which is a part of Drucker's "theory of the business". The assumptions relate to the "identification of customers and competitors, their values and behavior, technology and its dynamics, about a company's strengths and weaknesses."

From the point of view of today's digital environment and Big Data, a *business model is a plan for successful operation of a business, identifying sources of revenues, customer base, products, and financing details.*

1.2.1. The Impact of Big Data

Technological progress is ahead of organizational implementation. Currently, it unclear what needs to be done with large amounts of data generated by sensors and the information technology. The following questions must be answered:

- Which benefits can be drawn from the data?
- Which filter should be used for the information flow to distinguish which data are relevant and which are not?
- The statistical methodology is necessary to find the key data in Big Data. Probability distribution, time series analysis and regression analysis are the possible examples. With the support of application management, the correlation of the input – output factors could be detected to build a forecasting model.

Technical handling of a Big Data volume is not the central problem. Powerful mainframes and computers and main memories in the size of petabytes have become available. Economic application solutions related to the new generation of SAP[8]'s business suite[9] S/4HANA[10] are in the ramp-up phases[11].

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8 SAP SE: Systems, Applications & Products in Data Processing is a German multinational software corporation that makes enterprise software to manage business operations and customer relations.

9 A Business Suite is a computer application with a set of integrated business functions, collaboration, industry-specific functionality and scalability.

10 SAP Business Suite 4 SAP HANA (or SAP S/4HANA) is a business suite offering that is built on an in-memory computing platform called SAP HANA. It integrates functions from lines of businesses as well as industry solutions. In: S/4HANA – What CIO and IT Procurement Teams should do now. http://www.upperedge.com/2015/08/s4hana-what-cios-and-it-procurement-teams-should-be-doing-now/

11 Ramp-up is a term used in economics and business to describe an increase in company production ahead of anticipated increases in product demand. Alternatively, ramp-up describes the period between product development and maximum capacity utilization, characterized by product and process experimentation and improvements. In: Terwiesch, Chr. & Bohn, R. E.: *Learning and process improvement during production ramp-up*. International Journal of Production Economics, 70(1), 2001.

The first implementations already took place in productive operation. Finance, sales and logistics are available, and most industry-specific solutions will follow soon.

The success of global businesses does not only depend on technologically unique products or technologies. The creation of value added achieved by business models instead of pure technical production has revolutionized industrial manufacturing.

A manufacturing, industrial company is today understood as a platform in the global network. Company success is based on flexible business processes characterized by an extensive range of interfaces through the entire supply chain.

The development of the concept of controlling has always implied a close relationship between controllers and managers. Over time, their relationship transformed from financial data masters to overall data transparency masters, and ultimately to the level of business partners.

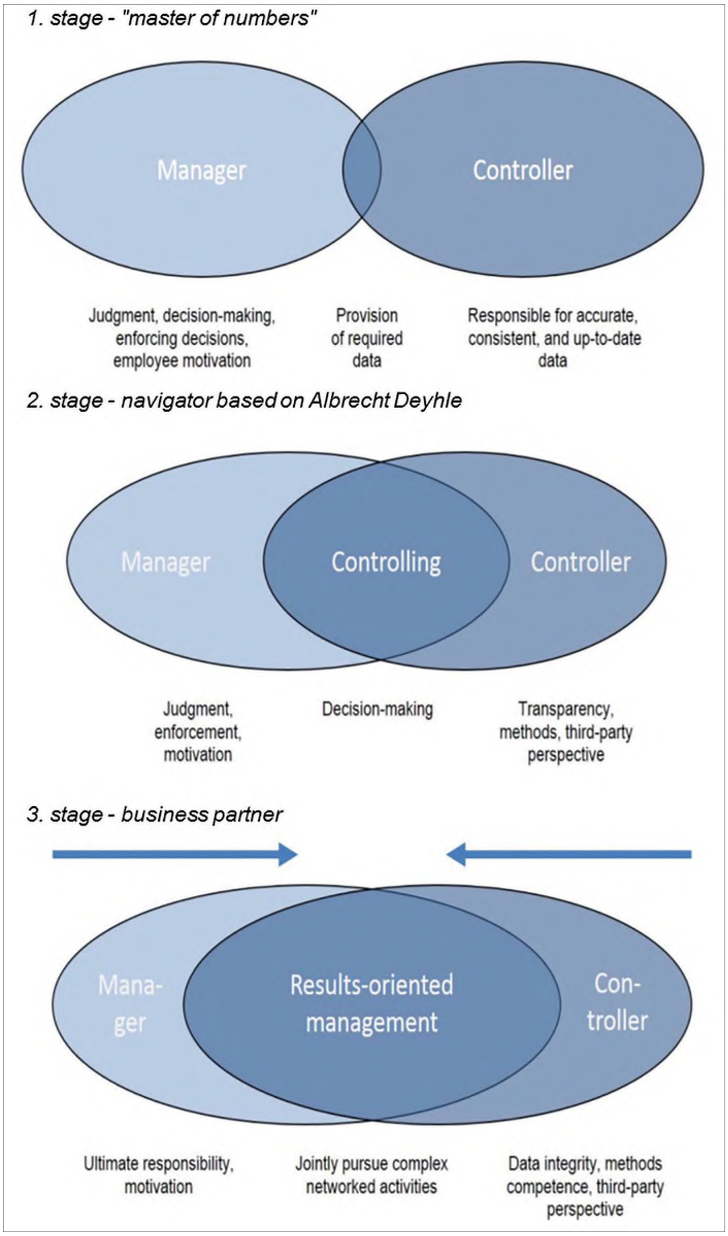
Over the years, business knowledge and experiences of controllers were supplemented by managerial skills so they can be rightfully called business partners. The advisory role of controllers is predominant. Nowadays, in the digital environment and in the future, additional knowledge of computing, statistics, mathematics, and contemporary economics is of utmost importance. Controlling transformation will be directed towards business analyst / data scientist symbiosis. Controllers will provide overall support to management and boost company performance.

The Management – Controller relationship has changed in the digital age. In the past, it seems that controllers were DCOs – Data Collecting Officers – and now, controllers are CMCs – Chief Management Consultants. With the new role of the controlling, positioned as an interface between the data scientist and the management, it is the responsibility of the controlling to avoid misinterpretation of data and find decision-relevant key data. Management and controlling are subject to a paradigm shift. Management and controlling of globally operating companies no longer focus mainly on the factors of production, but on the business models and therefore the resulting business strategies.

The central role of production controlling is to optimize the production and support the production management. Production controlling helps achieve production goals by calculating target-actual variances, determining the consequences of variances, developing solutions, participating in production planning, and implementing production application.

However, productivity and profitability of a company no longer depend mainly on technical capacity, but rather the capability of business processes and their interfaces. The technology itself does not lead to company success in the digital age without experts who are able to use it efficiently. Therefore, human resources developing innovative concepts are the key success factors.

Figure 3: The Management – Controller Relationship



Source: Schäffer & Weber, n.d.

Central problems of production controlling in the digital age are:

- How to achieve efficient and effective production controlling in the networked production environment?
- How to build a "business model oriented" production controlling that currently does not exist in practice? Does the networked production need a paradigm change in controlling, especially in production controlling?
- Which information is required from the manufacturing execution system to achieve an efficient production controlling?

The challenge is solving the issue of an explosive increase in data volume by simultaneous increase in demand regarding processing speed.

1.2.2. Requirements for the Concept of Controlling

The technological progress of the fourth industrial revolution with Big Data analytics, Cyber-Physical System and the Internet of Things leads to a production system with globally connected semi-autonomous production units.

This progress leads to the short interval technology approach[12]. In short interval technology production is understood as a closed loop which can, in microseconds efficiently react to interruptions.

The methods of production controlling using this technology will be explained by the possibilities of computer science such as in-memory computing, using cloud technology, especially a community cloud, and an ERP-system with simplified processes in operations, logistics, accounting, and controlling.

For process-oriented controlling, manufacturing scorecard has been developed for the evaluation of a single production process. Production controlling is supported by the Manufacturing Execution System (MES)[13]. Key figures in this scorecard are machine utilization, delay, advancement in production, and work in the process.

A century of smart factory brought new requirements for an effective controlling system. It requires new metrics measuring the effectiveness of globally networked production systems. It is necessary to develop concepts that will enable successful coordination of the smart factory.

The task of an effective controlling system is to develop new optimization solutions. We propose the conceptual framework based on information technology – analysis of the topics Smart Factory and Computer Science System followed

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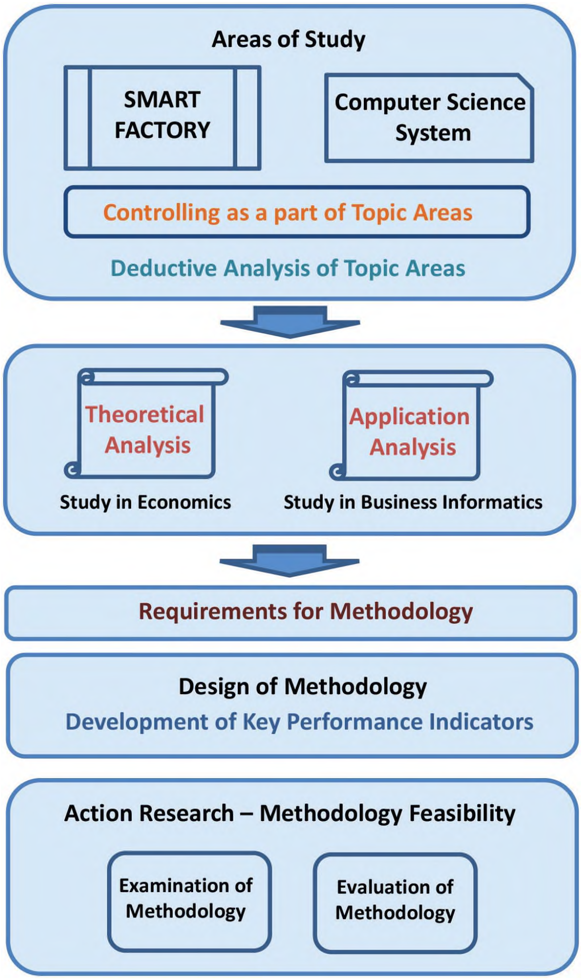
12 Kletti, J. (Ed.): MES – Manufacturing Execution System. Moderne Informationstechnologie unterstützt die Wertschöpfung. Springer, Heidelberg, 2015, p. 31.

13 MES is a computerized system used in manufacturing to track and document the transformation of raw materials to finished goods.

by a specification of the two pillars of applied production controlling, business administration, and business informatics. The methods of operational and strategic production controlling are also presented.

Figure 4: Conceptual framework for process-oriented controlling



The conceptual framework has two dimensions. The first dimension is the economic-conceptual analysis with the objective to define key performance indicators based on a decision-oriented business administration. The second dimension is the computer science system, with which the concept of process-oriented production controlling could be implemented. The second dimension is therefore viewed as a study in practice. The review of the developed process-oriented controlling concept is based on the use of operational and strategic analysis methods.

SUMMARY

Nowadays, the world is a networked industry that is obviously a precondition for achieving flexibility as a response to constantly accelerating changes in the market. Big Data, the Internet of Things, cyber-physical systems, and similar solutions lead to a production system with globally connected semi-autonomous production units. Under these circumstances, that can be defined as a new area of digital economy, the role of controlling as a management sub-system has to be changed. Development has shifted from descriptive analytics, through diagnostic and predictive, to prescriptive analytics. Big Data characterized by volume, variety, velocity, and other attributes enable the use of more sophisticated methods in controlling. Efficiency measurement has become imperative in creating a business model that provides a plan for successful business operation. The controller-manager relationship has to be changed and controller has come closer to becoming a business partner of the management. A controller is nowadays the manager's consultant and positioned as an interface between data scientist and the management with the responsibility to find key data relevant for decision-making and to avoid business failure. Production controlling is a part of the overall controlling system whose aim is to optimize production and support production management. This implies that controller's tasks are calculating target-actual variances, determining the consequences of variances, developing solutions, participating in production planning, and implementing production application. Nowadays the key issue is to find efficient and effective controlling in the networked production environment. A new metrics is needed to build a business model-oriented production controlling, i.e. to develop key performance indicators, manufacturing scorecard, manufacturing execution system (MES) for measuring machine utilization, delay, advancement in production, and other tasks in the production process.

QUESTIONS

1. How does digitalization affect the performance management system?
2. What is the meaning of the fourth industrial revolution?
3. What are cyber-physical systems?
4. What do we know about Big Data?
5. What is the impact of Big Data on management decisions?
6. Describe the controller-manager relationship.
7. What are the tasks of process-oriented controlling and what needs to be changed in the controllers' approach?

2. The Basics and Concepts of Smart Production

The progressive industrial development in technical and organizational aspects accompanied by international economic cooperation[14] means that nowadays a product is produced in all industrialized nations of the world in comparable quality. The technical features and the the quality of the product are no longer the only decision criteria for the customer. With the globalization of technical standards, the range of substitutes has expanded and become virtually unlimited.

Purchase decision used to depend on the product; today, the vendor provides a complete solution that leads to the conclusion of a sales contract. A good example of the requirements for the conclusion of a delivery contract is provided by:[15]

- ISO[16]/9001 or TS/16949[17] certification
- Record of regular auditing
- Purchaser's approval of supplier
- Quality Agreement, process documentation and batch detection
- Initial sampling
- Material analysis for each product
- FMEA process and products[18]
- …

14 The international cooperation of 34 countries in Europe identifying best practice, comparison policy experiences, seeking answers to common problems and coordination of domestic and international policies, is within the scope of tasks of the OECD (Organization for Economic Co-operation and Development). The objective is to stimulate economic progress and world trade.

15 Brauckmann, O.: Smart Production. Wertschöpfung durch Geschäftsmodelle. Springer-Vieweg, Berlin, Heidelberg, 2015, p. 3.

16 ISO - SO is an independent, non-governmental international organization with a membership of 162 national standards bodies. Through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market-relevant International Standards that support innovation and provide solutions to global challenges. In: http://www.iso.org/iso/about.htm

17 The ISO/TS16949 is an ISO technical specification aimed at the development of a quality management system that provides continuous improvement, emphasizing defect prevention and the reduction of variation and waste in the supply chain. It is based on the ISO 9001 standard and the first edition was published in June of 1999 as ISO/TS 16949:1999. In: http://www.iso.org/iso/home/store/catalogue_ics/catalogue_detail_ics.htm?csnumber=30512

18 Failure Mode and Effects Analysis. An FMEA can be a qualitative analysis, but may be put on a quantitative basis when mathematical failure rate models are combined with a statistical failure mode ratio database. Rausand & Hoylan, 2004, p. 88.

This example shows that the product moves to the background. The solution is crucial.

The competition shifts from product competition of products to competitive business models.

2.1. New Forms of Industrialization and the Benefits

Development of new industrialization forms generally originates from a new form of value creation. Whereas products were previously fully manufactured at specific locations, today's products are the result of a globally networked value chain. This leads to a certain anonymity of production, since the original locations of individual components are no longer known to the customer. However, the requirement for flexibility and variability is founded, because it results from production networking. Customers expect increasing variety of products at lower prices.

Technical flexibility of industrial equipment through flexible manufacturing systems supports, but cannot fully meet these requirements. A comprehensive customer service and flexible control of the production process are needed. Lopatowska outlines that production order controls itself independently through the production process.[19] This means that a manufacturing execution system is responsible for coordinating the entire production landscape. [20]

The study of the Fraunhofer Institute IAO[21] resulted in the following major statements on expectations about the production work of the future:

19 Lopatowska, J.: Improving the production planning and control process. In: Zarządzanie i Finanse Journal of Management and Finance Vol. 13, No. 4/1/2015, p. 127.

20 "Self-learning, self-adaptation, and self-development in the process of production planning and control in the environment of dynamic changes enables improvement to the degree that will meet customers' expectations."

21 FRAUNHOFER Institute for Industrial Engineering and Organization (IAO): PRODUKTIONSARBEIT DER ZUKUNFT – INDUSTRIE 4.0. Within the scope of its tasks, the FRAUNHOFER INSTITUTE declares: *"Industry 4.0 includes intelligent networking of objects in production. In the year 2020, 50 billion connected devices will lead to a different networked production in comparison with today's. Technologies are mobile, flexibility is short-term, qualification is direct. New and convertible production structures, networked and Lean Management lean ERP systems are possible. Together, we develop economic applications and new business models for your production of the future."* 2013 Study. Downloaded as PDF on March 5, 2016, p. 135.

- *"Automation is possible for smaller and decreasing series – yet human work remains an important part of the production."*
- *Flexibility is still the key factor for production work in Germany – but more short-term in the future.*
- *Flexibility needs to be targeted in the future and systematically organized – "holiday package flexibility" is no longer enough.*
- *Industry 4.0 becomes CPS networking as the future includes intelligent data acquisition, storage and distribution of objects and people. Decentralized control mechanisms take full autonomy of decentralized, self-controlling properties, but for the foreseeable future. Safety aspects (safety and security) have already been considered in the intelligent production design.*
- *Tasks of traditional production and knowledge workers continue to grow together. Production workers assume increased responsibilities for product development.*
- *Employees must be must be trained for shorter-term, less predictable work."*

In their study with Dieter Spath[22] as the editor, the IAO reached the following conclusion:

> *"The competitive advantage in the future lies in the mastery of complexity and complex technologies along with the necessary know-how."*

This leads to the requirement for transparency with regard to economic consequences of design and coordination of complexity.

2.1.1. Automated Controlling in an Intelligent Factory

With growing globalization and the consequent complexity of production processes, it can only be managed with a high degree of automation. The share of software engineering in mechanical engineering is estimated to 40 percent of the total engineering volume in this branch.[23]

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22 Spath, D.: Director of IAO, currently Chief Executive Officer of the company Wittenstein AG.
23 Niggemann O., Jasperneite J., Vodencarevic A.: Konzepte und Anwendungsfälle für die intelligente Fabrik. In: Bauernhansl T., ten Hompel M., Vogel-Heuser B. (eds) Industrie 4.0 in Produktion, Automatisierung und Logistik. Springer Vieweg, Wiesbaden, 2014, p. 173.

In an interview, Stetter, R. detects the following:[24]

> *Vehicles will drive at a time even. New competitors emerge, such as Google, which exhibits for the first time at the IAA, 2015. Machines are the only computer (networks) mechanics depend on.*
>
> *Everything changes and is digital and virtual, and the companies that want to survive must be fast, agile, and completely flexible to dominate new business.*

2.1.1.1. Intelligent Automation

In the world of the Internet of Things, the amount of data will increase immensely. Mastering the automation in globally networked production systems leads to the challenge to analyze large amounts of data in real time to identify, extract and evaluate relevant information. Rigid linked material flow and inflexible machine chain systems will no longer meet the requirements of dynamic production. This also applies to production controlling. A rigid metrics production controlling at the end of the production line corresponds to production monitoring, but not to future-oriented production controlling with real-time analysis and the resulting decisions at operational and tactical levels.

The basis for such a production controlling scenario is placed at the operating level in the production:

- Self-diagnosis
- Self-configuration
- Self-optimization.

Warnecke & Hüser[25] developed the fractal factory model in which decentralized production structures are defined as a closed-loop control circuit. The fractals should act autonomously and optimize themselves. The technical basis for such a fractal factory has now become available and the fractals of the factory could be networked and transferred to the entire supply chain using cyber-physical networks. This means that the fourth industrial revolution is similar to the second industrial revolution: the evolution from Taylorism to networked manufacturing units.

24 Stetter, R.: General Manager of ITQ GmbH. Interview on November 11, 2015 at the IT2 Industry Open Conference, http://www.blog.it2industry.de/2015/09/30/interview-dr-rainer-stetter-itq-gmbh/.
25 Warnecke, H. J., Hüser, M.: Die Fraktale Fabrik - Revolution der Unternehmenskultur Springer, Heidelberg, 1996.

In view of *self-diagnosis*, production units can detect and diagnose unusual situations. The technical components are sensors, actuators, and control systems, that take control of the machine. *Self-configuration* and *self-optimization* are achieved at the automation level by hypothetical simulation and evaluation. Hypothetical simulation means a reconfiguration and its review based on a constantly updating and self-learning reference model.

This leads to a paradigm shift of the operational and tactical production controlling. In the classic process, experts have been thinking ahead and programmed solution knowledge. This descriptive automation is replaced by new IT and new reference architecture.

At the Institute of Industrial Information Technology in IT[26] in Lemgo and the Fraunhofer Application Center for Industrial Automation IOSB-INA[27], intelligent automation and assistance systems are developed in various projects. New technological basis does not only cover production planning and control, but also production controlling.

The basis for intelligent automation is measurement of process data in the related sensor and control technology. The measured values are compared to the preset data, the deviations of which are detected at a technical level. Technical changes can be identified and forwarded to the associative level. These specifications may not only be the result of disruptions or interruptions of the machine, but also characteristics of the product which might be the result of the basic or changed configuration of the product.

2.1.1.2. Process Data Structuring

It is important to conduct process data structuring at the associative level. An environment model is required for the evaluation of the existing production processes; it is necessary to define a higher-level automation strategy for automation. The objective of the associative level is classification and standardization for a better integration into the existing approaches to solutions.

The symbolic level consists of the search for an explanation based on purely logical conclusions. The specific evaluation of the process situation is carried out at this level. This level is comparable with the general structure experience of people in general and controllers in particular. The symbolic level suggests an adjustment of the process by updating process-relevant parameters.

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26 The Institute Industrial IT (inIT) of the Ostwestfalen-Lippe University of Applied Sciences in Lemgo carries out research in the field of industrial informatics and industrial automation for cyber-physical systems and is situated within one of the most important clusters of machine engineering and industrial electronics in Germany. https://www.hs-owl.de/init/en/

27 The Fraunhofer Application Center Industrial Automation (IOSB-INA) in Lemgo provides clients innovative hardware and software solutions in the following areas: • Industrial Internet, • Intelligent Automation and• Usability Technical Systems. http://www.iosb.fraunhofer.de/servlet/is/7305/

These new specifications are simulated at the associative level. Which forecast values of the production process result from the actualized parameterization?

A central role in this scenario is the ability to learn. Increasing information leads to a better interpretation and higher-quality proposals, which is the case for human beings and intelligent automation alike. The synthesis of similar quantitative states into a single symbol is the conversion of quantified states to discrete states in this learning process; the transfer of a steady continuous state to a clearly determined state.[28]

The experience at the machine level and, ultimately, at the level of humans in controlling leads to frequent completion of conclusion rules and their use for analytic (diagnosis) and synthetic (optimization) functions.[29]

It can be concluded that *intelligent automation provides the basis for a better interface between the technical production process and humans by a self-learning control-system supporting the controlling system with qualified information in real time.*

2.1.2. Service-Oriented Production Network

Service orientation means orientation to customers. As mentioned above, the networked industry of the 21st century requires the company to convince the customers of product performance. This performance is evident not only in the quality and delivery time, but also in the service. This includes company flexibility and the manner in which the company could react to changing demands of the market.

The preconditions for flexibilityare organization (fractal factory), technology (man-machine interaction), and the possibility to measure corporate performance. These topics will be discussed in the following sections.

2.1.2.1. Fractal Factory and Man-Machine Interaction

"Only complexity can handle complexity." This quote by Ashby[30] detects the challenge in the new century of networking. Due to global competition, the requirements regarding supply availability, price elasticity, compatibility of products,

28 Niggemann, O., et al. describe in their report the reference architecture of intelligent automation which is the conceptual basis for human-machine interface in production control, further developed for production controlling. Technical relations are in the focus of the report, while the transmission into the machine-human-interface and corporation between intelligent automation and process-oriented production controlling will be discussed in this book, 2014, p. 176.

29 By analogy with Niggemann's remarks and the quotation mentioned in his report: *"A language consists of symbols that convey meaning, plus rules for combination of those symbols, that can be used to generate an infinite variety of messages."*

30 In Bauernhansl, Th.: Die Vierte Industrielle Revolution – Der Weg in ein wertschaffendes Produktionsparadigma. In: Bauernhansl T., ten Hompel M., Vogel-Heuser B. (eds) Industrie 4.0 in Produktion, Automatisierung und Logistik, Springer Vieweg, Wiesbaden, 2014, p. 14.

and reliability of counterparties in the market have been growing. This increases the complexity of global production. The competitive pressure is forcing companies to become increasingly flexible. Customers expect a timely customer-tailored solution. Additionally, political and economic crises affect the global economy, which further increases external complexity for enterprises.

On the other hand, increasing product, customer and supplier portfolio, extensively distributed decentralized production chains, and therefore supply chains, various process technologies and information technology systems are driving internal complexity in a company. “The challenge lies with the company to bring external and internal complexity in harmony.”[31]

The solution is in decentralized autonomous intelligence synergetic structures, as described in the previous chapter of this book: Automated controlling in an intelligent factory. This means that the fractal factory with self-organizing production fractals is the answer to increasing complexity. Although the concept has been developed in the last century, the technological basis is available now.

The objective is *to find the correct granularity of production process modules and link them.* Thus, each product and product variant can take a different route through the production system. The higher or more flexible the granularity of the production process realized, the more individual product-related production process. This means that the product itself controls its way through the entire production system. The technical flexibility of production utilities can now be used more efficiently with the available information and communication technology of the fourth industrial revolution.

The granularity of production processes has therefore consequent granularity of information on production controlling.

The human-machine interaction enables humans not only to seek mechanical support for their tasks, but also to observe and possibly interfere with the process before the occurrence of any disruption.

Man-machine interaction is illustrated by the following example:

A problem occurs in production and can be recorded with a smartphone using an app[32]. For this purpose, a picture or a barcode could be scanned in order to clarify the problem in the production control department. The corresponding workplace and the product will be identified. However, the problem can also be reported to the MES and shared in the Big Data cloud. It searches for solutions. The identified symptoms can be identified at a very high level and could prove very responsive and focused.

31 Ibid, p. 15.

32 App – An application software for mobile devices or mobile operating systems, developed with HTML5. Although the term refers to app as an abbreviation of the English term Application Software on any type of application software, it is often equated in the German language with application software for mobile devices. It usually implies applications for smartphones and tablet computers.

The decision on the solution will be taken in the production control department, supported by automated intelligence of the MES in a service-oriented networked production control system.[33]

2.1.2.2. Overall Equipment Effectiveness (OEE)

Overall equipment effectiveness (OEE) is the gold standard, i.e. best practice for measuring manufacturing productivity. It identifies the *percentage of manufacturing time that is truly productive*. Based on the technical possibilities described in the previous section, process-oriented key performance indicators (KPI) can be made available within the MES for operative production controlling. A central KPI in manufacturing is OEE*.* To count this compound KPI, information on availability, process data, and quality information are needed.

Data are collected at the technical process level and transmitted to monitoring (see the previous Figure 4 about reference architecture for intelligent automation). This is implemented as an aggregated analyzing service in service-oriented architecture of the production information system. A combination of KPIs can be selected and analyzed using the KPI-app for each workplace in the production process, especially that of a machine.

In terms of process-oriented production controlling, a real-time overview of the important production process KPIs is available. It supports:

- Process planning and control
- Active intervention for external control and self-control of the production process
- Individual configuration of key figures charts
- Update of templates containing defined scenarios.

Companies have to constantly adapt to the markets in order to remain globally competitive. In recent years, numerous improvements of machines and products of economic acquisition and information processing have been made at the technical level, but usually only in closed IT systems. Networking and linking the information from the physical production with the digital world still require a lot of effort. Therefore, the introduction and operation of such IT systems to optimize factory planning and factory operations in both large companies and in small and medium-sized enterprises have not advanced. With the help of a federal and secure platform for distributed service-oriented applications, the virtual Fort Knox, this information fracture has been overcome. For example, the information from factory planning and production control can be used to schedule production processes flexibly.

33 Bauernhansl, Th., op.cit., p. 27.

Simultaneously, the use of the virtual Fort Knox, due to its distributed cloud-based architecture, leads to a reduced effort on the part of companies.[34]

Virtual Fort Knox is a platform for production companies offering appropriate production-related IT-solutions. It supports large companies and SMEs, also in the implementation and operation of IT systems to optimize factory planning and factory operations.

A paradigm change has occurred in the information and communication technology. Centralized systems will be replaced by cloud-based decentralized systems. The classic software suite (like SAP's Business Suite, comment of the authors of this book) will be replaced by software as an app-based service. The integration of application modules and systems is replaced by networked communication. The delay in getting the real picture while reading data from the database will be replaced by real-time information using in-memory computing and cyber-physical systems.

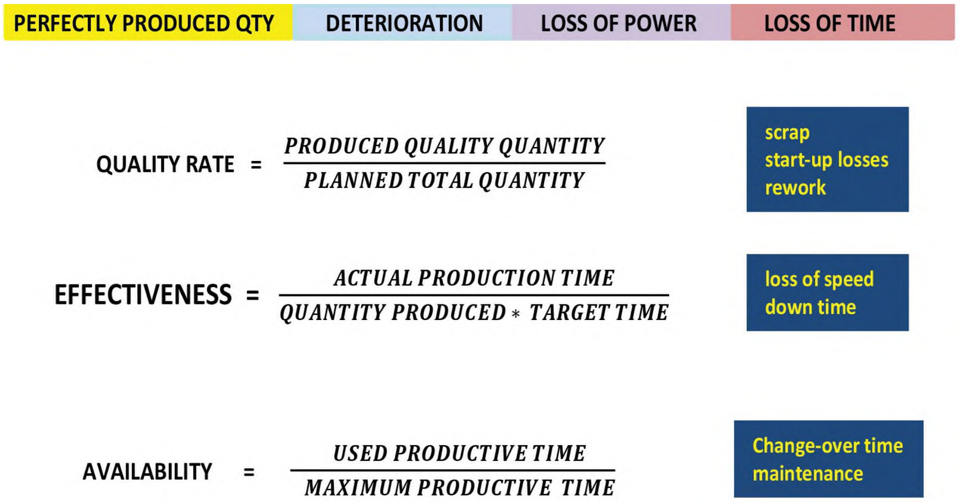
The benefits of using the technology of the fourth industrial revolution and networking are estimated by:[35]

- **Stock costs:** reducing safety stocks, avoiding the bullwhip-effect.
- **Manufacturing costs:** improvement of the overall equipment effectiveness, improvement of vertical and horizontal personal flexibility.
- **Logistic costs:** increasing the range of automation.
- **Complexity costs:** reducing troubleshooting costs.
- **Quality costs:** real-time quality cycles.
- **Enterprise asset management costs:** predictive maintenance. Dynamic priority setting.
- **Overall equipment effectiveness (OEE)** measures the actual effectiveness of an installation by setting error-free output quantity in relation to the maximum possible amount.
- **A drill-down-analysis of production units,** individual products and periods or types of errors should be possible. Opportunities for optimization should result from the analysis. In general, higher OEE represents higher effectiveness. However, if marginal costs are too high, optimization could be wrong if the ratio of productivity and profitability deteriorates.

34 Fraunhofer Institute, downloaded on March 18, 2016. URL: https://www.virtualfortknox.de/ueber-virtual-fort-knox.html
35 Bauernhansl, Th., op.cit., p. 31.

The OEE is the single best metric for identifying losses, benchmarking progress, and improving the productivity of manufacturing equipment. The calculation of the OEE is illustrated in the figure below.

Figure 5: Calculation of Overall Equipment Effectiveness (OEE)



The benefits of the new technology will be evident on the market. It is an investment in new technology, but also in new business models and new forms of organization. Hence, the request is forwarded to a business model-oriented controlling in general and production controlling in particular.[36]

The quality rate defines the portion of yield quantity in relation to the total produced quantity.

$$\text{Quality Rate (QR)} = \frac{\text{Total Quantity} + \text{Scrap}}{\text{Total Quantity}}$$

Plant availability defines the portion of availability time in relation to the uptime of the plant.

$$\text{Plant Availability (PA)} = \frac{\text{Uptime} - \text{Downtime}}{\text{Total Time}}$$

Plant effectiveness defines productivity: what quantity could be produced in comparison to the time needed. It is defined by the portion of the possible production quantity in relation to the realized production quantity. The theoretical cycle rate defines the capacity of the plant; how many products can be produced in a time unit.

36 Ibid, p. 23.

$$\text{Equipment Effectiveness (EFF)} = \frac{\text{Ideal Cycle Time} * \text{Total Quantity}}{\text{Run Time}}$$

The quotation shows that, if the theoretical cycle rate is higher with constant total quantity and constant net uptime, the equipment effectiveness is lower.

Overall equipment effectiveness is defined as follows: **OEE = QR * PA * EFF**

Find an example at the end of the textbook – Exercise 1.

2.1.3. Real-Time Process Optimization

The optimization of production processes is one of the key factors for productivity gains of the fourth industrial revolution. But, how can processes be optimized or problems identified at all if their key figures had not been recognized? While processing times of a workpiece are logged in detail at their individual production levels, usually based on the monitoring functions of production machines, little attention is devoted to the capture of previous waiting times. However, the analysis of waiting time provides the opportunity to identify and exploit the potential for optimization considering technically based workflow in the production.[37]

2.1.3.1. Optimized Value Chain

A central element of the fourth industrial revolution is non-hierarchical communication, where there is no longer a central controlling instance that controls the production process, but the product itself in communication with decentralized semi-autonomous production instances.

While in the hierarchical communication structure decentralized regulation and control equipment at production facilities measure process data and forward them to local computers and further to a central production control system, the communication flow will be implemented through decentralized enterprise communication networks.

At the operational level, technologies such as RFID[38], robotics, and smart sensor technology provide technical conditions for machinery, equipment, products, and components to interact with each other, exchange data and information in real time, execute actions and control each other.

37 At the 2016 Hannover Fair, the Center of the Enterprise Resource Planning RWTH of the University of Aachen represents an ERP model with the function of identification of real-time delays in the production workflow. Retrieved from http://www.pressebox.de/pressemitteilung/asseco-solutions-ag/Industrie-40- Demonstrator-zeigt-effiziente-Prozessoptimierung-durch-Echtzeit-Positionsdaten-mit-APplus/boxid/790782 on April 16, 2016.

38 RFID - Radio-Frequency Identification. Identification aided by electromagnetic waves is a technology for transceiver systems for automatic, contactless identification and localization of objects and living beings with radio waves. Taken from: https://de.wikipedia.org/wiki/RFID.

The challenge for companies is the ability to derive relevant patterns from enormous amounts of data (Big Data) to derive knowledge for further operational and tactical management in general and production management. The realization of the networked, Internet-connected industrial production is a result of close connection with enterprise resource planning systems (ERP), manufacturing execution systems (MES), databases with real-time information from factories, supply chains, as well as customers and products. Network production system instances require a virtual platform that serves as a "marketplace" for fast, easy and secure exchange of information.

Regarding the communication through the Internet Protocol Version 6 (IPv6), the address space of the Internet of around 4 billion addresses is expanded to 340 sextillion (10^{38}) addresses. Thus, any cyber physical system will be uniquely addressed and identified worldwide.[39]

While cyber physical systems (CPS) enable data transmission at the operational level, Big Data and cloud computing are the key information technologies. In-memory technology and analysis solutions as a basis for Big-Data applications are the backbone of the IT in which the manufacturing companies must invest if they want to use the possibilities of CPS. Analysis of solutions for efficient and effective production control as well as production controlling are already available and will be further developed. They offer manufacturing companies development of new business models that expand far beyond sole usage in manufacturing.[40]

SAP has developed the new SAP S/4HANA technology that serves as a platform for new-generation business applications Smart Logistics and Smart Financials. While SAP HANA has already been successfully used for machine-machine communication, business applications are in the ramp-up phase. This means that the first successful implementations widen exponentially due to enormous demand. Applications, which can be used economically due to the new technology, are, for example, short-term product demand forecast, automatic replenishment based on the current production status, and condition-based maintenance of the production facilities.

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39 This comprehensive network enables large quantities and new types of data – Big Data. In addition to economic purposes, Big Data can be also be used to answer questions about the networked production. Conventional statistical models are developed. Thus, vast Big Data records can be purposefully evaluated and information extracted. New insights, forecasting and analysis use Big Data in many areas – from weather forecast to medical research and diagnostics. In: Industry 4.0 and the digital economy. Stimuli for growth, employment and innovation. German Federal Ministry for Economic Affairs and Energy. Published in 2015.

40 Kleinemeier, M.: Von der Automatisierungspyramide zu Unternehmenssteuerungs-Netzwerken. In: Bauernhansl T., Ten Hompel M., Vogel-Heuser B. (eds) Industrie 4.0 in Produktion, Automatisierung und Logistik, Springer Vieweg, Wiesbaden, 2014, p. 576.

2.1.3.2. Performance Idea

With regard to the topic of this book, technologies like cloud computing and in-memory computing are a contribution to the fourth industrial revolution. Cloud computing has many features that make it attractive to business, such as: no up-front investment, lower operating costs, easy access, reduction of business risks and maintenance expenses.[41] By in-memory computing companies could crunch and analyze large volumes of data in near real-time and run sophisticated 'what if' simulations. SAP's in-memory computing technology called 'Hana' (an acronym for High-Speed Analytical Appliance) uses sophisticated data compression techniques to store information in RAM which is 10,000 times faster than standard disks, enabling companies to analyze these data in seconds instead of hours.

SAP positions its own idea for performance.[42] SAP addresses the innovation of in-memory computing with the in-memory database named HANA (High Analytical Appliance). Data records are not stored line-oriented, but column-oriented. In a classic database, data records are stored sequentially one after another. If a program needs to select one or more attributes or a key figure of every data record, the program must read the whole data record, one after the other. HANA saves the records column-oriented. The program only has to read the respective columns of the required attributes or key figures. This accelerates reading time a thousand times. In a globally networked industrial group, it is a decisive competitive advantage. In the global networked production systems that need to make production decisions in real time, this is an absolute must.

The platform for future scenarios of distributed production systems are business networks in which there is a cross-link between producers, suppliers, customers, and service providers. Figure 6 demonstrates a scheme for the following scenario: a customer can be a source of ideas and therefore also the innovator. Supported by professional designers, the innovation phase will be realized in cooperation with customers, designers, and manufacturers.

In the design phase, online networks of distributed production systems will provide assistance in production and in cases when there are supply interruptions with predictive analysis and propose alternative production options in a short time.

The task comprises:

- engineers' solutions (for example, sensor technology),
- computer science (digitization of analog data), and
- organization with optimized resource management.

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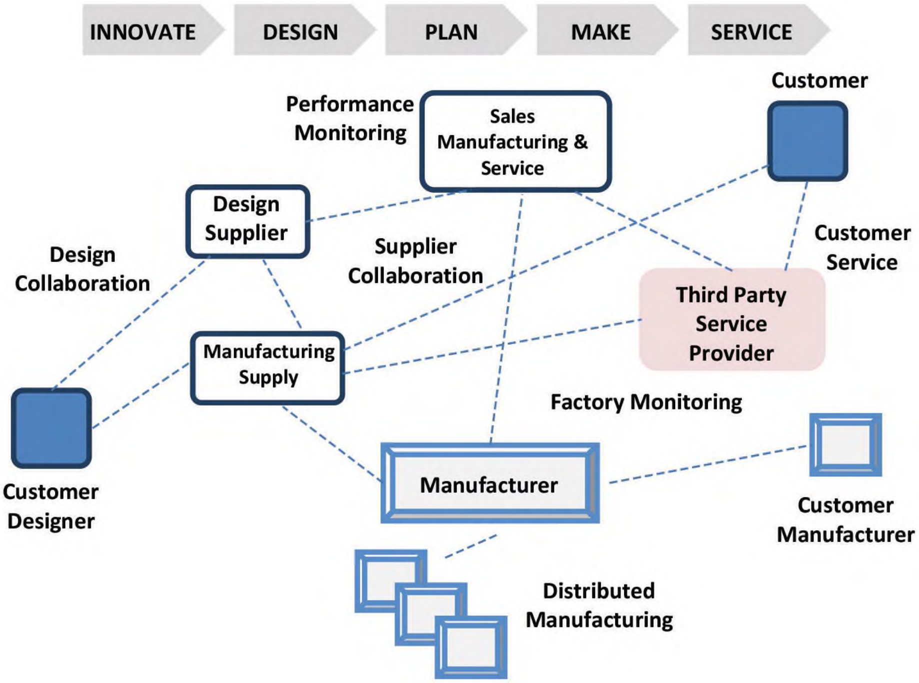
41 Zhang, Qi, Lu Cheng, L, Boutaba, R.: Cloud computing: state-of-the-art and research challenges, J Internet Serv Appl, 2010, p. 7.

42 Kleinemeier, M., op.cit., p. 573.

2.1.3.3. Business Network

From the perspective of services, the interlink of manufacturing execution systems (MES) will exchange data and therefore provide performance monitoring at each location of the production system. Efficiency and effectiveness of partial processes and the entire production process can be measured at each location of the business network, depending on data access authorities.

Figure 6: Business Network



Source: Modified from Kleinemeier, M., 2014, p. 577.

The above figure shows changing of classic rigid business processes with sequential workflows of traditional supply chains through value-added business networks. The core of the new business model is that business partner relationships can be built and configured in a short time. Digitalization and always-on connectivity enable real-time optimized value chains.

The success factor is in the dynamic calculation of delivery time based on real-time feedback from the supply network while considering varying conditions such as legal issues, risk, liability, and export control.[43] For operative production controlling, this means that, in order to make the decision on changing the supply chain, all production and logistic scenario-relevant data for the alternative scenarios must be available in real time.

43 Ibid, p. 576-577.

With the intelligence and communication capability of machines and the autonomy and self-organization ability of production units, the information about the actual status of the production process are transferred to the MES and further to the ERP system. The production management has a real-time overview of production and can react in a short time to solve any kind of interruptions if the self-controlled semi-autonomous production units have not already done it themselves

Considering the tactical and strategic production management and controlling, linking the production data to more corporate information results in new possibilities to generate process optimization and new business ideas. An example would be the production of highly specific parts for individual customers, efficient control of energy consumption in the production, or the best possible utilization and distribution of equipment, employees and resources. Companies can identify operational risks earlier and solve potential problems before they arise.[44]

2.2. Business Models and Smart Production

In general, it is fair to say that everything in the fourth industrial revolution and the related technology focuses on data generated by the combination of machine data and process data.

Business model dimensions are described as follows:[45]

- **The customer:** To what extent have we fulfilled the customer's requirements?
- **The benefit:** What benefit do we provide to the customer?
- **The value chain:** How do we generate performance?
- **The revenue mechanism:** How do we generate value added?

Taking into consideration the previous chapter, the terms *innovate*, *design*, *plan*, *make*, and *service* are the dimensions of business models in terms of new commercial competition.

Development of commercial competition arises from products based on a holistic solution of the business model.[46]

It may be an innovation based on existing business models, change and optimization of the existing business models or generation of new business models.[47]

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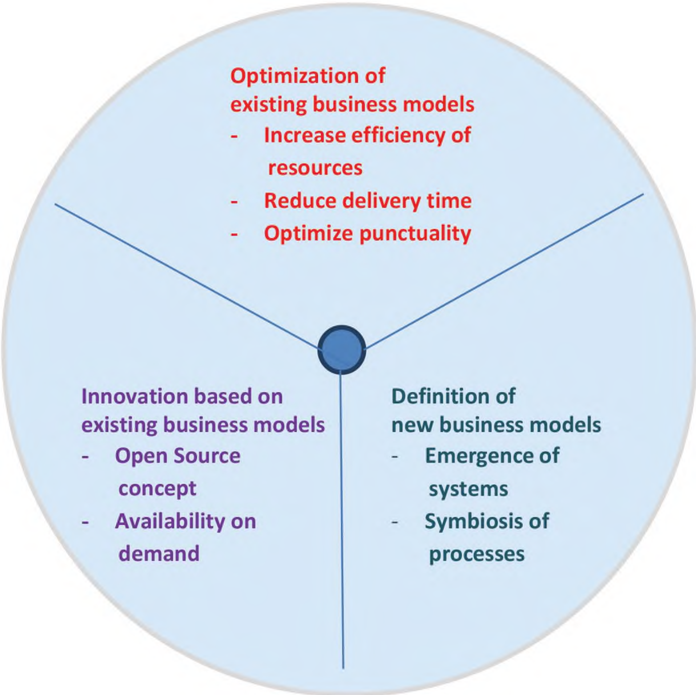
44 Kleinermeier does note such new possibilities in the integration of top-floor and shop-floor control in the production environment. Ibid.

45 Kaufmann, T.: Geschäftsmodelle in Industrie 4.0 und dem Internet der Dinge. Der Weg Vom Anspruch in die Wirklichkeit. Springer-Vieweg, Wiesbaden, 2015, p. 11.

46 Brauckmann, O., op.cit., p. 23.

47 Kaufmann, T., op.cit., p. 11.

Figure 7: Business Model Optimization



Business model innovations based on existing business models are characterized by the fact that they have already been pre-planned in other areas; they, however, constitute a new application for the company.

New business models can emerge through the application of new technologies designed in view of the fourth industrial revolution in the fields of sensors, actuators, and new information technologies such as the cyber physical system (CPS), Big Data, and rapid transmission of information.[48]

2.2.1. The Importance of Business Models for Companies

A business model is an organization concept aiming to create business. The concept includes a product (or a product idea), the process of its production, structural and procedural organization, cooperation, and interaction with other companies as well as financial arrangements.

The companies take into account the value of the proposition and the total cost of ownership. A business model is a part of the business strategy. It is necessary to achieve strategic goals and objectives of the company.

48 Ibid, p. 12.

Firstly, we will devote a few sentences to the meaning of a business model and why it is important for the company.

A business model consists of:[49]

1. Service offerings,
2. Value added,
3. Revenue model.

1. *Service offerings*, including product range, are one of the essential business model dimensions. They describe the product and the target client. This includes the description of product characteristics and customers' benefits. The key question is which services and product functions generate customers' benefits. This point of view is also defined as the external perspective.
2. *Value added* is, on the other hand, focused on internal perspective. The central question here is: "How is money made and how is it spent?"

   The "value added" dimension consists of two sub-categories: service creation and marketing model.

   - Provision of services – when designing a business model, a company must consider how it wants to create power products. Questions about make-or-buy, the organizational structure, core competencies or cooperation with other partners will be answered here. It has a central influence on the cost structure of the company.
   - Marketing model – sales are investigated in the marketing model. Communication and distribution channels need to be considered here. Which communication activities support the sales and which distribution channels, such as direct sales, distributors, private sales, telesales, the Internet, etc. are used?
3. The revenue model is different from the marketing model because the focus is on "how" the revenue will be generated. What are the pricing models? Is there a regular service fee or a flat rate? Is it the sale of the actual product or a license fee? Will the revenues be generated primarily through advertising revenues like Facebook, AOL, Google, and Yahoo?

2.2.1.1. Market Creation through Production

Classic customer benefit is achieved by the features and functions of the product. In addition to the purely technical functions; it includes features such as product

49 Design Thinking in Marketing, within 6 steps to product innovation, in www.marketing.de, retrieved 04/2016.

design and image, which is generated in particular by product marketing. Customers' benefits nowadays do not depend solely on the product itself, but on pairing with a package of additional services such as program diversity, its availability, energy saving, recycling, and sustainability. By combining products and services, the business foundation has changed as well as the requirements for inspecting and controlling the success of the change in business processes.

This means that the product itself creates its market. Examples include smartphones, digital cameras and personal computers. If customer benefit is only obtained with the generation of business models and their application, the process is not completely predictable. The sub-processes in combination with alternative business processes within alternative business models are based on a dynamic design of customer-supplier relationships. This results in the requirement for an harmonization of the management and controlling of business models and the associated processes.

This means a shift from the automation and control pyramid towards a near real-time tracking of production processes as a basis for business model-oriented management and controlling

Companies are worthless without a functional interaction with the market. A business model reinvents the business, defines the business, and establishes the value of products, thus creating company value.[50] A company that sleeps through the transformation of the business models makes a strategic error that often cannot be corrected. Examples of failed business models are the mail-order company QUELLE and the manufacturer of mid-sized computers NIXDORF.[51]

2.2.1.2. Justification of the Return on Investment

The business model determines the return on investment (ROI) to evaluate the efficiency of an investment. Example: an airplane cannot create return on investment (ROI) unless there is a business model for the aircraft. The success of aircraft manufacturers depends directly on the success of the airline, which in turn must generate successful air routes in the market. The market strategy

50 Brauckmann, O., op.cit., p. 29.

51 QUELLE: On June 6, 2009, the company announced it was no longer able to pay rent for its department stores, which the company had previously sold and lease backed. Three days later, the company filed for bankruptcy. The classic business model of sending a catalogue and getting the orders via post letters was declining. Nixdorf: On October 1, 1990, Siemens took over the Nixdorf shares and the merger between the Nixdorf Computer AG and Siemens to the Siemens Nixdorf Informations-Systeme (SNI) followed. Thousands of people lost their jobs in Paderborn in the same year because Siemens had to shrink the company. Mid-sized NIXDORF computers were replaced by much more efficient personal computers.

could be connected to a proactive strategy offering a high frequency of flights and comfortable trips. However, it can also be a cost leadership strategy, which offers incomparable low-cost travel.

Business models create companies. For example, there is no doubt that Rolex is an accurate watch, which could be purchased for 100 EUR. The remaining 19,910 EUR is payment for something other than the watch: jewelry, fashion, lifestyle, and public image. The computer manufacturer Dell got out of a difficult economic situation as the leading manufacturer of personal computers. Its business model relies on online configuration by the customer and direct delivery to the customer.[52]

2.2.1.3. The Profit Impact of Market Strategy

However, it must be noted that, over time, dynamics leads to the lack of scientific approach to principles of business models. The business management discipline of strategic management is based on the framework of the past.[53] Nevertheless, the Profit Impact of Market Strategy is a fundamental study in this research field, described as follows:

1. *Definition: An empirical research project in the field of strategic analysis and planning (strategic management), was initiated by F. Borch at the beginning of the 1960s and led (scientifically) by S. Schoeffler. The aim of the empirical study was to reach the highest possible number of regularities in strategic business areas ("Laws of the Market Place") derived to determine the success of these kinds of shops. These laws should lead to general and industry-independent recommendations for the design of strategies. They also temporarily coined the theoretical framework of a number of approaches to portfolio analysis.*
2. *Development: Initially, the project was referring exclusively to General Electric businesses and was used only by this company.*

   The desire for broadening the base study and generalization of the results were reasons for the project becoming independent in the Marketing Science Institute (Harvard Business School). In 1975, the project was carried out by the independent and non-profit Strategic Planning Institute (Cambridge, Mass.).

52 Brauckmann, O., 2015, p. 32.
53 Ibid, p. 34.

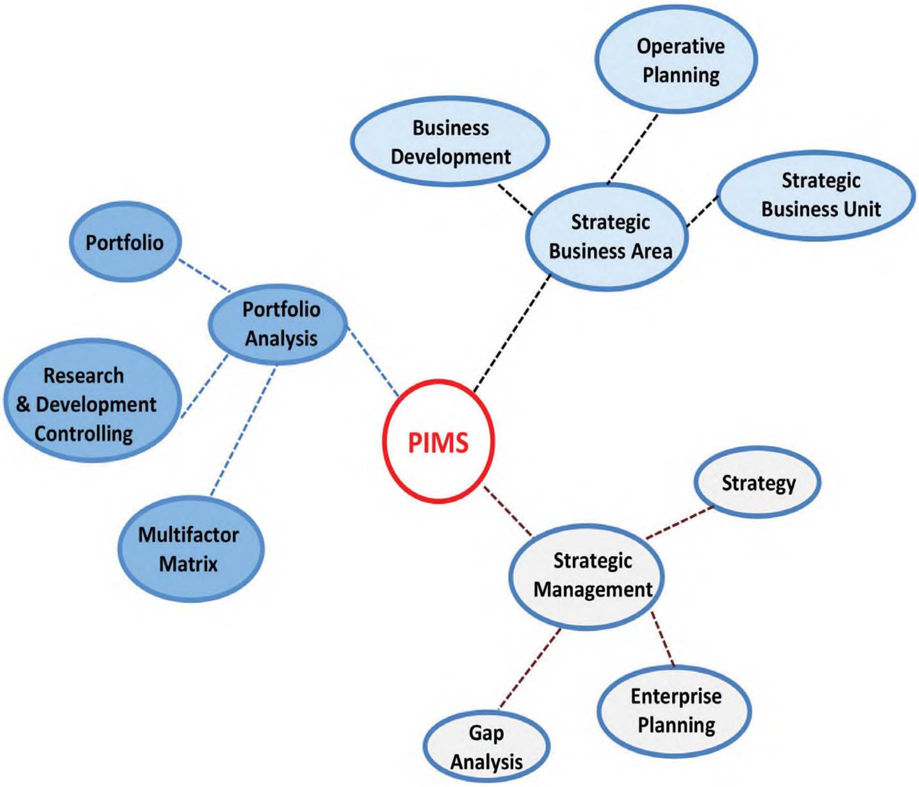
3. *Research results:*

    a) *The main result: About 80 percent of the business profitability variance (return on investment in percent before tax) may be explained with about 40 factors. The corresponding statements can be distinguished in many directions (for example, by strong and weak growth of the business).*

    b) *Specific results are reports on three special operations of member companies – employers in comparison with another business in similar situations: the Performance Audit Report (statements on "normal" profitability); Strategic Analysis Report (strategy simulations); Optimum Strategy Report (identification of successful strategy combinations).*

4. *Criticisms: narrowness of statements from cross-sectional analyzes; lack of cross-linking of model variables, sampling; inductively-led research design; sector-independent basis for comparison with individual analyzes.*

Figure 8: The Profit Impact of Market Strategy



The PIMS study represents a long-pursued search for the science of success. As long as the results are formulated from a higher economic standpoint, there is danger of trivial statements which can also be turned into their opposites.

However, if there is a possibility to associate business model patterns on the basis of real-time process data in production processes and to empirically demonstrate behavior, the operational production control can support a business model oriented to production controlling.

2.2.2. Improving the Processes to Perfect Production

This section describes technical development using an example of economic methodology used to perfect production. There are many points of view and possible solutions that could be used in the environment for perfect production. An Internet website provides an idea for a perfect production.

"Short interval technology" as the technical dimension, "value stream diagram" as business reengineering methodology, and "branch and bound" as an economic method, are used to provide an introduction to production improvement methodology.

2.2.2.1. Elements of Short Interval Technology

The objective in perfect production is in the so-called "*short interval technology*" (SIT) to improve the existing production of a company by building faster control loops in terms of transparency, responsiveness, and efficiency.

Traditionally, production optimization leads to technical optimization of production facilities and reduction of throughput times of production orders with simultaneous maximization of capacity utilization. This requires coordination of individual locations across the entire supply chain management.

There are *five steps on the way to perfect production*

1. Clarification of the *status quo*,
2. Lean production,
3. Implementation of the manufacturing execution system (MES),
4. Lean production planning,
5. Process-oriented key figures of production.

While the first two points will be discussed in this chapter, MES will be explained in the next segment of this chapter. Lean production planning and process-oriented production key figures will be included in Chapter 4 that covers building of a key figure system.

In drawing up the *status quo*, the goal is to create an overview of the production processes. Weak points are identified and measures for improvement of the processes are to be developed. Investigation of the overall process and relationships between partial processes within the overall process are important. The focus is on the evaluation of value-added processes, support processes, and the associated planning and information processes.

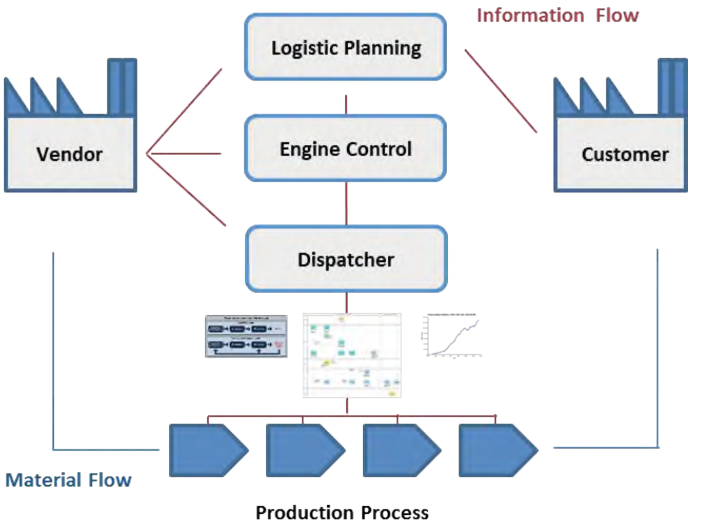
The related information flows are examined on the basis of material flows. The examination results are recorded in the so-called *value stream map*. Products with the same or similar processing steps are assigned to a product family. The findings can be applied to all products of the product family.

2.2.2.2. Value Stream Scheme

One of the main objectives of a value stream is to link all processes in the value stream in order to create a flow. This value stream is largely controlled by customer pull. The close linking of the processes in the value stream aims to achieve a reduction of lead time as well as a simultaneous reduction of stocks, errors, and scrap. The objective is *to shift the control of individual processes to the control of total, efficient, customer-oriented current flow value*.[54]

To identify opportunities for improvement, processing times in the production process and process efficiency can be calculated on the basis of the information recorded in a value stream diagram.

Figure 9: Value Stream Scheme



54 Klevers, Th.: Wertstrom-Mapping und Wertstrom-Design. Verschwendung erkennen – Wertschöpfung steigern. mi-Fachverlag Redline GmbH, Landsberg am Lech, 2007, p. 33.

The process efficiency indicator measures the efficiency of the production process. It is defined as the ratio of value-added time and throughput time. Value-added time is the *production time*, while other times, like down-time and block-time, reduce the throughput time to value-added time. If unexpected down-time, like using predictive maintenance of the production equipment, could be avoided, value-added time could be increased, thus increasing the efficiency of the production process.

The *process efficiency degree* (PED) is defined as follows:

$$PED = \frac{\text{Value Added Time}}{\text{Overall Throughput Time}}$$

The Overall Equipment Effectiveness Index - OEEI has been explained In the previous chapter 2.1.2.2 as follows:

$$\text{OEEI} = \text{Availability Degree} * \text{Effectiveness Degree} * \text{Quality Degree}$$

The combination of the process efficiency degree and the overall equipment effectiveness leads to the *Lean Performance Index* – LPI:[55]

$$\text{LPI} = \text{PED} * \text{OEEI}$$

The LPI status describes the areas in which improvement can be expected. The short interval technology (SIT) of production processes using faster control loops (compare to chapter 2.2.2.1) is detected in a checklist to identify the starting points for process optimization. The LPI is also used to detect the extent to which the manufacturing execution system is used to automate the production process.

A prerequisite for fast production controllability within the meaning of the perfect production and the associated SIT are lean manufacturing processes. The founder of lean production, Taiichi Ohno,[56] defined seven types of waste inflating the production process:

- Overproduction which unnecessarily overloads the production processes.
- Waiting times due to intermediate stocks, equipment shortages, lack of materials, and lack of tools. These processes are not adding value and interfere with the production process.

55 Kletti, J., op.cit., p. 73.

56 Taiichi Ohno was a Japanese industrial engineer and businessman. He is considered to be the father of the Toyota Production System, which became lean manufacturing in the U.S. He devised the seven wastes (or *muda* in Japanese) as part of this system. He wrote several books about the system, including Toyota Production System: Beyond Large-Scale Production. In: https://en.wikipedia.org/wiki/Taiichi_Ohno.

- Internal transport, particularly if it relates to a great distance by non-optimal layout of production planning.
- Inefficient processing if processing effort could be reduced.
- Storage, especially if stock movements are inefficient due to unavailable warehouse management system (WMS).
- Superfluous movements due to non-optimized workstation ergonomics.
- Errors leading to a considerable additional expenditure, for example, by reworking in production.

Kletti and Schumacher[57] added two waste points:

- Waste by lack of staff retention and motivation
- Waste through poor information interfaces.

2.2.2.3. Process Improvement

Rationalization of production processes is possible through measures reflected in the following:

- Creation of a clean and efficient work environment by removing unnecessary items from the workplace and an ergonomic arrangement.
- Reducing setup times by various methods depending on the objective, which could be low throughput time or maximum capacity utilization.[58]
- Predictive maintenance of the production facilities, which reduces interruption times and ensures quality.

The method introduced below enables the reduction of the setup time necessary to switch from one product to another on the same production equipment. Examples of setup time are changing the tools, cleaning, and setting up electronic control.

The setup time differs depending on product types. In a make-to-stock production scenario, the sequence of production orders is flexible, because no sales order sets the delivery date.

The determination of a production order sequence with similar products leads to the reduction of setup time.

57 Kletti, J., Schumacher, J., 2014, p. 76-77.

58 Different methods of reducing setup times are discussed in: Lebefromm, U.: Produktionsmanagement. 5th edition. Oldenbourg, München. 2003, p. 277.

The principle of the *Branch & Bound (B&B) method*[59] is the following:

When changing from one product to another, setup times are entered into an initial matrix. Since the order combination searched for is the one with the lowest setup time, only relative setup times are required. For this reason, the matrix can be reduced.

The most favorable predecessor-successor relationship is the *coefficient value zero*. If in each column and each row of the matrix at least one coefficient has the value zero, row or column reduction is not required.

What does the value zero mean for a coefficient? *The value zero in a column states that, of all the other coefficients in the column, the combination with the coefficient zero represents the lowest predecessor cost. The value zero in a row states that, of all the other coefficients, this combination represents the lowest successor cost*. Each row or column can also have several zero coefficients.

How is a column or a row reduced? Column reduction: subtract the lowest coefficient of all other coefficients in the column. Line reduction: subtract the lowest coefficient of the line from all the other coefficients in the line. Thus, at least one coefficient (the lowest in each case) becomes zero. On the other hand, if a column already has a zero coefficient, the reduction, logically, does not result in any change in the other coefficients in the column or row.

The steps to be performed in the Branch & Bound procedure for calculating the order combination with the lowest setup times, i.e. setup costs are as follows:

Check whether each column and each row have a zero coefficient. If not, apply column or line reduction. For each zero coefficient, add the minimum value of row and column. This means, which is the higher predecessor (column) or successor (row) that would arise had this order combination not been selected. The zero coefficient with the highest sum is the order combination sought in this step, since this combination achieves the highest cost avoidance of all the other combinations..

Delete the row and column of the selected combination, since this combination no longer has to be taken into account (BRANCH). Apply the next iteration until all products or orders have been considered.

A calculation example is presented below.

59 B&B is an algorithm design paradigm for discrete and combinatorial optimization problems, as well as mathematical optimization. It is based on the principle that a total set of feasible solutions can be partitioned into smaller subsets of solutions which can be evaluated systematically until the best solution is found.

The following is the output matrix of the setup costs of four product types:

From product i to product j	1	2	3	4
1	x	3	2	4
2	5	x	1	3
3	8	6	x	4
4	4	8	10	x

The table defines the setup cost from one order to another. On the main diagonal, the coefficient has an “x”. An “x” means that the setup costs are zero or that a change from the product (respectively production order) in a row to the product in a column is not possible, usually due to technical reasons.

Calculation of order sequence according to the Branch & Bound method:

Reduction of Columns

From product i to product j	1	2	3	4
1	x	0	1	1
2	1	x	0	0
3	4	3	x	1
4	0	5	9	x

For each column and each row, a minimum of one coefficient must be identified as value zero. A zero coefficient is a candidate for the selection of a combination of products. To identify such a coefficient, reduction of columns is calculated first. This means that, in each column, all coefficients are subtracted from the highest value of the column. Each column must have one or more zero-coefficients in the result. With regard to the column, such coefficients have a minimum predecessor cost.

Secondly, the focus is on the matrix row. The focus is on the successor cost. Each row must have a minimum of one zero coefficient to be a candidate for selection. For each row which does not have a zero element, all coefficients are subtracted from the highest coefficient in the row.

Line Reduction

From product i to product j	1	2	3	4
1	x	0	1	1
2	1	x	0	0
3	3	2	x	0
4	0	5	9	x

Each column and each row now contain a zero-element. The minimum value of the previous order (minimum value in the column of the zero-element) and the minimum value of the following order (minimum value in the line of the zero-element) will be added to each zero-element. This operand indicates which previous and following additional setup cost would occur had these order combinations – represented by the zero element – not been selected. The zero element with the highest operand is therefore to be selected, because it contains the highest preventable opportunity cost.

Each zero-element calculated plus the minimum value of the element's column and element's line:

From i to j	1	2	3	4
1	x	1+2=3	1	1
2	1	x	0+1=1	0+0=0
3	3	2	x	2+0=2
4	**1+5=6**	5	9	x

The combination including order no. 4 to order no. 1 must be selected. The column and line of the selected element will be eliminated (branch) and the next step will follow with the reduced matrix.

From i to j	2	3	4
1	**1+2=3**	1	1
2	x	0+1=1	0+0=0
3	2	x	2+0=2

The following order combination is order no. 1 to order no. 2. With the two order combinations, the complete order sequence is found, because only order no. 3 is left.

The order sequence with the lowest setup cost is: {4 - 1 - 2 - 3}

The limitation method for line balancing of partial processes is provided with the position value method. For this purpose, individual steps in the production process are allocated to workstations. Under the restriction of equal cycle time at all workstations, the utilization of each workstation should be maximized. Line balancing does not only match the process steps in one location, but all locations across the entire production network and in interaction with the customers and suppliers.[60]

An important, if not crucial, building block in perfect production is the manufacturing execution system (MES), which will be introduced in the next chapter.

2.2.3. Manufacturing Execution Systems (MES)

The level of enterprise resource planning (ERP)[61] in production planning handles the production orders and their status, but not the process and the sub-processes. This is the application of the MES. Regarding the production costs, only those directly related to the processing of products, for example, setup costs, processing costs, and storage costs are considered. However, in traditional cost accounting, the cost of unused resources remains undetected. Depending on the degree of utilization in the production area, improvement potentials therefore remain unrecognized. Activity-based costing (ABC) can contribute to the solving of this problem. However, real-time data of the production processes are necessary for the implementation of such a cost accounting method.

Horváth noted that the new potential of information technologies will fundamentally change value creation processes in the company and refers to industry 4.0. Through the Internet of Things and Big Data, information is provided by the controller who will considerably enhance decision-making.[62]

The role of MES is crucial. It is not only an extended machine controller or an extension of an ERP system. In recent years, MES has widely been considered the key figure generator for production. *MES is an element of planning and quality assurance which supports the optimization of the production efficiency in the short term*. A modern production must be reactive in order to respond quickly to changing customer requirements or trigger situations. MES can ideally provide the necessary transparency of production processes.

60 Kletti, J. provided an example of how to replace cycle steps extended by the customer with the identified alternative cycle steps. Time balancing has to be achieved with technical or organizational measures. op.cit., p. 84.

61 ERP – Enterprise Resource Planning System. ERP provides an integrated view of core business processes, often in real-time, using common databases maintained by a database management system. ERP systems track business resources; cash, raw materials, production capacity, and the status of business commitments: orders, purchase orders, and payroll. The applications that make up the system share data across various departments (manufacturing, purchasing, sales, accounting, etc.) that provide the data.

62 Horváth, P. *et al.,* 2015, p. 27.

2.2.3.1. The Problem of Classic Production Planning and Control (PPC)

The problems of classic production in terms of organization and IT solutions are:

- **Lack of transparency in production.** Data in production processes are confirmed with a time delay, so a quick reaction to changes in the production process cannot be guaranteed. In addition to the actual quantity of good material and scrap, actual times must be confirmed promptly to enable process optimization.
- **Missing or inadequate data collection.** The key figure overall equipment effectiveness (OEE) has been explained in the previous Chapter 2.1.2.3. The calculation of OEE requires real-time detection of process data. However, an effective shop floor management is only possible on the basis of process data.
- **High inventories and intermediate stocks.** High stocks result in a lack of flexibility, because the stocks will diminish at first, and replenishment will follow. In particular, high intermediate stocks can slow down the current production process. Besides, high inventory leads to high capital tie-up and reduced efficiency.
- **Another problem are long lead times in production and, even worse, the fact that individual times of processing times are often unknown.** Measuring only the start and end time of a production process is insufficient. Each part of the process must be recorded. This includes the setup time, processing time, handling and storage times, waiting times, transport times, and the duration of occurring interruptions. The potentials for process acceleration can be identified only by accurate capturing of all individual times.
- **Poor punctuality.** Punctuality is affected by a number of time-consuming factors: unplanned shutdowns, fluctuating setup and machining times, as well as changes in disposition-relevant data like delivery date, changing in routing and bill of materials. This problem cannot be solved with classic production planning methods. The classic methods are:
  - Planning against infinite capacity,
  - Planning without knowledge of the actual situation due to unavailable online functionality for measuring the production order and machine status,
  - Manual planning boards, Excel or paper-based scheduling. This problem can only be solved by “lean planning”.[63] This will be discussed later in the book.

63 Parsons, N.: Palo Alto Software (USA). Article 12/2014, www.paloalto.com.

Lean planning is a process, not a document. *Lean planning is a set of tools for discovering a business model that works, building an action plan to test assumptions, creating financial models and a plan for viable business and performance tracking.* Lean planning is planning faster with less writing in contrast to the classic "waterfall" process.

A real business plan is a tool for growing a smarter, faster and more profitable business than the competition. Missing synchronization between the organizational units includes the synchronization of production planning and control (PPC) with the tooling, whereby the tools are not available on time. The same applies to production department synchronization, which causes a suboptimal order sequence.[64]

Finally, the synchronization of the production with maintenance possibly generates unplanned time interruption or stops. Predictive maintenance is the concept that could solve this problem.

2.2.3.2. The Sustainable Factory

Every company that wants long-term success needs economic success. This can only be achieved if the resources are used in a regenerative manner. Motivated employees and the lowest possible consumption of resources as well as environmental compatibility contribute to a long-term increase in the company's success. *The sustainability factors are:*

- Social responsibility,
- Ecological responsibility,
- Innovation.

Sustainability can be measured with *ecological balance sheets, life-cycle analysis of the products, and environmental impacts of products.* Aspects measured in corporate sustainability reports are reduction of emissions into air and water, increased production and energy efficiency, discussion of non-renewable resources, waste and wastewater reduction by recycling, recovery and use of residual materials, development and use of eco-efficient technologies, development of innovative products and services, and occupational health and safety.[65]

64 Compare to section 2.2.2.3: Process Improvement in this book.
65 Austrian Chamber of Economy, www.wko.at.

This shows that a sustainable factory has its aspects in both ecological and employee responsibility, as well as in the economic matter of innovation. In this book, the focus is on the innovation aspect.

To successfully survive in globalized world against competing companies, a company must take into account the requirements and wishes of customers and, on the other hand, production improvement in terms of effectiveness and efficiency.

From a customer's perspective, quality has always been the first factor, followed by delivery punctuality. Globalization and increase in competition added the low prices requirement.

Merging of customer requests for short delivery time, quality and low prices with the company's goals of profitability and punctuality can be achieved only by production flexibility. Therefore, the ways to provide flexibility and time delivery performance must be developed on the one hand, and profitability maintained on the other hand.

The prerequisites are transparent reactive production processes. This is defined with the short interval technology.[66]

Using the classic methods of production planning and control, companies invest a lot of effort in establishing the supply chain management in a networked production.

Manufacturing execution systems can extract important information for the production management and production controlling from the mass of data in the production area.

Short interval technology is an approach to creating a perfect, responsive, transparent, and cost-effective production. For this purpose, manufacturing and manufacturing management are viewed as a control loop which may optimally respond to incoming events. These events could be capacity problems, rush orders or missing stock quantity.

On principle, *production can be understood as a closed loop system in which the input signals (resources and outcomes) and the output signals (product-related, dates, quantities, costs) are generated.*[67]

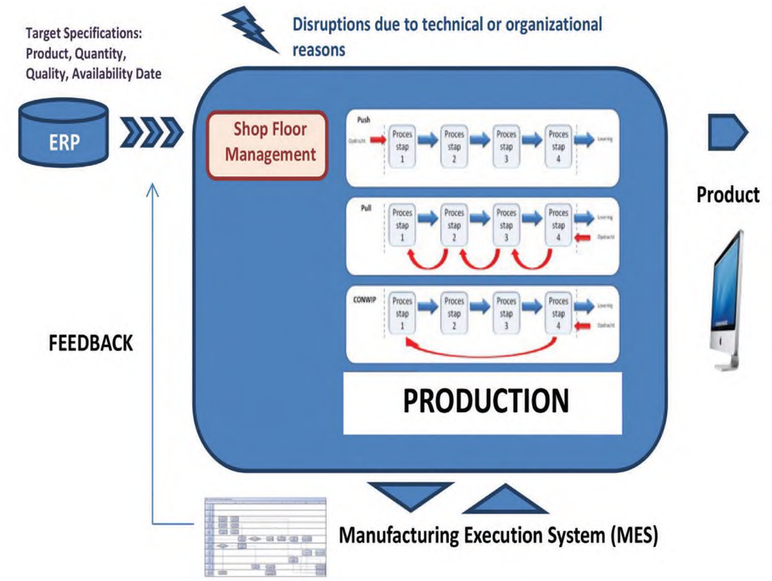
This production system can be controlled at production management levels in the ERP[68] system, the shop floor management in the MES, and the production process itself.

66 Kletti, J., Schumacher, J., op.cit., p. 73.

67 Ibid., p.13

68 ERP – Enterprise Resource Planning

Figure 10: Closed Loop Production System



The key target figures of the SIT are:

- Increasing the reaction speed of the control loop to real-time responses and
- Increasing the accuracy of decision-relevant information.

The interaction of information in real time, the resulting transparency in production and short-designed control loops enable a rapid response to interruptions that are the basis for a lean, responsive, and effective production.[69]

2.2.3.3. Information Management in Manufacturing with MES

Classic controlling as a subsystem of corporate governance is concerned with collecting, reviewing and preparing information to assist the management. For the – now technically possible – self-learning system in semi-autonomous production units which have been addressed in section 2.1.1.1 (Intelligent Self-Automation), data aggregated by the ERP system are insufficient. MES is an important supplier of decision-relevant data.

Therefore, MES is to be understood as a data hub, where company-wide production planning data are exchanged with data from the manufacturing process. The MES is thereby directly coupled with the production process detection technique. This includes machine controls, sensors, and radio-frequency identification (RFID) technology.

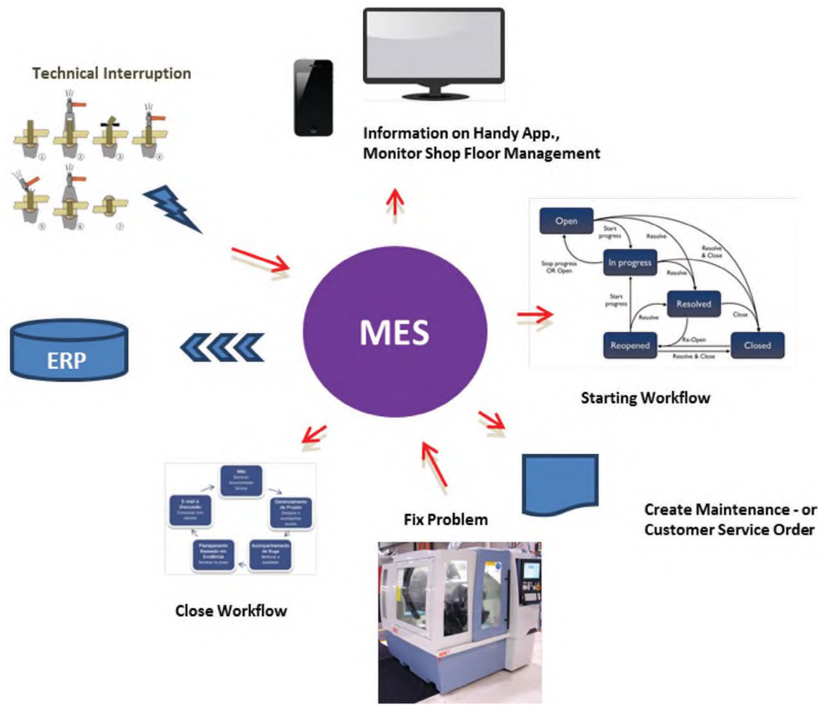
69 Ibid, p.14

The connection of the MES with production technology has a technical and logical dimension. As part of the technical connection, machine signals and pulses are passed, for example, via Extensible Markup Language (XML) or Open Platform Communication (OPC).

The most important data passing through the MES to production facilities are defined target values, process value specifications, processing instructions as well as distributed numeric control (DNC) programs. The most important data which a MES gets from the shop floor level are receiving machine cycles, counting pulses, operating signals, machine status, measurements, and process data. The purpose of this connection is a high degree of automation, thereby increasing the efficiency and reducing operator errors and the quality of production process and, of course, the product itself. The intra-logistics is also viewed as a part of the production. Internal transport of workpieces in the production often takes place in driverless transport systems. It can send information to the logistics system through the process data available in the MES and – with cross-over location transport – also to the logistics provider about start and end times, delays, and material quantity.[70]

In order to make the central role of MES clear, an example of a tool breakage is given in the figure below.

Figure 11: The Role of MES – Example



Source: Adapted from Kletti, J., 2015, p. 241.

70 Kletti, J., op.cit., p. 234

A tool breaks on a machine, starting an elaborate processing logic across multiple levels. The MES sets the status of the machine to “standstill” and sends corresponding information to a mobile phone application or to the shop floor management system in the production control department. To solve the situation, MES starts a workflow, whereby a programmed sequence informs the organizational unit responsible for maintenance and troubleshooting. The successful execution of maintenance is signaled to the MES.

It can be checked in the ERP system whether the clients were affected by the interruption. Furthermore, ERP can search for alternative processes to avoid the time delay. Finally, data come together in process-oriented production controlling for economic calculation and evaluation.

Today – and in the future – we need sustainable management decisions, meaningful evaluations, and performance measurement systems (Smart Data). This is based on integrated MES solutions with standardized interfaces. These data can be recorded locally, processed across multiple systems and recycled. This also shows the importance of MES systems as central information and data hubs. This will also continue in the future, because the MES knowledge empowers production manager and their staff to affect productivity. With an integrated MES system like Hydra MPDV[71], manufacturing companies sustain their competitiveness and are already laying the foundation for industry 4.0. Management support is therefore also an important component of the institutional strategy MES 4.0[72] which already summarizes the requirements for future production strategies. No matter how smart and independent production becomes in the future, people should ultimately take responsibility and implement the right decisions. In order to do that, they need reliable information. Knowledge is power.

For consistent communication across all company levels, each of the used indicators must be based on a common database. This could be captured with MES data (for example, production volumes) which are therefore compressed, combined with other data and displayed as target group ratios. The operator can thus directly see the quantity produced and the OEE[73], calculated from these and other data. Additionally, timeliness of evaluated information is of great importance. It should be noted that some indicators reflect the current state while other indicators reflect the progress of key performance indicators. Period-related metrics are usually meaningful only after the end of each interval (for example, productivity), whereas real-time metrics can be viewed at any time (for example, quality rate).

71 www.mpdv.com
72 www.mes4.0.de
73 OEE – Overall Equipment Effectiveness. Compare to section 2.1.2.3.

2.3. Megatrend: Big Data

No other entrepreneurial topic in the last few decades has had such an enormous impact like the economic debate about Big Data. The technical possibilities of Big Data lead to nothing less than a structural change in the society through digitalization and networking of the world, which will also make a socio-cultural impact.[74] Beside social, there are also *economic and legal dimension* of Big Data. The economic dimension is reflected in new business models and shift in information contents and delivery. The legal dimension refers to ownership, liability, insolvency, and other issues in the context of privacy and security.

The increasing digitalization leads to an ever-increasing data volume that extends to all areas of life. The reason for this development are mainly technological innovations, like smartphones, tablets and wearables in connection with data exchange platforms: social networks, chats, and blogs. However, considerably larger amounts of data will be produced by the machine – machine communication in the Internet of Things. The machines are linked in real-time and integrated into value creation scenarios. Overall, the ever-increasing digitalization affects the products and services of the company. Physical parts of value processes are replaced by digital information platforms (online shopping). The cooperation between business partners is organized electronically with the involvement of eco-systems, the so-called “business networks”.[75]

From this aspect, *information is to be understood as a core competence without which a company cannot exist in the globalized competition*. Machine-collected and processed information help managers make decisions in real time according to accurate and reliable data.

2.3.1. Analysis in Controlling Based on Big Data

The world of data is changing due to the methods and technologies of the fourth industrial revolution. The volume of data obtained for the collection, storage, and analysis has considerably increased. Meanwhile, not only terabytes, but petabytes and even zettabytes are collected and must be evaluated quickly to obtain reliable knowledge.

Data characteristics are changing. While mostly structured data had previously been selected as a basis for control and controlling, semi-structured and unstructured data in the form of images have occurred lately. However, the biggest challenge is the fact that data are needed in real time.

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74 Bachmann, R., Gerzer, Th., Kemper, G.: Big Data – Fluch oder Segen. Unternehmen im Spiegel gesellschaftlichen Wandels. Mitp. Heidelberg, 2014, p. 62.

75 Seufert, A.: Das Controlling als Business Partner: Business Intelligence at Big Data als zentrales Aufgabenfeld. In: Gleich/Grönke/Kirchmann/Leyk (eds.): Controlling und Big Data. Anforderungen, Auswirkungen, Lösungen. Haufe, Freiburg and Munich, 2014, p. 25-26.

The information needs to be viewed as a resource that integrates the impact on value chains and products and services of the company. It is no longer the main objective for obtaining information as a basis for current decisions. Information is rather part of innovation which could fundamentally change business models. Business intelligence is defined as a set of decision-relevant corporate information in a business warehouse data pool. The progress of business intelligence systems can be defined with five levels that have been the milestones in its development.

These levels are the following:[76]

Level 1: **Organizational Units**

In the IT-Backend-Systems, production planning and control are only possible within a single organizational unit – a plant. Additionally, all instances of production networks cannot be reduced to a plant. Distribution centers, warehouses, and transport equipment must also be taken into account. Such a global supply chain production network can be launched using the IT-solution “Data Warehouse”, also called Business Intelligence (BI). Today, process data of all production processes can be analyzed in real time across different systems used by the production partners in the global production network.

Level 2: **Internal Processes**

An empirically observable expansion is in the process-oriented use of BI. It is noticeable that many companies had initially invested in the development of support processes and gradually started analytical investigation of value-adding processes. (Figure 12)

Level 3: **Internal and External Processes**

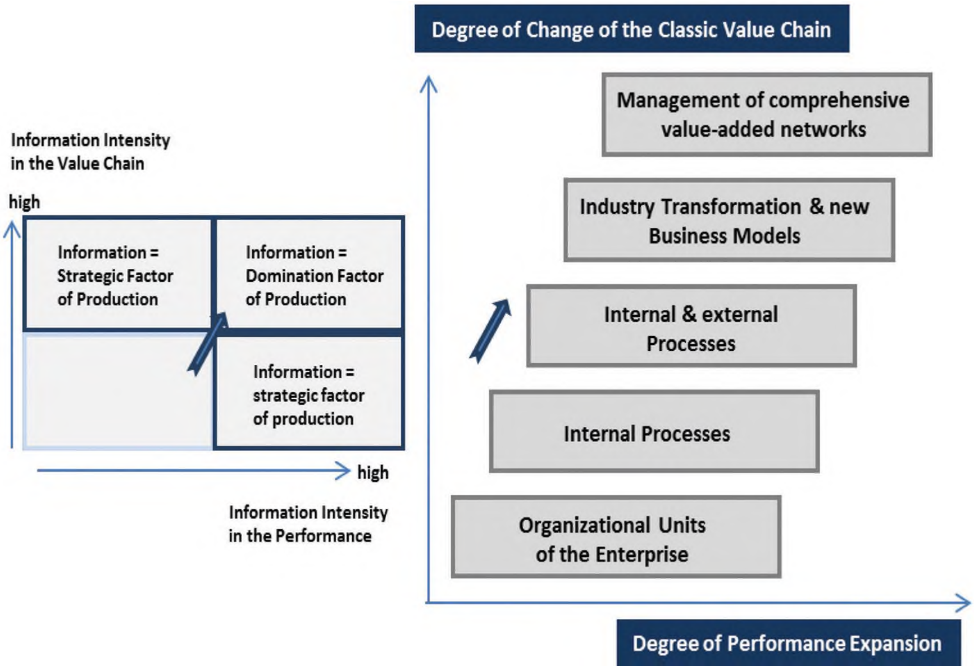
Another development step is to extend process-oriented BI deployment to enterprise-wide support and value-added processes. These include liquidity management in the corporate group or real-time supply chain control.

Level 4 and 5: **Industry transformation and new business models as well as management of comprehensive value-added networks.**

The use of resource information to establish new business models or even entire ecosystems has emerged from traditional companies. In companies in which information is a predominant factor of production, however, information plays the prominent role. Using Big Data and cloud services, data are networked world-wide and analytics is used intensively to establish new disruptive business models. Amazon, Google, and Apple are pertinent examples. These companies increase their business and compete with the traditional industries.

76 Ibid, p. 28

Figure 12: Progress of Business Intelligence and Big Data



Source: Modified from Seufert, A., 2014, p. 28.

2.3.2. Data Scientist & Controller

The use of Big Data is associated with the role of data scientist. *A data scientist combines the statistical methodology and the information technology, but it is not in his scope of tasks to forecast, plan and monitor the business.* This is the task of the controlling. While the data scientist proves the robustness and effectiveness of forecasting models, the controller creates the ideas and hypotheses to be proven. *The controlling draws the conclusions and takes the role of management consulting.*

Big Data can lead to a management revolution if there is a possibility to generate economic benefits of Big Data. For this purpose, however, we need more qualified personnel specialized in data analysis methodology.[77]

77 Horváth, P., Aschenbrücker, A.: Data Scientist: Konkurrenz oder Katalysator für den Controller? In: Controlling und Big Data, p. 47, 2012, available at 47https://www.haufe.de/finance/finance-office-professional/data-scientist-konkurrenz-oder-katalysator-fuer-den-controller_idesk_PI11525_HI7186208.html,

A recent study by the Institute for Business Intelligence shows the fundamental importance of data scientists. The role of a data scientist is required for the conversion of data from Big Data into information. The benefits of Big Data can only be achieved by the information obtained.

Therefore, development of appropriate skills and a sensible organizational integration of the data scientist role is a critical point for a value-added contribution of Big Data. The role profile is described in Horváth's paper, which relies on Davenport's[78] contribution.

The roles of a data scientist are: [79]

- **Hacker.** A data scientist is familiar with scripting and programming methods which can be used for rapid generation of business applications. These include the implementation of Big Data technologies.
- **Scientist.** It refers to design skills, UDN construction, conducting experiments. This includes the analysis and description of experimental results. This is a basis for business decisions.
- **Analyzer.** When all data are collected and structured, they are analyzed using mathematical and statistical methods. Presentation of the results should meet the requirements of a management-oriented view. This makes the results particularly clear, which is supported by visualization.
- **Trusted Adviser.** In this role, a data scientist is a strong communicator who has knowledge of decision-making processes in the company. This particularly includes the coordination between decision-makers (management), the users of Big Data analysis – results (controller) and data suppliers (IT specialists).
- **Business Expert.** In this role, a data scientist has knowledge of the business model, understands the competition and the problems that need to be solved for the company. This requires development of ideas which will maintain and increase the company's competitiveness.[80]

The use of Big Data offers great opportunities and potential for improvements in decision-making. Predictive analytics enables the forecast of possible scenarios in corporate and environmental development. It also supports the management in the selection of the best alternative action (best practice). A more efficient design of business processes is the result. A data scientist is not a new controller. He supports the controller with his job profile in using Big Data as a basis for economic decisions.[81]

78 Davenport, Th.: Big Data @Work – Chancen erkennen, Risiken verstehen. Vahlen Munich, 2014, p. 88.

79 Horváth, P. *et al*., op. cit., p. 88.

80 Compare to section 2.1.3.2: Performance Idea.

81 Horváth, P. et al., op. cit., p. 59.

SUMMARY

In today's global economy, the reality is a global networked value chain leading to a certain anonymity of the production cycle. As a result of production networking and complex production process, this requires flexibility, variability, and transparency. Dynamic production will also apply to production controlling. Due to the Internet of Things, the amount of data in the production process has also been increasing. The tasks of controlling are self-diagnosis, self-configuration, and self-optimization. It is important to structure process data at the associative level, which means classification and standardization for a better integration into the existing approaches to solutions. Evaluation of process situations is carried out at the symbolic level based on a purely logical conclusion. Controllers need to update process-relevant parameters and have the ability to learn, because increasing information leads to a better interpretation and higher-quality proposals. The complexity of global production and competitiveness pressure forces companies to become increasingly flexible. The solution is a fractal factory with self-organizing fractal production. Regarding the manufacturing execution system (MES), process-oriented key performance indicators can be developed. The central one is "overall equipment effectiveness" (OEE) which measures the actual effectiveness of an installation by setting error-free output quantity in relation to the maximum possible amount. For the purposes of process-oriented production controlling, KPI supports process planning and control, active intervention for external control and self-control of the production process, individual configuration of key figures charts and update of templates containing defined scenarios. The benefit of using technology is the possibility to analyze different types of costs (stick, manufacturing, logistics, quality…) The fourth industrial revolution also enables optimization of the production value chain. Cloud and in-memory computing help supply interruption and production with predictive analysis and propose alternatives. From the perspective of services, MES could exchange data and provide performance monitoring at each location of the production system. For this reason, the efficiency and effectiveness of partial processes and the entire production process can be measured at each location of the business network, depending on data access authorities.

Nowadays, innovations are very important for the organizational concept that aims to create business. Technology benefits also support business model dimensions (innovations, design, plan, making, and service). A business model consists of service offerings including product range, value added, and revenue model. Business model-oriented management and controlling require a shift from the automation and control pyramid towards a near real-time tracking of production processes. Efficiency evaluation should be determined using some of the key indicators, like return on investment. The aim is to achieve perfect production using technical development.

There are five steps leading to this goal: clarification of the *status quo*, lean production, implementation of the Manufacturing Execution System (MES), lean production planning and process-oriented key figures of production. In production planning, Enterprise Resource Planning (ERP) manages production orders, but processes and sub-processes are handled by the MES application. Many different costs could be considered by MES, but some need to be detected by other methods like activity based costing (ABC). The Internet of Things and Big Data could provide information to the controller who will analyze them and improve decision-making. For long-term success, every company needs economic success which can be achieved if the resources are used in line with sustainability factors: social, ecological, and innovation. Sustainable management decisions, meaningful evaluations and a performance measurement system based on integrated MES are needed in the future. Due to the methods and technologies of the fourth industrial revolution, the volume and structure of data have increased considerably and are a part of an innovation that could change the business model. A new profile of experts are data scientists who combine statistical methodology and information technology, but business forecasting, planning and monitoring are the controller's tasks. Their mutual contribution is critical for a value-added Big Data contribution.

QUESTIONS

1. Which are the new forms of industrialization and what is their benefit?
2. What impact will intelligent automation have on production controlling?
3. What are the benefits of the fourth industrial revolution and networking?
4. What is the measure of overall equipment effectiveness (OEE)?
5. What is real time process optimization?
6. Describe business model dimensions and the importance of a business model for the organization.
7. Explain MES (Manufacturing Execution Systems) as a production generator.
8. What is the problem of classic production regarding IT solutions?
9. Explain the impact of Big Data on controllers and data scientists.

3. Management Figures for Decision Support

"You can only manage what you can measure." This quote by the US oil economist Peter Drucker significantly illustrates the principles of performance measurement systems. For, what you cannot measure, you have not yet understood, and what is not understood, you cannot steer.[82] The *performance measurement system helps the management in decision making through various analyses and reporting information regarding company efficiency and effectiveness.*

Management quality depends on the quality of the indicators. According to several studies, it has been detected that ratios are mostly unused or inadequately used for corporate management. It is therefore not surprising that it has been established in the studies that almost half of the top managers are unhappy with their available indicators.[83]

The principle is to calculate central measures so that the management could focus on decision-relevant information. The so-called key performance indicators (KPIs) are calculated for this purpose. *KPIs are a set of metrics (no more than 20) focusing on those aspects of business that are most critical for the current and future organization success. KPIs need to reflect the company's goals, be measurable, and are crucial for the company's success.*

3.1. Key Figures and Ratio Systems

Key figures always appear in an attempt to recognize items quantitatively. With their help, it is possible to describe business matters and define accurate statements. To define a figure, business matters must be quantifiable. This quantification is measurability presented on metric scales. Complex data can be represented by key figures in a clear and simplified form. Indicators are suitable for controlling due to their informative character. Large data collected through various sources can be summarized into meaningful information. The Internet of Things concept supports business processes integrating pervasive and ubiquitous information.

3.1.1. The Creativity of Key Figures

The creativity of key figures is the actual performance of company management with which it can compete in the market. Development of indicators would require initial patterning of top business objectives at all company levels.

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82 Peter Ferdinand Drucker (1909-2005) was an American management consultant and founder of the modern business corporation. He was also a leader in the development of education and the founder of modern management.

83 Brauckmann, O., op. cit., p. 128.

Breaking-down the top objective, for example maximum profit, to sub-objectives, such as reducing costs at constant revenues to a level of individual production workers with the specification of material saving, is not useful. This would be tautological.[84]

This fundamental premise is used in a key figure category called "earning before" – like EBIT (Earnings before Interest and Tax) or EBITDA (Earnings before Interest, Tax, Depreciation and Amortization). For the comparison of businesses from different companies, the so-called PIMS[85] program was used in the 1960s, a code that hid individual company financing and tax situation and later became well-known as the EBIT. EBIT represents the company's operating earnings before interest and taxes, but after depreciation and amortization. When a company has a large value of material assets, for example, heavy industry, it will surely use EBIT instead of EBITDA.

The creativity of indicators is also visible in their implementation. It is necessary to implement these concepts and strategies based on ratios and progress of key figures. People are responsible for implementing strategies that will achieve company objectives with their qualifications, motivation, and creativity.[86] „If you can measure it, you can improve it" is a well-known phrase. To be competitive, a company has to improve performance and therefore, one of the reasons for creating indicators is, among others, to be aware of any risky situation that could jeopardize the set goals.

3.1.2. Ratio Systems and Scope of Tasks

Full detection of a situation and correction of the use of individual indicators are not enough. Ambiguities can be excluded and possible dependencies between the key figures determined only by grouping key figures into a performance measurement system.

"A performance measurement system is an ordered set of metrics in a relationship and therefore a complete information system about an issue."[87] The term metric refers to measuring business activity. This set of metrics content is logically and mathematically connected and a structured combination of absolute or relative figures called the *ratio system*.

The ratio system includes key figures (sometimes called key performance indicators - KPIs) used to assess the performance of a company or its division.

84 Tautology (logic), a statement that is always true, regardless of the truth value of the underlying constituents.

85 Compare to section 2.2.1.3 in this book.

86 Brauckmann notes that a key figure should be defined in pure theory. The creativity of indicators particularly stems from their expressiveness and feasibility, op. cit., p. 133.

87 Horváth, P. *et al.,* op. cit., p. 288.

Quantitative calculation illustrates measurable facts and presents them in a form suitable for decision-making. If several key figures are mutually related, they can be combined into a single key figure system. The goal of such systems is to provide full information on company performance.

A key performance indicator (KPI) covers a strategic objective and measures performance in relation to a goal. This is the only difference between a metric and a KPI. KPI systems align with their control task and are individual. Nevertheless, attempts have been made over the years to develop universally applicable performance indicator systems. In this case, two categories have emerged. Firstly, there are computing systems and other order systems. In the computing systems, individual metrics are mathematically linked to each other, so that key performance indicators are defined at the top of the key figure pyramid. It is called a deductive system of indicators. A familiar example is the oldest ratio system ROI, or ROA. Classification systems group indicators based on objective or content criteria. In addition to these two categories, there is a concept of selective indicators. It must be ensured that the optimization of the performance indicator system is used for its optimization with regard to the objective of perfect production controlling.

3.2. Systems Forming the Key Performance Indicators

The environment of distributed production systems and semi-autonomous production lines results in distributed controlling tasks. The orientation of distributed controlling to the overall company objective is regarded a critical success factor. The so-called "*stereotyped thinking*", i.e. focusing on one's own department goals, is unthinkable in the networked world of the fourth industrial revolution.

The consideration of partial autonomy of decentralized networked production units in production controlling is just beginning. Increasing autonomy and the associated self-control potential of the production units has a corresponding impact on production control, controlling in general, and production controlling in particular. Controlling is no longer limited to central management and central controllers. By Internet technology and its further development to the Internet of Things, each decentralized organizational unit participates in the information network and draws its specific benefit.

Web technology supports the use of new control parameters by which the tension between the autonomy of decentralized production units on the one hand and focus on the overall objective of the company on the other hand can be solved. Finding the balance between the concession of partial autonomy and focus on the overall goal is critical for the success or failure of the company.[88]

88 Schindera, T. F.: E-Business und die Steuerung teilautonomer Organisationseinheiten. Gabler, Wiesbaden, 2001, p. 98.

In this respect, the first major question is whether profit-oriented coordination of decisions from partially autonomous organizational units can be supported through the formation of performance indicators.

3.2.1. Requirement Criteria for Key Performance Indicators

In order to successfully compete, a company must be flexible, but decide and act holistically. For the purposes of a networked organizational structure, an alignment of each organizational unit is necessary in terms of both vertical and horizontal integration. A successful implementation of a business strategy requires coupling of the strategy with performance indicators defining the discretion of individual organizational units.

With the key performance indicators, controlling ensures the orientation of organizational units to the overall objectives of the company. By linking the control variables, it must link vertical and horizontal alignment. This is accomplished by visualization of interactions. For example, the need to change a production order to another production line has an impact on vertical production planning processes.

The methodology for the creation of performance indicators is aimed at supporting the organizational units targeted in their decisions. The requirements for the methodology can be distinguished in content-related and structural requirements.

3.2.2. The Architecture of Ratio Systems – Structuring Elements and Key Figure Pyramid

One of the most renowned performance measurement systems is the scheme for calculating Return on Investment (ROI). This indicator tree has the top key figure ROI, which is gradually divided into other sub-indicators from which parent ratios are calculated (deductive system of indicators). The relationship between the peak or the key indicator representing the company goal and other indicators help explain that the key indicator is logical, i.e. determined by a logical or mathematical transformation.

The following structuring elements are derived from the orientation to the key performance indicator – *return on investment:*

- **Breakdown**. Total value is split into portion values.
- **Substitution**. A portion size is replaced with other sizes. Example: Key figure “contribution margin” is replaced by “revenue – variable costs”.
- **Extension**. The output code is extended in the numerator and denominator by the same amount.

The architecture of a ratio system following the structuring elements can be explained in the following example of a relative contribution margin:

- There are definitions – logical relationships, such as Profit = Revenue – Cost between the key figures at the lower level of the ratio system.
- At the upper levels, absolute key figures are transformed into relative ratios by mathematical operations.

The relative contribution margin sets the absolute contribution margin in relation to a limiting factor (for example, limited duration of a production machine).

Example: Calculation of a relative contribution margin.

Product I with the contribution of 30 EUR has the production time of 1 hour. Another product, Product II, with the contribution of 20 EUR, requires only ½ hour on the same machine. If this machine is now a bottleneck, it is primarily useful for producing Product II. Its relative contribution margin is 20 EUR / 0.5 hours = 40 EUR per hour, while the relative contribution margin of Product I is 30 EUR per hour. If Product II was produced for 8 hours, total contribution margin would be 8 × 40 EUR = 320 EUR. If Product I was produced for 8 hours, the total contribution would be only 8 x 30 EUR = 240 EUR.[89]

The advantage of the Du Pont[90] system is its simplicity and comprehensibility, yet high significance. It is particularly evident in the case of ROI calculation that simplicity is the basic success factor for the success of the performance measurement system.[91]

Another example for mathematical relations in a key figure system is given with the key figure pyramid.[92]

The main substantive issue in the construction of a metrics pyramid is the question of key ratio. The key ratio is to convey the economically most important statement of the system in a compressed form. Another consideration relates to the formation of groups with metrics in specific areas to provide information, for example, about cost composition.

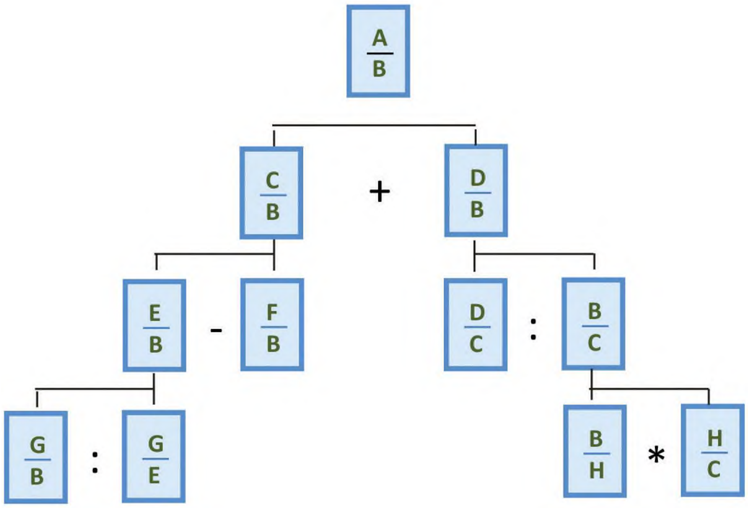
89 www.welt-der-bwl.de

90 E. I. du Pont de Nemours and Company, commonly referred to as DuPont, is an American conglomerate founded in July 1802 as a gunpowder mill by Éleuthère Irénée du Pont. In the 20th century, DuPont developed many polymers such as Vespel, neoprene, nylon, Corian, Teflon, Mylar, Kevlar. http://www.dupont.com/corporate-functions/our-company.html.

91 Gladen, W.: Performance Management. Controlling mit Kennzahlen. 6th edition. Springer Gabler, Wiesbaden, 2014, p. 96.

92 Horváth, P. *et al.*, op. cit., p. 289.

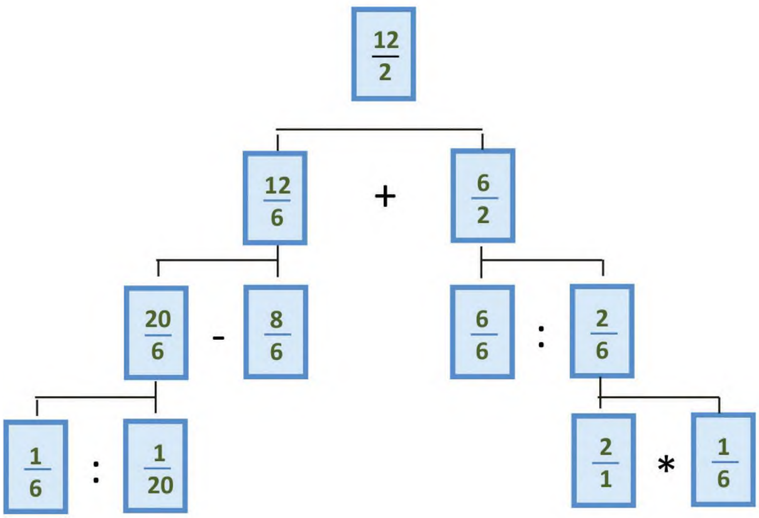
Figure 13: Example of a Metrics Pyramid



Source: Horváth, P. *et al*., 2015, p. 289.

This pyramid metrics is often used in performance measurement. It is based on a deductive method where the starting point expressed through the main goal is on top. All deductive indicator systems express logical content and mathematical dependence. To develop such a system of deductive indicators, three main requirements need to be followed: 1) content of indicators, 2) interrelations between them, and 3) relations with the main goal.

For example:



However, Horváth defined the limits of performance measurement systems:[93]

- Performance measurement systems with a single targeting neglect the objective pluralism of reality.
- Systems with a key ratio are not suitable for the controlling of distributed organizations. Sectoral metric systems are needed here.
- Focusing on purely mathematical relationships excludes the consideration of non-quantifiable criteria.

Therefore, it is proposed to use two types of measurement systems:

- *Analysis of performance measurement systems.* They are caused by the gradual decomposition of output facts into its elements.
- *Control ratio systems*. The design principle is the orientation to organization-specific criteria. In addition to the object's logically specific splitting (sales - cost = contribution margin) delivers organization-specific splitting (calculation of contribution margin in education ≠ calculation of contribution margin in consulting ≠ calculation of contribution margin in the sales organization).

The *key figure pyramid in production controlling is based on the process indicators recorded by the manufacturing execution system*.

These process indicators measure the *efficiency of the production process* defined by:

- Utilization of the production equipment,
- Product quality,
- Flexibility to serve different product variants,
- Flexibility to react to interruptions.

The key figure pyramid must be defined by a combination of sub-indicators and indicators.

The efficiency of the production process is defined as a combination of

efficiency of the equipment (overall equipment efficiency)

+

efficiency of the logistic process

=

efficiency of the production system

Efficiency of the production system can be viewed through *operational and strategic dimension.*

93 Ibid.

The methods for operational and strategic production controlling must refer to the appropriate business methods on the one hand, but must be complementary on the other hand. This means that a strategic business-model decision in the sense of production controlling should make logistic success factors the first priority.

Fast, flexible and problem-free production processes lead to customer satisfaction and success. On the other hand, only profitable business models make sense. Therefore, controlling is performed with operational, tactical, and strategic controlling methods.

The operational side is supported by process-oriented indicators. The tactical level has to be supported with the outsourcing method and the measurement of such an option. The strategic level will be defined by the shareholder value-added approach.

3.2.3. Content and Structure Criteria for Key Figures

General and predominant requirements for the key figures are *clarity* and *consistency* at all company levels. The calculation of the key figures would be accepted by the management only if the calculation of the key figures could be reconstructed. The same applies to cross-organizational usage of the key figures. If every organizational unit in the company would define its own key figures and ratio system, there would be no success in the networked production system. Therefore, the basic principles in the definition of key figures must be followed.

3.2.3.1. Content-Specific Requirements for Key Performance Indicators

Company management based strictly on financial ratios is no longer adequate in view of the networking companies in the fourth industrial revolution. However, financial success is crucial, but the way to financial success must be comprehensible and thus controllable through process-oriented indicators and their integration in the overall ratio system.

Content design of the key figures leads to the detection of the following formal requirements:

- **Multidimensional.** The key performance indicators must be designed foresightedly. Productivity, market- and process orientation are important dimensions of decision-relevant indicators.[94]

94 Compare to the introduced reference architecture of intelligent automation in section 2.1.1.1 of this book. The association of control data needs anticipatory information and, therefore, key figures. Christians, 2006, p. 125.

- **Enabling free-forward and free-feedback loops.** The dynamics of competition requires a continuous ongoing adjustment of the company. The feedback mechanism should ensure the adaptation of the company to changing markets. The feed-forward mechanism means forward-looking orientation of the company by construction of potentials. This potential structure should be reflected in the key figures.

- **Transparency.** Only through transparent and operational criteria that follow the indicators hierarchy can transparency be achieved at all operational, tactical and strategic levels in the ratio system. Comprehensibility and receiver focus are the key characteristics of indicators for ensuring transparency.

- **Changeability of performance indicators.** Partial autonomy of self-controlling organizational units in the production network also requires flexibility to react to specific process situations. For this reason, it might be necessary to adjust the control parameters regarding the achievement of the objectives. However, this does not mean that, depending on the situation, control variables are questioned in an *ad hoc* response. It rather means coming to an evolutionary adaptation of the key figures if this would improve the achievement of company objectives.

Example: Performance indicator "service level" leads to the satisfaction of customer demand on the one hand and service level costs on the other hand. If the disposition time in which the customers are placing an order is shortened, service level cost might increase. In this case, service level will be reduced just to maintain service-level costs. In this case, a calculation is necessary to find out the effect on customers' behavior. Finally, it should be examined whether both the service level and its cost would be increased through an extension of the production system.

The difficulty in considering long-term effects of changes in production can, above all, lead to focusing on short-term goals and success factors. However, the future of the company depends mainly on sustainable business processes.

Regarding this aspect, the operational and tactical decisions should always consider long-term goals of the company in the general context, but not in terms of a rigid target pyramid managing the idea of business-model orientation. This might lead to unconventional approaches.[95]

95 Compare to section 2.1.3.2, which covers the span from idea to performance. A product creates its production process and, furthermore, its market. In general, this section is oriented to Schindera, T. F., 2001, p. 153.

3.2.3.2. Structural Requirements for Key Performance Indicators

Some key figures are not real process indicators or are not specifically related to a single process, such as employee satisfaction. Yet, they are relevant. How to measure employees' motivation? Surveying is the standard methodology. A regularly performed survey could be used to explain the fluctuation. The survey should detect the reasons for unsatisfied staff.

This criterion especially affects managers: "*Indicators must be derived from the company's objectives, formulated top-down*." Mismanagement will occur if the divisions optimize their own values without taking into consideration the sufficient overall result. Based on the company's objectives from the top- to the operational level, all the key figures have to be defined in the overall relationship.[96]

> *No measure without targets – no target value without controlling.*

Regarding process orientation, there are two structural criteria for defining key figures.

1. **Generic applicability**: The method of defining indicators must not be limited to a single company level. The key figures and derived indicators must be usable at any company level. However, the requirements of organizational units must also be taken into account.

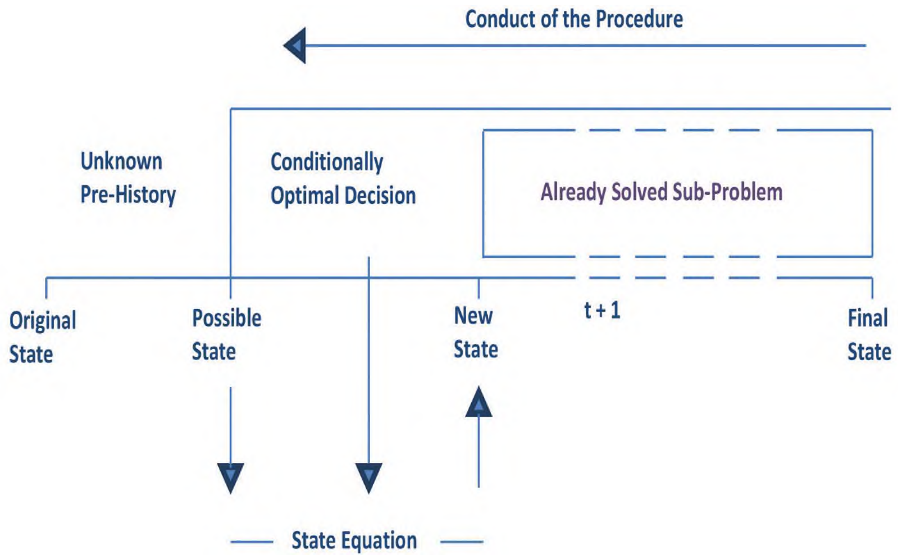
The definition of a kind of a mixed code is not possible, since the requirements of individual organizational units are too specific and a key figure in this form would not be meaningful. The compatibility of individual indicators in the performance measurement system is important.

2. **Recursion**: The sub-problems are solved by successively examining the sub-periods of the entire planning period until the problem has been identified.

The goal of this method is to go for the optimized final state from the initial state at minimum cost through a series of decisions. Because the so-called optimal initial state is unknown, all possible initial states with which the final state could be achieved will be calculated separately for each sub-problem. This results in conditionally-optimal partial decisions.

96 Herb, Th.: Global Quality Systems Manager at BorgWarner Turbo Systems GmbH. Documentation of an audit to obtain certification ISO 9001. *"Work on the documentation system of Pottbäcker & Partner has been completed. Announce the upcoming ISO 9001 audit to Ms. Macchiato and the company management. But then, everything changed: the auditor asked for power measurement."* https://www.qz-online.de/specials/prozessorientiertes-qualitaetsmanagementsystem/ziele-und-kennzahlen-im-prozessmanagement

Figure 14: The Principle of Backward Recursion



Source: Adapted from Waldner, 2007, p. 73.

For an optimal solution, the decision alternatives must be evaluated in any newly added period. This results in the solution of a partial problem and therefore a conditionally optimal partial decision. This partial optimal solution must be coordinated with the overlying part of the problem. The backward recursion thus ends with the extension of partial problems to the overall problem. The process therefore consists of a backward recursion followed by a forward calculation.

SUMMARY

Decision-making is supported with a measurement system as a prerequisite for efficient management. Various analyses and reporting information help the management lead the company. One of the main tasks of controllers is to prepare the information suitable for analyses and present them to the management in order to help them in decision-making. The controller's role is to create ratios and propose the key performance indicators (KPIs). KPIs are a set of metrics crucial for concrete business performance and organization of future success. A set of metrics contents, i.e. a logically and mathematically connected and structured combination of absolute or relative figures, is called the ratio system. Computing systems help individual metrics to be mathematically linked, so that key performance indicators are defined at the top of the key figure pyramid. It is called deductive system of indicators recognized as the Du Pont system of indicators for measuring return on assets (ROA) and return on equity (ROE). Creativity and development of the key figures depend on the goals and objectives which have to be set at all organization levels. Controlling ensures the orientation of organizational units to the overall objectives of the company.

Production system and semi-autonomous production requires distributed controlling tasks. Due to technological improvements, increasing autonomy and the associated self-control potential of the production units, they have a corresponding impact on production control, controlling in general, and production controlling in particular. Using Internet technology and Internet of Things, controlling is no longer limited to central management and central controllers, because each decentralized organizational unit participates in the information network and draws its specific benefit. The key figure pyramid in production controlling is based on the process indicators recorded by the manufacturing execution system. They measure the efficiency of the production process defined by utilization of the production equipment, product quality and flexibility to serve different product variants and react to interruptions. Content design of the key figures needs formal requirements: multidimensionality i.e. the possibility to use them for foresight, enable free-forward and free-feedback loops (forward-looking orientation), transparency, a flexible reaction to a specific process situation in order to adapt the control parameters to the objectives.

QUESTIONS

1. What are KPIs and how are they created?
2. Define the performance measurement system, forming of KPIs and requirements for their design.
3. Explain the architecture of the ratio system using the key figure pyramid.
4. What is based on the key figure pyramid in production controlling?
5. How do we define production process efficiency?

4. Operational and Tactical Production Process Controlling

The classic short, medium and long-term corporate planning and the resulting controlling no longer meet the requirements for company management and corporate controlling in the environment of the global dynamic market and competition. Taking into consideration the ongoing increasing market dynamics, companies need to adapt to technical and methodological terms. The technical basis for this is now available with the technical transformation in the ongoing fourth industrial revolution; this was discussed in the previous Chapter 2.

With the availability of transfer technology, pending need for technical improvement to make the transition of the business processes can be fulfilled. The question arises, what is the impact of the dynamics of business processes on corporate planning, company management and, therefore, controlling. The answer lies in the evolving process orientation and, in the next step, orientation on business processes.

The development of corporate organization, corporate management, and corporate controlling transfers from a functional, departmental thinking to a process-driven approach. For example, this has been successfully used in the Lufthansa company.

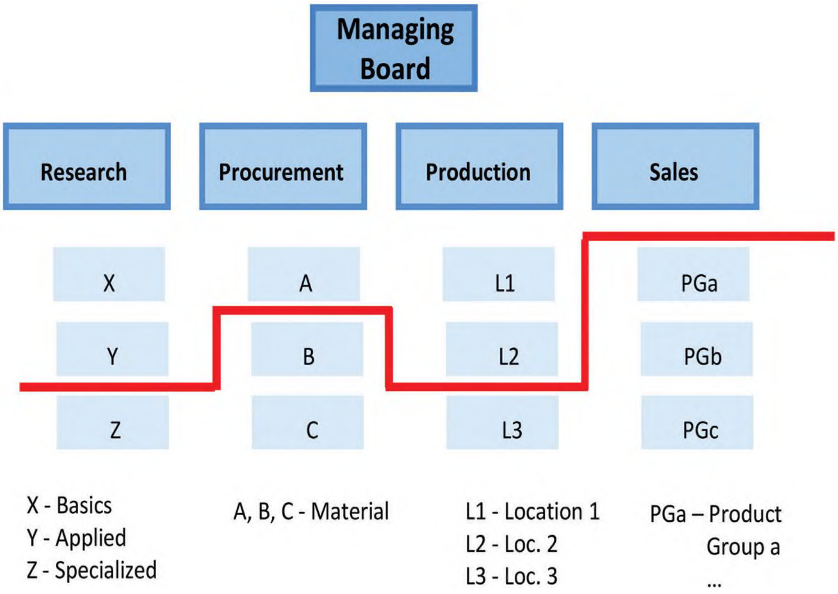
The path from a classic to operational, function-oriented organization is just a part of a company-wide joint venture organization. Classic, autonomy-oriented management will be further developed to a service-based approach to business processes.

Orientation on services and its impact on company management and controlling is therefore in the focus of examination in this chapter.

4.1. Components and Determinants of Process-Oriented Controlling

A business function can be understood as processing of business objects and business processes. In a classic company organization, aligned to and oriented on the functional scope of tasks, it comes to dynamic changes of business processes through the hierarchies, impressively presented in the following figure.

Figure 15: Dynamic change of business processes through the hierarchies



Typical characteristics of a function-oriented organization are a high level of execution-oriented divisions, a high degree of professional specialization, usually direct instructions, the centralization of decisions at the highest hierarchical level and the so-called "line system".[97]

Typical symptoms of a purely functional orientation are long decision processes, the need to consider many instances to take decisions and collection of knowledge by many sub-organizations. This causes processing errors and high costs.

The limits of a purely function-oriented organizational structure are widening variety of products, increasing customer orientation, increase in coordination and the importance of employee motivation, also because this reduces the benefits of specialization due to extensive range of global markets.

In this regard, process orientation in the company was initiated in the last century and has been accelerating under the development of technology transfer in the fourth industrial revolution.

97 Line organization is the oldest and simplest method of administrative organization. According to this type of organization, the authority flows from top to bottom in a business group. The line of command is carried out from top to bottom. This is the reason for calling this organization a scalar organization, which means that scalar chain of command is a part of this type of administrative organization. In this type of organization, the line of command flows on an even basis without any gaps in communication and coordination taking place. In: MANAGEMENT STUDY GUIDE, http: managementstudyguide.com.

4.1.1. Business Process and Process Orientation

A process is a sequence of operations in which information is processed (input) and which leads to a goal-oriented result (output). Business processes take into account the economic aspects of processes:[98]

A business process is a targeted time-logical sequence of tasks which can be performed by several labor organizations and organizational units with the use of information and communication technologies. The business process is used to achieve the objectives derived from the company's strategy.

Process orientation in a company means understanding a basic attitude that considers the functioning of the entire company as a combination of processes. Since these processes are partly horizontal, breakdown of conventional structures such as departments and divisions is unavoidable.

Deming[99] sees process orientation as a prerequisite for the successful application of a management program in order to increase quality and productivity. Process orientation is possible in continuous improvement of processes, focus on the wishes and requirements of customers facilitated in the involvement of all employees at all levels of company organization.

Each activity can be regarded as a process and improved accordingly.

A process is basically understood as a sequence of repetitive activities with a measurable input, measurable value added, and measurable output. The process is characterized by a higher-level interaction between people, machines, materials, and methods along the value chain to achieve an objective. This can be the provision of a service or the production of a product. In this regard and in accordance with Deming's point of view, the process does relate to both technical and dispositive activities. These manufacturing and dispositive processes can be summarized under the term "business process". The decisive factor is that no separation of activities and operations is carried out within the meaning of strict division of labor.

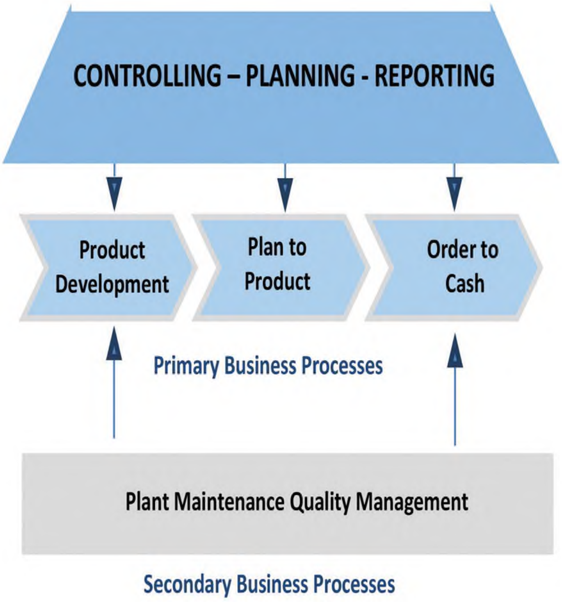
98 Gadatsch, A.: Geschäftsprozesse analysieren und optimieren. Praxistools zur Analyse, Optimierung und Controlling von Arbeitsabläufen. Springer Vieweg, Wiesbaden, 2015, p. 1.

99 William Edwards Deming (October 14, 1900 – December 20, 1993) was an American engineer, statistician, professor, author, lecturer, and management consultant. Educated initially for an electrical engineer and later specializing in mathematical physics, he helped develop the sampling techniques still used by the U.S. Department of the Census and the Bureau of Labor Statistics. In: *Deming, W. Edwards (1993). The New Economics for Industry, Government and Education. Boston, Ma: MIT Press, p. 132.* It is a common myth to give credit for the Plan-Do-Check-Act (PDCA) to Deming. Deming referred to the PDCA Cycle as "corruption". Deming worked from the Shewhart cycle and over time eventually developed the Plan-Do-Study-Act (PDSA) cycle, which has the idea of deductive and inductive learning built into the learning and improvement cycle.

Above all, *the following process requirements should be considered*:

- Effectiveness in terms of predefined tasks and objectives.
- Efficiency in the performance.
- Controllability by responsible persons regarding the process status and the ability to take corrective actions.
- Adaptability of the process to the environment.
- The process orientation does not only refer to core processes, but rather includes all business processes.

Figure 16: Process-Orientation



Splitting a business process only makes sense if no process and workflow relationship are interrupted. To guarantee efficient business processes, the following principles have been defined by the competence center of digital administration.[100]

The business process breakdown divided the business process into its component processes. The sub-processes group coherent, i.e. related tasks together. A partial process combines technical and time-related business tasks for generating a completed intermediate result or a part of performance (value chain).

100 Picot, A.: Prozessorientierte versus funktionsorientierte Unternehmensorganisation. Lecture at the Technical University of Munich, 2002, p. 15.

Requirements:

1. Dissect the management process into the basic building blocks of its value chain.
2. Connect the sub-processes with their role-players.
3. Simultaneously structure the process model. Now a partial process model can be created for each sub-process.
4. Define process interfaces and clear criteria and conditions for the specification of the respective “process status”.
5. The transition to a process-oriented organization therefore requires process management, which will be explained in the following section.

4.1.2. Process Management & Business Process Management

Process management, also called workflow management, allows organization of business processes with the objective to save time. Example: an employee creates a purchase requisition. The purchase requisition triggers a workflow, which leads to an incoming mail to the responsible office. The office will make the decision on approval. *Business process management, on the other hand, is optimization of processes.* Process management and business process management (BPM) are engaged in the identification, design, documentation, implementation, control, and improvement of business processes. Holistic approaches of business process management do not only address technical issues, but also organizational aspects such as strategic direction, organizational culture or the integration and management of process participants.[101] Business process management can be defined as a set of methods used for analyzing and improving processes to be more efficient and effective. This primarily means alignment with the organization’s strategic goals, designing and implementing process architectures, establishing process measurement systems.

4.1.2.1. Objectives of Business Process Management

The objective of business process management is to use the existing company information on their own business processes to adapt to the customer and to achieve corporate goals as a result of BPM. These include identification of the company’s business processes, creation of process improvements, optimization of business processes, documentation of the processes, in particular due to legal requirements, process-oriented cost calculation, and mapping of business units with clearly defined roles and rights. If necessary, the business process must be flexible enough to be the exception to the standard.

101 Brocke, J., Rosemann, M.: Handbook of Business Process Management 2, Heidelberg, New York, 2010, p. 10.

It is important that clear interfaces between the processes are set, so that process chains and nesting of processes can be easily formed.[102]

Regarding the objective, BPM is an economic management task, and not a mere scope of tasks in the information technology (IT). However, the IT enables the BPM; it is therefore necessary to examine the economic dimension and the IT dimension simultaneously.

Process orientation is considered a central component for an increased shareholder value in the company Deutsche Lufthansa AG. For the first time in the company's history, a functional division-driven thinking within a corporate restructuring project has been replaced by a new approach with cross-department process-oriented thinking. Detailed identification and analysis of process flows, including participating responsibilities within the overall context of the company, was essential for revealing many obstacles, but also potentials in the value creation. Problems like Maverick-Buying[103] could be identified and solved through the process of thinking across department boundaries and definition of clear indicators. In general, process definitions are part of a process map, which includes 16 core processes of the Lufthansa Group. Each of them is run by a special core process owner.

4.1.2.2. The Life Cycle of Business Processes

The life cycle of a business process consists of *modeling (1), implementation (2), and optimization through restructuring (3).*

(1) Business process modeling is a prerequisite for business process reengineering. A business process model is the result of business process modeling. Specific activities and their sequence are identified in the process of defining the activity model. Specific data objects needed to perform business process activities are identified in the process of defining the data model. Thirdly, the organization model will be defined by the explanation of the company's organizational structures and the relationship between the organizational units. To accomplish this, the sub-processes must be linked and the interfaces between the processes defined. This indicates which data are needed to perform specific operation functions in different organizational environments.

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102 Fischermanns, G.: Praxishandbuch Prozessmanagement. Ibo Schriftenreihe Band 9. Verlag Dr. Götz Schmidt. 10th edition, Gießen, 2012, p. 14.

103 Maverick-Buying or wild shopping is a term from procurement management. Basically, the concept is called Maverick-Buying when departments are indiscriminately purchasing from various providers, usually service providers. Maverick-Buying is the „Maverick Standardized Procurement Channel". Wannenwetsch, H.: *Erfolgreiche Verhandlungsführung in Einkauf und Logistik,* Springer; 3rd edition, 2008, p. 68.

(2) Implementation of business process models is defined by deployment of a business process model into the information system landscape of the company. This involves the issue of information technology tools that can be used to support and automate business processes. The objective is to find best practice.

(3) Optimizing business processes is also referred to as business process reengineering (BPR) and is needed when, for example, new organizational structures are introduced, or company tasks are to be outsourced, and business processes are restructured, streamlined or improved. Key figures, such as throughput time, familiarization time or setup time are checked in the production environment.

A business process is based on corporate strategy and follows a process model. The target framework is specified in the corporate strategy of the company. The process model defines the design of process steps (workflow) and process performers.

The alignment of business processes with the company's strategy is carried out through investigation of measurable contribution of the business process to the fulfillment of corporate objectives. As a part of this review, it is also important to identify unproductive or redundant business processes. The consequence of unproductive business processes is restructuring of the processes until they comply with corporate goals.

A technical concept is created in addition to the conceptual modeling of business processes. Therefore, the business process is modularized. This implies a division into sub-processes, which can be perceived as a person's task or be automated.

Monitoring is a continuous scope of tasks aiming to provide follow-up. This involves comparison of the achieved results with the expected results. The results are the basis for process controlling. However, controlling based on control includes the tactical and strategic aspect which will be defined in this book with the concept of process scorecard.

4.1.2.3. The Basics of Process Optimization

Process optimization is defined as a gradual and sustainable increase in company's competitiveness by aligning the processes with customers' requirements. Therefore, the focus is on customer-driven processes in the company. This is no radical redesign of the existing processes, but their further development.[104]

This applies to customer-related business processes in general and also to processes triggered by customer actions. An example would be separate

104 Gadatsch, A., op. cit., p. 27.

sales order processing with the construction of a simultaneous cost estimate. These processes are clearly in focus; however, they have an impact on upstream and downstream processes. Therefore, a strategy that follows the cause-effect principle should be used.

Among the economic-organizational methods, there are the following options:

- **Renunciation.** This includes media discontinuity processes or, for example, unnecessary licensing requirements.
- **Outsourcing.** External specialists, who do not count among the company's own strengths, can implement these processes more effectively.
- **Group.** This is one of the basic issues of process management; establishing process responsibility by assigning processes to process managers.
- **Parallelizing.** A classic method of lead time reduction in production planning can generally be applied to processes.
- **Displacing process steps.** For example, a complete recording of customer information upon the creation of a sales-order.
- **Accelerating.** Here, for example, central documentation of the processes in BPM as best practice leads to the possibility of a more rapid consideration of the changing process environment and dynamic process requirements.[105]

4.1.3. Success Factors in Process-Oriented Production Controlling

The previous sections describe process orientation of corporate management from the economic-organizational point of view. Based on the process orientation in the company organization and corporate management, this section covers production success factors on the one hand and production controlling on the other hand.

Based on the understanding of controlling as a sub-system of the management system and a coordination function, controlling is not viewed as a bundle of tasks, but as a process. The controlling process starts with analyzing the production process, understanding the process, planning and monitoring the process.

105 The company "1 for All GmbH" in Switzerland published: "With iGrafx, companies have the ability to process knowledge at the source, namely the process owners. This information can be managed and shared across the enterprise through a process repository. The ability to optimize processes before they are implemented in an exemplary system is essential for success of any initiative for process automation... The automation of non-optimized processes may even amplify process inefficiencies and the already existing problems." Access: http://www.prozessmanagement.ch/iGrafx/Ps/ekurs/teil1.htm.

4.1.3.1. Identification of the Success Factors

Service quality of controlling is the central part of this concept of controlling in general and production controlling in particular. The measurement of service quality is carried out with regard to process quality and outcome quality. However, since the quality of results can only be measured after the completion of the process, focusing on the quality of results is not the real-time approach to modern production controlling.[106]

Basically, process quality is a prerequisite for achieving the desired quality[107] of results. Proper conclusions may be drawn from results of the processes only through accurate measurement of key performance indicators (KPIs). Therefore, processes and outcomes are closely linked.

Kneuper[108] defines a *quality model for the assessment of processes* as follows:

- Agreements and promises
- Defined embedment in the process environment
- Effectiveness
- Quality of results
- Customer satisfaction
- Business benefit
- Efficiency
- Productivity
- Reuse of results
- Quality costs
- Conformity to relevant standards and specifications
- Process capability
- Process stability.

106 Heimel argues that process quality relates to the operations during the provision of services and thus faces various difficulties. This opinion is also followed in this book. However, modern information technology based on cross-linking within the fourth industrial revolution is available and capable of accessing real-time data and evaluations during the process to create production processes and evaluate the calculation of alternatives. Heimel, J.: Prozessorientiertes Controlling. Konzeptualisierung, Determinanten und Erfolgswirkungen. Springer-Gabler, Wiesbaden, 2014, p. 55.

107 According to the standards of EN ISO 9000, standards are created documenting the principles of quality management measures. Together they form a coherent set of standards for quality management systems to facilitate mutual understanding at national and international levels. Kneuper, R.: *Was ist eigentlich Prozessqualität?* Lecture at the symposium at the University of Berlin, 2011, www.informatik2011.de

108 Ibid, p. 6.

Based on these quality requirements, the focus of this book is on customer satisfaction and satisfaction management. Customer satisfaction results from the evaluation of the discrepancy between expectations and the actual fulfillment of needs, i.e. performance. Customer satisfaction affects customer loyalty. In terms of controlling, customer satisfaction refers to controlling services for the management. The management uses the controller's information to make management decisions. The more satisfied the management with the information of controlling due to its decision-making relevance, the more it relies on the controlling information.

Since provision of information is the basis of management decisions, controlling has an influence on management decisions. The more intensively controller's information is taken into account in decision-making by the management, the greater the influence and thus more successful controlling.

The operative success of controlling is increased quality of management decisions due to the efficiency of controlling information. Leading scientists in the field of controlling are defining the basic function of controlling as keeping the rationality of management decisions on the one hand and the coordination function of controlling on the other hand.[109]

Empirical evidence for the success of process orientation of controlling have been created by several authors and their research results, which are the basis for further investigation.[110]

In addition to customer satisfaction, a key success factor is measurability and quality of data based on the conclusions of controlling. This aspect has been discussed in the previous chapters of this book covering IT services.

4.1.3.2. Value Drivers and Value Management of Manufacturing

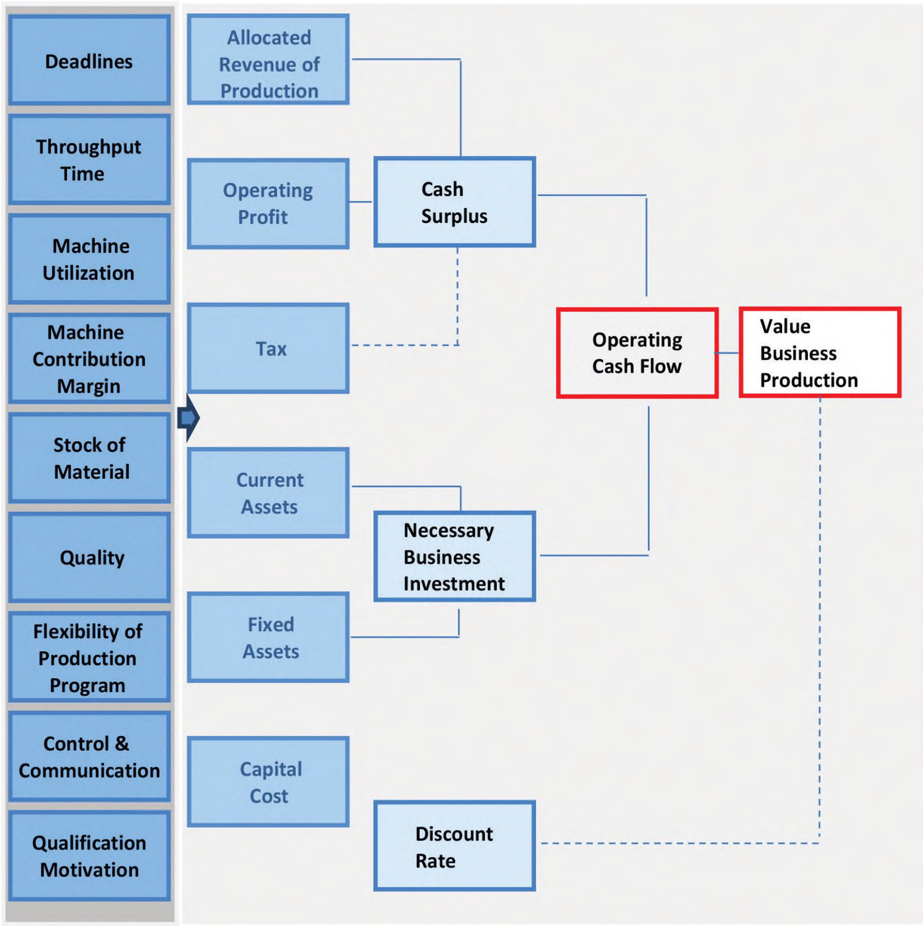
In the production management, the alignment of internal processes with the financial success of the company leads to the question of contribution of production to increasing companies' value. According to Bauer and Hayessen:[111] "… to deliver the value propositions and shareholder expectations of excellent financial returns."

109 Weber defines the function of controllers as mainly keeping the rationality of management's decisions. Weber & Schafer, *Einfuhrung in das Controlling,* 2011. Horváth emphasizes the coordination function of the controlling. Horváth, P. et al., 2015.

110 Heimel, J., op. cit., p. 59.

111 Bauer, J., Hayessen, E.: 100 Produktionskennzahlen. Cometis, Wiesbaden, 2009, p. 17.

Figure 17: Value Driver in Production



Source: Adapted from Bauer, J., Hayessen, E., 2009, p. 17.

Bauer has defined 12 value generators, of which eight are included in the previous figure. From the customer's perspective, meeting deadlines and production flexibility fulfil their requirements. Production flexibility is achieved by investing in innovations such as flexible manufacturing systems as well as the appropriate information technology.

Another crucial point generator is called "time to market", which is the time span from product idea and production engineering to market launch. With simultaneous engineering, process owners could be involved in the developing process at an early stage.

Throughput time of orders through production or through the production network is directly correlated with self-scheduling in the system. This was discussed in this book in Chapter 2.2.3 covering the manufacturing execution system (MES). The development from classic central production control towards decentralized self-controlling production units in the networked production will affect the flexibility and reduce throughput time. In particular, non-value added phases in the production process such as setup, transport, and downtimes can be reduced with process information availability in real time.

To increase the economic result of the company, the focus is on logistic key figures as mentioned in the previous figure. The value drivers obtained in this way can be used for process evaluation..

4.1.3.3. Process Scorecard for Production Controlling

Process controlling can be viewed as part of the scope of controlling tasks, with the focus on processes. The *Process Scorecard* (PSC) is a variant of the general Balanced Scorecard (BSC). Its characteristics are:

- Focus on the strategic agenda of the concerned organization.
- Selection of a small number of data items to be monitored.
- Mix of financial and non-financial data items which have to be balanced with goals and objectives within perspectives.

The Process Scorecard has been developed as a key figure-based management and control system. The Scorecard consists of key figures from different interdependent and reconciled perspectives. Basic BSC consists of four perspectives: internal processes and learning & growth as internal aspects and customers and financial perspective as external aspects of business.[112] The individual perspectives of the Balanced Scorecard describe the areas of impact of business processes, which should support business objectives as balanced as possible.

"Nominally, the Balanced Scorecard approach was supposed to support business processes, but, in fact, most organizations have used it to support a more traditional department-based organizational design, and, frankly, the models that Kaplan and Norton use do not represent a very sophisticated understanding of business processes."[113]

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112 Popović, Ž., Vitezić, N.: Revizija i analiza – instrumenti uspješnog donošenja poslovnih odluka (Auditing and Analysis – The instruments of successful decision-making), HZRFD, Zagreb, 2009, p.181

113 Harmon, P.: A Scorecard for Process Managers. Business Process Management Conference, 2014, http://www.bptrends.com/a-scorecard-for-process-managers/

"Today, most companies use some kind of a modified scorecard system tailored to their specific organizational needs. Similarly, several process groups, such as the Supply Chain Council (SCC) have developed their own scorecards tailored to the needs of a process-based approach. Also, BP Trends (Business Process Trends) has worked with companies to adopt the scorecard approach for organizations employing a matrix design and have both departmental and process managers."[114]

An interesting further development and a different view of the Scorecard is provided by Zangl.[115] The so-called *Process Scorecard* (*PSC)* as a further development of the Balanced Scorecard (BSC) does not have more than four different perspectives of the BSC (finances, processes, employees, customers), *but is controlled uniformly via the process view.* From a holistic point of view, employees and customers are an integral part of business processes.

The central management control via two measurement- or performance measurement systems are:

- Short- and medium control over monetary issues with two measuring ranges: profitability and financial strength
- Medium and long-term control over four key performance indicators:
    - Innovation,
    - Customer loyalty,
    - Process stability,
    - Corporate culture.

KPI and monetary metrics are in a strong interaction. A long-term, sustained and successful corporate development is pursued with the KPI, and monetary values reflect the success of current operations.

114 Harmon, P.: Using a Balanced Scorecard to Support a Business Process Architecture, 2007, www.pbtrends.com.
115 Zangl, H.: Process Scorecard. University of Munich, http://dodo.fb06.fh-muenchen.de/zangl/ProcessScorecard.htm

Figure 18: Process Scorecard Production

Process Scorecard	Key Figures	Actual	Target	Measure
100% in Manufacturing - Procurement - Inventory - Manufacturing - Control	Shopping price Quantity in stock Downtime Productivity-Time	100 % 500,000 2,000 75 %	97% 300,000 1,200 80%	Contract KANBAN Preventive PM Decentralized control
Throughput Time - Production process BU 1 - Production process BU 2	Weighted to order volume [hrs] Weighted % Weighted %	28 22	22 24	Increase flextime Increase flextime
…				

Source: Zangl, H.: Process Scorecard. University of Munich.

The company as a whole and individual business processes are controlled through the management of process scorecards. Annual or long-term objectives are operational measures / projects, e.g., business process management (BPM) projects. It could be examined whether the process is "on the right track", or whether it needs intervention in the project / process.

It should be pointed out that the Balanced Scorecard is used as an information, communication, and learning system, not a controlling system. Elements of a *controlling system are:*

- Controlling tasks,
- Controlling organization,
- Controlling information,
- Controlling instruments.

The internal control system is a sub-system of the management system. Planning and control system and information-providing system are simultaneous.

The *two essential characteristics of controlling are*:

- System-forming and coordination in the sense of creating the key figure system and measurement conclusions,
- System coupling, which means integration of different operational information systems and the creation and analysis of corporate relationships.

Therefore, the scorecard process records decision-relevant indicators from different perspectives for the creation of a controlling concept that relates to different scenarios.

4.2. Strategic Process Controlling

The objective of process monitoring is to establish process orientation in the company. This includes a holistic view of business processes in the company that leads to a business model. From the aspect of strategic process controlling: controlling supports the strategic process management as well as process owners in managing their processes through managerial methods. Strategic process controlling helps the management in strategic decision making by analyzing various internal and external factors which could affect strategic goals.

The subjects of analysis are strategic process objectives and strategic process alternatives. Process orientation success at all management levels should be ensured in particular; there is thus no organizational gap between corporate strategy and operational management of the company.[116]

4.2.1. Objectives and Strategy

The objective of strategic process controlling is studying business process objectives and business process strategy. If operative sub-process targets cannot be reached, a strategic analysis process must be initiated. On the other hand, there is also the possibility that external events may, for example, require new competitors in the market who start an analysis of their own business processes.

4.2.1.1. The Scope of Tasks of Strategic Process Controlling

Strategic process controlling is responsible for a holistic view of business processes and for establishing and maintaining an integrated and holistic company management approach. Another aspect is maintaining target consistency of the objectives of operational and strategic business processes. In the spirit of controlling, strategic process controller seves all process managers.

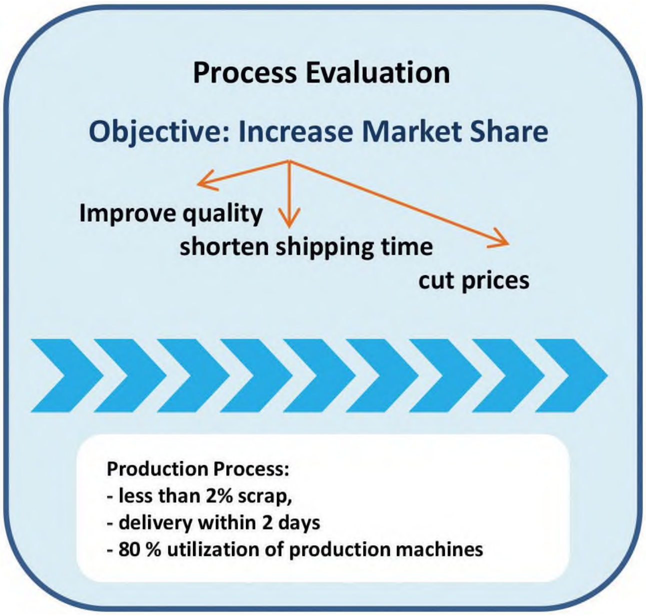
116 Ahlrichs, F., Knuppertz, Th.: Controlling von Geschäftsprozessen. Prozessorientierte Unternehmenssteuerung umsetzen. 2nd edition. Schäffer Poeschel, Stuttgart, 2010, p. 188.

The management needs strategically relevant process information to which the Process Scorecard is a valuable contribution.

The process concept is not limited to specific process controlling. It has influenced all aspects of controlling. In the past, controlling used to be very departmental and function-related. The focus was on controlling the manufacturing, distribution, etc. Only in recent years has it been recognized that the planning, management, and control of integrated processes of suppliers is crucial to customers. Moreover, increasing proportion of costs is generated in the processes. These are often costs that cannot be directly assigned to a product, the so-called “overheads”. A process analysis is necessary to make them visible.

The starting point for process objectives must always be the company’s long-term strategy that will be fully formulated by the Board or the Management. From this point of view, specific objectives will be derived for each process. The following figure provides an example.

Figure 19: Corporate Strategy as a Basis for Process Evaluation



Source: Modified from Fiedler, 2015, p. 17.

Additionally, definition of a general perspective for the entire company and ensuring the dissemination of information across all organizational levels of the company belongs within the scope of tasks of strategic process controlling.

The support of the information and communication technology is evident throughout the workflow.[117] With this technology, it could be ensured that the responsible employees are automatically informed about an event that requires action.

4.2.1.2. Triggering the Analysis Process

Typical input information for triggering strategic process analysis are strategic disorders. These are early warning signs that may affect the achievement of process goals. It is important to be familiar with the strategic environment of the company to recognize the strategic nature of such information and interpret them analytically. This cannot be assumed by the process owner of operational processes. This once again points out the special role of controlling.

The *criteria for evaluation of information-triggering process controlling* are described below.

- **Assumption controlling:** comparing the information with the assumptions. Information can only be interpreted correctly when they are compared with the assumptions about the existing processes. For example, the actual production volume must first be compared with the planned production volume to be categorized. However, this simple comparison of planned and actual production volume is insufficient. The entire process information must be used to correctly assess the current situation. General conditions and time factors, where appropriate, have the key role.
- **Scenario controlling:** evaluation of the actual information using scenario analysis. A part of the scenario analysis is analysis of the effects of individual variables on a particular portfolio. The factors that probably affect the future progress of the process to be analyzed are extracted first. The influencing factors are correlated next and possible links between these factors have to be identified. Three scenarios are usually taken into account: a positive progress opportunity, and another, mainly negative. The third scenario is based on probable progress. Possible counter-measures will be defined after defining interruptions. Finally, the scenarios are transmitted on both the subject matter and strategy to be developed. In an impact analysis, the strategies and scenarios are considered in a matrix: “What happens if I use strategy 1 with scenario 1?”, etc.

117 An orchestrated and repeatable pattern of a business activity enabled by the systematic organization of resources into processes that transform materials, provide services, or process information. (Software AG). The automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules. In: Business Process Management (BPM) Center of Excellence (CoE) Glossary. www.slideshare.net/skemsley/business-process-management-center-of-excellence, retrieved on April 25, 2016.

- **Controlling of the critical success factors.** These are the key performance indicators that must be reached to guarantee the company's continued existence. If the critical success factors are not achieved, the overall objectives of the company are affected. Critical success factors in general are defined by Haufe:[118] vision and determination, professional project management, clear and realistic objectives, consensus among the stakeholders, ensuring resources, clarification of the framework, definition of the starting position, etc.

Success factors for entrepreneurial innovation strategy in production are:[119]

- **Technology roadmap:** perspective view of the production environment and the production process. This is typically done with respect to one's own product development and benchmarking with the competition.
- **Use of technology coordinators:** they link expert knowledge from various organizational units, also in the context of cooperation between companies that collaborate on carrying out product development and innovation.
- **Internal and external competence network:** it includes the power to contact research institutes and development departments of other companies, also in the context of symposiums. This synergy can be detected and used for the purposes of know-how transfers.

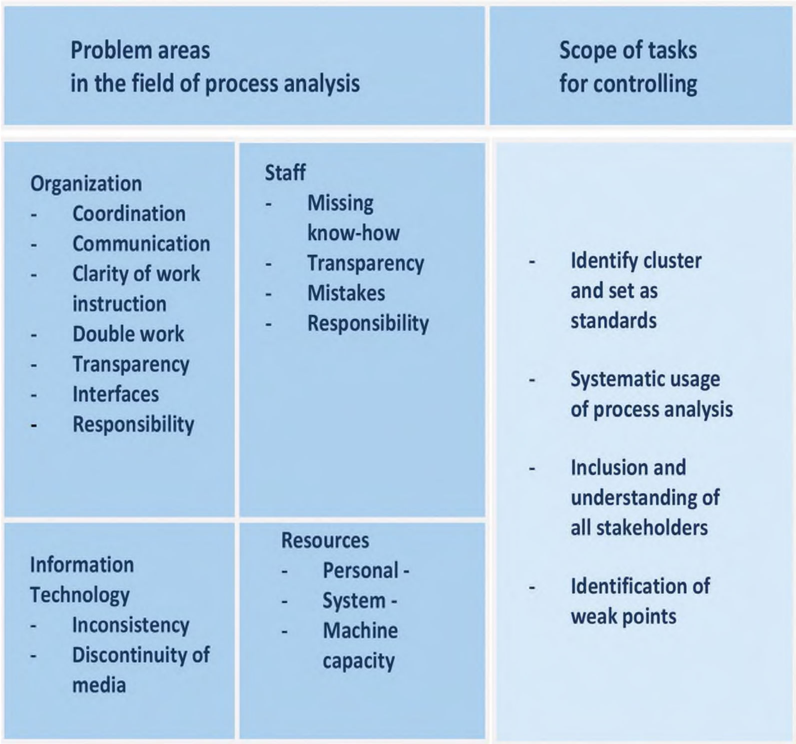
4.2.1.3. Fields of Analysis

The tasks of controlling in process analysis are related to the organization, IT systems, and staff. The focus is on the coordination of the processes involved and the definition and application of standards to ensure efficient running of processes. The following figure provides an overview of the fields of analysis and related tasks of process controlling.

118 www.haufe-medconsult.de

119 Ramm, A., Kutzleb, A., Hipp, Chr.: Erfolgsfaktoren für das strategische Innovationsmanagement in der Produktion. Berichte aus der INPRO Innovationsakademie. Berlin, 2012, p. 287-289.

Figure 20: Fields of Analysis in Process Controlling



Source: Ahlrichs, F., Knuppertz, Th., 2010, p. 197.

Documentation of analysis results should have a standard-related form. An example of a production analysis process is the following:

- Process: product development
- Process objective: 12-month development
- Status: projected maturity over 18 months
- Causes: lack of staff capacity for product development, process manager unsupported by corporate management, key performance indicator information are inconsistent
- Impact on other processes: sales process burdened by delayed launch, reduced credibility, and loss of sales potential
- Affected areas of action: skills, potentials, resources, pro-control expertise, customer requirements, management support.

4.2.2. Methods of Strategic Process Analysis

There is a principle in controlling: *you cannot control what you cannot measure*. This means that objectives and metrics must be defined and checked methodically. In business and economic studies, corporate planning methods are available, but need to be adjusted in terms of process orientation. The benchmarking methods, SWOT analysis and business process outsourcing will be analyzed in this section. These methods are a representative selection of strategic corporate management methods.

The *process analysis* is primarily used to increase the company's competitiveness and improve business management results. A constant process optimization can be achieved by creating transparent process evaluation.

Suitable strategic analysis methods are only those focused on the business process. The *benchmarking concept* is used here for process benchmarking. The *SWOT analysis* focuses on process-related strengths and weaknesses. Opportunities and threats always need to be taken into account in any strategic decision about production processes. The outsourcing concept relates to the question which process and sub-process should be outsourced or insourced to obtain experience and enhance the company's knowledge.

4.2.2.1. Benchmarking

Benchmarking is an ongoing systematic process of comparing one's business processes and performance indicators with the most successful company in the branch. Benchmarking may be focused on products, services, business practices and processes of the recognized leading organization. The objective is to fdiscover success drivers. To do this, the indicators can be identified in companies' publications, public statistics and branch key figures such as the one published by the Organization of Economic and Corporate Development. At the very least, the aim of benchmarking is to catch up with the best organizations and eventually outrun them.

Benchmarking could be used in strategic and operative process controlling. However, the focus of the method is on performance comparison; this method is therefore more frequently used in strategic process controlling.

The objective of benchmarking is a comparison with economically successful or even the best companies. It is therefore necessary to clarify the comparison criteria. With the so-called "internal benchmarking", two or more divisions are analyzed. For external benchmarking, the focus of the investigation is on the comparison of a subsidiary in a company group as well as competitive business groups (competitive benchmarking). In this case, the basic precondition is similarity or comparability of tasks.

As an ongoing process, benchmarking consists of steps or phases. The benchmarking method for processes is based on indicators, but also qualitative comparison criteria. The detected improvement measures can be selectively developed on the basis of comparison results.

Figure 21: Steps of the Benchmarking Process

INITIATION & PLAN	COLLECTION & INVESTIGATION	ANALYZE & REPORT	ADOPT & IMPROVE
• Initiation through set strategic goal • Select the process to be improved • Determine target measure or benchmark • Set project team • Determine methods for data collection (type, sources, metrics, methods, models...)	• Collect process data from different sources • Check data reliability • Investigate using a variety of tools (interviews, questionnaire, observation...)	• Compare process data • Detect differences and identify causes • Suggest improvement solutions • Write reports with conclusions and recommendations • Presentation and distribution of recommendations	• Adopt target measure • Select improving activities and determine responsibilities • Planned actions and launched actions • Measure action effectiveness and improve it

An important success factor is the implementation of improvement measures. It often occurs that proposals developed in the proposal analysis phase remain a draft that cannot be implemented. The reason is that the implementation of changed processes creates additional workload which must be executed in addition to the employees' regular work. This requires the appointment of process managers with appropriate skills and competences.

4.2.2.2. The SWOT Analysis Process

The objective of the SWOT is analysis of the company's market position compared to customers' requirements and available company resources. SWOT analysis is used as a tool in the context of a partial marketplace process. Below is the breakdown of strengths and weaknesses on the one hand, and opportunities and threats on the other hand integrated with the link to "competition".[120]

120 Ahlrichs, F., Knuppertz, Th., op. cit, p. 203.

Figure 22: Process-Oriented SWOT Analysis

SWOT	STRENGTHS WEAKNESSES	OPPORTUNITIES THREATS
SUBJECT	Processes and available potentials compared to the competition	Processes and their positions compared to the competition
OBJECTIVE	Which factors have a sustainable influence on the position in relation to the competition?	Which factors influence the market position?
APPROACH	Assumptions from which a conclusion can be drawn	

Source: Ahlrichs, F., Knuppertz, Th., 2010, p. 203.

In terms of process orientation, the focus is on consistent view of the processes. This means that the horizontal holistic view of the company is the central element (as opposed to the vertical, hierarchical view) in process evaluation. Horizontal viewing extends beyond company boundaries and incorporates the customer and the supplier. Due to perspective change, the hierarchical organizational structure of the company is pushed into the background. The focus is on process organization, mainly the customer and his interests. This concentration allows a company to recognize its value-added processes and, specifically, improve as a continued improvement process.[121]

A combined consideration of process-related customer requirements and direct comparison with the competition will be performed for this purpose. The task now is to identify one's own strengths and weaknesses in the processes.

Efficient process management helps achieve optimum process design and the company can significantly stand out from the competition since customer-oriented processes are difficult to imitate.

121 Fischermann, G., op. cit., p. 24.

The internal analysis of the processes is done by splitting the process into sub-processes and their investigation. The sub-processes are evaluated with regard to the requirements of customer's own performance level and performance level of the competition. Regarding this restriction, the data of the competition cannot be detected directly and commissioning of experienced consulting companies is required.

The external analysis is usually performed by a customer survey.

Different potentials and resources are compared during studying of the processes. For example, a high process-potential arose because a company continued to invest in product development. However, this potential cannot be measured according to the general criteria, but individual sub-processes in product development, for example, brainstorming, product decision, product design, marketing concept, and market launch.

The tasks of the new process controlling in process-oriented SWOT analysis are the selection of standard valuation methods, identifying performance limits of the company and the development of sourcing concepts as well as developing variants for business processes to meet customer requirements.

The core is development of process models, leading the precursor to development and achieving business model controlling.

4.2.2.3. Strategic Alternatives with Business Process Outsourcing

In the investigation of business processes, especially in logistics, sourcing is a strategic method for reviewing one's competences. Both insourcing and outsourcing are possible. The objective is to develop a process model considering the strategic alternatives process. Studying of the processes in production and logistics starts on the basis of one's core competencies. This includes the processes and sub-processes that the company can execute much better than the competition.

Many examples in the industry have shown that a shift from the core competencies towards a "global world company" does not necessarily lead to increasing economic success. Horizontal and vertical integration of partner companies with their own processes increases the manufacturing depth and thus the core competence. The high value-added sub-processes of production and logistics are framed by assisted forming processes of product development, marketing, customer service as well as the procurement, which brings up the sourcing issue.

A way to identifying outsourcing potentials is creating process portfolios. Fischermanns[122] defines *five key reasons* for careful and constant dealing with the company's own process map:

- Focus on transparency,
- Value for customers,
- Process prioritization,
- Process responsibility,
- Process visions.

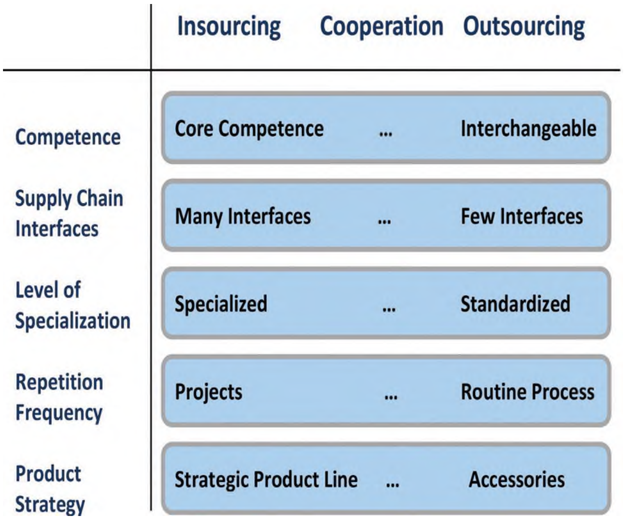
An insight into the process environment is the first good orientation as significant information and material flows pass through the companies. In view of customers' benefits, the company's strategy in the market must be clear. Specifically, the identification of end-to-processes is oriented to specific requirements of segmented customer groups. Prioritization of individual processes in the context of a process model is important and the processes should also be "lived" by the staff and process owners in particular. The assignment of process responsibility derives directly from the definition of the processes. Process visions are rough alternative solutions for business processes. For example, questions about the significance of processes in inter-company value chains are discussed here. Procedural make-or-buy decisions could lead to business process outsourcing or other collaboration solutions.

Business process outsourcing (BPO) means taking over a complete business process or parts of the business process. It is a subset of outsourcing that involves the contracting of operations and responsibilities of a specific business process to a third-party service provider. Originally, this was associated with manufacturing firms, such as Coca Cola, that outsourced large segments of its supply chain. Additionally, it also implies the necessity of the process-supporting IT infrastructure by an external service provider.

Fischermanns has summarized the processes decided on by the BPO provider in the following graphics:

122 Ibid, p.122

Figure 23: Criteria for Outsourcing Business Processes in Production



Source: Adapted from Fischermanns, G., 2012, p. 139.

Similar to in-house partnerships, joint ventures and cooperation, the cost-benefit ratio is a central issue in outsourcing. However, the previous figure shows that additional qualitative factors have to be considered.

Core competencies are not outsourced as sub-processes that have a strategic importance in further development of product portfolio. This means that the company's performance, the sustainability of which establishes the customer's decision in favor of its products, is not outsourced – and *vice versa*.

4.3. Operational Process Controlling

Operational process controlling is dealing with planning, analysis, and reporting of internal operational processes with the aim to align them with strategic goals. A developed measurement system is a part of business process management. For this reason, indicators are to be calculated as a comparative criterion of processes. For process orientation purposes, traditional cost accounting calculations are insufficient and ineffective; cost object accounting in particular. Logistics indicators must be used on the basis of value stream mapping. Chapter 2.2.2.2 introduced the value stream diagram. Pre-production processes in production are planning, management, and organization. They include scheduling of orders, releasing the orders into production, determining lot sizes and planning services, such as maintenance. If the processes of planning and organizing the actual value creation – production – can be associated with these processes, they are to be included in consideration.

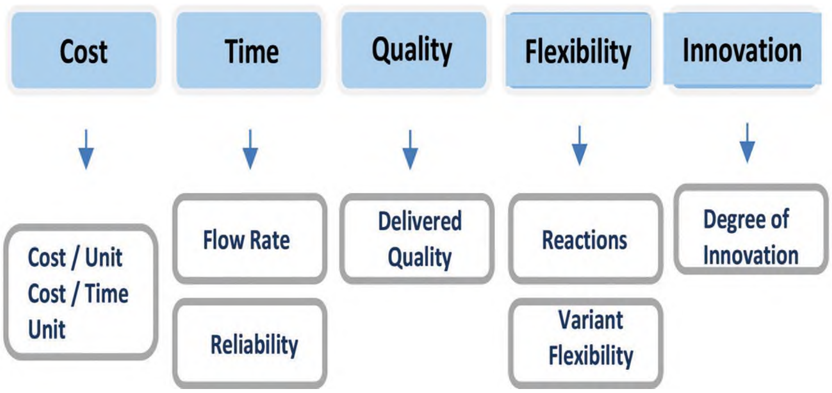
4.3.1. Target System and Target Key Figures

Process orientation in production and production controlling are derived from the focus on the company's orientation to customers. Customers' requirements often refer to product quality, additional services, and the company's flexibility. This is especially the case in plant construction and variant production. The ability of the company to realize innovation in new products, methods, technologies and, ultimately, in processes, is especially important.

Company objectives for the current value stream are derived based on customers' requirements. It is important that concrete, measurable key figures are derived for the current value stream in the production.

These key target figures are thus the basis for a value stream ratio system.[123] They are shown in the following figure:

Figure 24: Major Key Figures for Value Stream Analysis



Source: Adapted from Gottmann, J., 2016, p. 159.

The cost per unit calculation relates to fixed and variable costs. Process-oriented, but idle capacity costs must be considered. Also originating from classic cost accounting, there is no information about the influence of process parameters such as degree of flexibility, value added internal, and value added external. Activity-based costing (ABC) is used to consider these process parameters.

4.3.2. Value Stream Analysis

Value stream analysis is the basis for a value stream ratio system. A value stream analysis is a planning tool used to optimize the results of waste

123 Gottmann, J.: Produktionscontrolling. Wertströme und Kosten optimieren. Springer Gabler, Wiesbaden, 2016, p. 158.

elimination (transportation, inventory, waiting, defects, over production etc.). *A value stream includes all works and activities that are necessary to fulfill an order*.

The actual state of the process is presented in detail and all the important facts and figures are taken into consideration. High transparency of the processes created with this analysis clearly shows the processes that do not add value (waste) and those that have a negative impact on the operating result. The representation of the value stream contains both physical material flow as well as the related information flow. The representation of the value stream is also known as Is-Map, the design of an improved state target map (by a value stream map). *Value stream mapping (VSM*) is a method for illustrating and analyzing the logic of a production process. Value stream mapping (VSM) creates clarity and transparency:

- Of individual steps (Facts and Figures),
- Of the connection between the individual steps (activation),
- Of the stock situation (work in process) between stages,
- By a symbolized representation,
- By a standardized visualization structure,
- By significantly improved communication,
- By a better overall understanding of the entire process.

The *value stream analysis method* is defined as follows:

- Identification and selection of product families,
- Detection of the actual state (understanding the current situation),
- Developing the desired state (vision), designing a slim and synchronous process,
- Prioritization, generation of actions and organization of the implementation.

The basis for the definition of a *value stream ratio system* is value stream mapping (VSM), which is the investigation of the actual state of the process. Within VSM, the processes – in this book the production processes – are measured and visualized in detail. It is important to analyze the entire process, not only individual steps of the process, and take into account all the important numbers, data and facts. This recording is done by analyzing the production processes according to material and information flow. The methodologies for value stream analysis were introduced in the previous section 4.2.2 with methods of strategic analysis. This chapter presents the measurement of efficiency and effectiveness of production processes.

4.3.2.1. The Core Logistic Processes

There are five core logistic processes which are the basis for evaluation and therefore controlling through the key figures of a value stream ratio system (VSRS). This means that the key figures of VSRS are calculated separately referring to logistic processes. A weak point in the entire business process can be identified in comparison with key figure values among the processes.

The customer process contains all sub-processes performed within delivery of the products to the customer. This includes physical delivery processes as well as service processes like information center, maintenance, and repairing the products. The general marketing process is not included here, unless it is a customer-specific standard process. The following matrix in the next section of this book summarizes these sub-processes.

The second type of sub-processes contains all processes for production planning and control. These processes are sales operations planning, master production schedule, material requirement planning, capacity requirement planning, as well as release and control of the production orders.

Thirdly, all internal logistic processes are part of the value stream analysis. These are the processes for internal transport, handling the assemblies, storage, and delay. Regarding the development of new products, processes like construction, prototyping, and preliminary series are also part of logistic processes.

The production process is the core value-added process. It refers to the standardization of the product, to the extent to which sub-production processes can be standardized. High and increasing number of product variants in the 21st century and its fourth industrial revolution forces the industrial companies to define and implement the largest possible number of best practice scenarios.

Finally, delivery processes are the processes for the receipt and issue of goods. There are many dependencies between sales planning, production planning, and procurement planning. The solution for optimization of the integration is defined by the supply chain management and supply chain controlling. The following matrix provides an overview of the central target key figures on the one hand and central logistic processes on the other hand.

4.3.2.2. Value Stream Ratio System Matrix

The following figure shows target key figures for production on the one hand and the value stream processes on the other hand.

Figure 25: Value Stream Key Figure System for Production & Logistics

Target Key Figure	Success Factors Value Stream Processes				
	Delivery Process	Production Process	Logistic Process	Prodution Control & organization	Sales Process
Cost/Unit	Material Cost	Manufacturing Cost	Cost of Logistics	Process Cost	Transport Cost
Throughput Time	Replacement Time	Manufacturing Time	Lay Days Range of stock	Lot Size	Transport Time
Delivery on Time	Difference in Delivery Appointment	Variance in Product. Time	Availability of Resources	Difference in Delivery Time	Difference in Transp. Time
Quality of Goods	Error Rate	Error Rate in Production	Error Rate in Handling	Error Quote Assembly	Damage in Transit Quota
Reactivity	Replacement Time	EPEI, OEE	Availability Mat. IRT	Lot Size	Transport Route
Flexibility to Variants	Flexibility Var.Vendor	Flexibility Var. Prod.	Flexibility Var. Logistics	Flexibility Var. Organization	Flexibility Var. Transport
Level of Innovation	LOI Procurement	LOI Production	LOI Logistics	LOI Organization	LOI Sales Process

EPEI - Every Part Every Interval
OEE - Overall Equipment Effectiveness
IRT - Internal Replacement Time
LOI - Level of Innovation

Source: Gottmann, J., 2016, p. 163.

Explanation of the abbreviations in Figure 25 are the following:

- **Every Part Every Interval (EPEI) –** EPEI defines the necessary time for a production machine to produce all the product variants of a product based on the average required quantity in a single time period, usually per day. The more flexibly a machine can be switched to another variant, the shorter the duration of EPEI. A more elaborate explanation is given in the next section.

- **Overall Equipment Effectiveness (OEE) –** This key figure was explained in section 2.1.2.3.
- **Internal Replacement Time (IRT) –** Internal replacement time defines the time needed before an internally produced material is available for the pegged requirement which is the requirement source. It depends directly on the reaction time and the ability to react respectively. Regarding external replacement, concepts such as "just in time" and "just by sequence" delivery is used.
- **Degree of Innovation (DOI) –** "Innovation" means different things to different people, but, fundamentally, there are two main perspectives: those creating or providing the innovation and those buying, using, or consuming it. The creators invest in the innovation, which they then sell to generate a return on investment (ROI) that can either be reinvested or converted into wealth. Further explanation and proposal to calculate the degree of innovation is explained in the following section.

4.3.3. Key Performance Indicators of Value Stream Controlling

The success factors and indicators can be calculated to measure success by comparison of the objective indicators and value stream processes. This chapter will provide an explanation and calculation of the key figures relating to the optimization of value streams. These indicators are also the basis for business model-oriented production controlling, because the assessment of business models is not based on a black-box approach, but on the assessment of the related business model in business processes.

4.3.3.1. Cost per Unit

The classic material cost estimate is not used to calculate cost per unit. The calculation of cost per unit of time is rather based on the core production value stream, i.e. the *subject is the process*. Economies of scale should be considered in particular, which would be lost at the total cost basis. [124]

The calculation of unit costs in the procurement process is related to cost per unit of material. It, however, no longer works with the classic order quantity formula. In the procurement process, even against the background of outsourcing, all costs must be determined along the entire value chain such as logistics, transport… In practice, however, the determination of these inter-departmental and cross-company processes leads to difficulties, because traditional cost accounting practices with cost element accounting, cost center accounting,

124 Gottmann, J., op. cit., p. 169.

and product cost planning are not designed for this purpose and a meaningful database is therefore missing.[125]

Activity-based costing has been developed for a process-oriented calculation of unit costs. When this method is applied, the process must be split into its sub-processes. Secondly, the cost drivers of sub-process must be identified and the process cost per unit calculated. Finally, the parameters for the cost estimate like complexity have to be considered. These process costs will be calculated for the available process alternatives like self-procurement, using services for procurement, and total outsourcing of the procurement.

4.3.3.2. Throughput Time

This section provides an explanation of a performance measurement system for production controlling, which enables the evaluation of process productivity and cause analysis. The indicators measure productivity by throughput times of work orders through the entire production process and on all work orders in a workplace. The identification of additional indicators is calculated based on the results of throughput times. The indicators are a part of the lead time at maximum capacity, the production order progress, and schedule variances.

The *throughput time of a production order* is calculated based on the confirmation time for the production order at workplace *i* and the confirmation at the previous workplace *i*-1.

$$t_{TP} = t_{c,i} - t_{c,i-1}$$

with *c* – confirmation *TP* – throughput *i* – workplace i *c* – confirmation

The throughput time of a production order has to be corrected with the so-called incentive time which leads to time degree. The time degree usually increases the capacity.

Throughput time of the production order consists of the *setup time* and the *processing time.* The processing time is a multiplication of the processing time per workpiece with the number of workpieces to be produced in a production order.

125 Weißkirchen, F.: Beurteilung der Vorteilhaftigkeit von Outsourcing unter Berücksichtigung von Prozesskosten und Transaktionskosten. Weißkirchen, F. (ed.), Outsourcing - Projekte erfolgreich realisieren, Schäffer Pöschel, Stuttgart, 1999, p. 283-313.

The calculation of throughput time in terms of days is done by division through daily work time. Taking into account a time degree (incentive time):

$$t_{TP,DAY} = \frac{t_{TP,Min}}{TD - Cap_{Day,Min}}$$

TD – time degree *Min* – minutes *TP* – throughput time *Cap* – capacity

Transition periods are the sum of preparatory time, transport time, waiting times, quality inspections, and finishing times.

Throughput Time at a Workplace

With the flexibility of smart production, due to rapid data processing in the fourth industrial revolution, the calculation of average processing times at production workplaces in particular becomes increasingly important. It is possible to access flexible alternative production processes through the rapid transfer of information. A prerequisite is availability of real time information about production workstations.

The simple average throughput time at a workplace is the arithmetic mean of all the throughput times of the orders that have been processed during the period at the workplace.

$$\bar{t}_{TP,WP} = \frac{\sum_{i=1}^{n} t_{TP,PO}}{n}$$

TP – throughput time *WP* – workplace *PO* – production order

n – number of orders *i* – index PO

The following example explains that the calculation of the weighted average processing time leads to a more exact calculation in comparison to the calculation of simple average processing time.

Example:

The following throughput time is given:

Table 1: Production Order Throughput Time

PO	$t_{TP,PO}$ (days)
O101	12
O102	8
O103	10
O104	4
O105	6
	∑ 40

The *simple average throughput time of a production order at this workplace* is calculated with:

$$\bar{t}_{TP,WP} = \frac{40}{5} = 8$$

The simple average throughput time of production is eight days.

This calculation results in simple average processing time for an order. It does not consider any factors that might influence the processing time.

Simple average processing time does not take into account that the orders in the order volume may vary significantly. This may be due to the complexity of the product; therefore, it might occur that high-volume production orders are executed relatively slowly, as are orders with smaller contents (for example, if it has been determined that a production order with double work content needs 3 times throughput times).

The consideration of the work content (for example, order quantity) takes place in the calculation of weighted average throughput time.

$$\bar{t}_{TP,v,WP} = \frac{\sum_{i=1}^{n} t_{TP,PO_i} * v_{PO_i}}{\sum_{i=1}^{n} v_{PO_i}}$$

TP – throughput time	*WP* – workplace	*PO* – production order
n – number of orders	*i* – index PO	v_{POi} – volume PO

Example:

Compared to the previous example, the calculation is:

Table 2: Production Order Throughput Time with Weighting Factor

PO	$t_{TP,PO}$ (days)	VPO
O101	12	4
O102	8	5
O103	10	3
O104	4	2
O105	6	1
	∑ 40	∑ 15

The *weighted average throughput time* is calculated with (w – weighted):

$$\bar{t}_{TP,w,WP} = \frac{12 * 4 + 8 * 5 + 10 * 3 + 4 * 2 + 6 * 1}{4 + 5 + 3 + 2 + 1} = \frac{132}{15} = 8.8\ days$$

The weighted average throughput time is about 8.8 days.

The weighted average processing time is considerably higher than the simple average throughput time. This is always the case when production orders with a smaller order quantity are preferred. It can thus be determined whether processing times of production orders are proportional to increasing lot size or not.

This is a point where controlling investigates the degree of resilience of a specific production line.

Throughput Time for a Production Order

Key figures for the manufacturing order provide information on how long an order was bound in the production area and which factors have had an impact on throughput time.

The production order cycle time is calculated from the difference between the end and start time.

Considering the individual operations of the production order – defined in the routings – and taking into account parallel production considered with an overlapping factor, it results in:

$$\bar{t}_{TP,PO} = \frac{\sum_{i=1}^{n} t_{TP,O}}{n * OF}$$

TP – throughput time *PO* – production order *O* – operation def. in routings

OF – overlapping factor *n* – number of operations *i* – index for operations

The *weighted average throughput time can also be calculated for production orders*.

$$\bar{t}_{TP,x_{op}PO_i} = \frac{\sum_{i=1}^{n} t_{PO_i} * x_{op_i}}{\sum_{j=1}^{m} op}$$

TP – throughput time PO – production order op – operation t – time

x_{op_i} – number of operations of a production order i – index production orders

Table 3: Production Order Throughput Time for a Production Order with Weighting Factor

PO	TP, PO_i (days)	x_{op_i}
O101	12	6
O102	8	4
O103	10	5
O104	4	2
O105	6	3
	∑ 40	∑ 20

The weighted average throughput time of a production order is calculated as follows:

$$\bar{t}_{TP,x_{op},PO_i} = \frac{12 * 6 + 8 * 4 + 10 * 5 + 4 * 2 + 6 * 3}{6 + 4 + 5 + 2 + 3} = 9$$

The average lead time refers to the average value of all orders and not to the average values of all orders in a work center.

The key figure is used as a criterion for comparison. If the average throughput time for orders with a higher number of operations develops disproportionately, the reason for this could be, e. g., learning effects. If it develops progressively, the reason might be the switch to other production lines, when the number of operations exceeds a certain number.

The proportion of working time to throughput time

The proportion of working time (PWT) to throughput time is calculated with the ratio of working time and throughput time.

$$PWT = \frac{\bar{t}_{WT}}{\bar{t}_{TP}} \qquad \text{with} \qquad \bar{t}_{WT} = \frac{\sum_{i=1}^{n} T_{c,PO}}{n}$$

T_c – time confirmed for the PO

PO – production order

WT – working time

TP – throughput time

Example:

At a time degree of 1 (100%, no chord) and a daily capacity of eight hours, the following data are given:

Table 4: Confirmed Working and Throughput Time

PO	Confirmed Working Time	Confirmed Throughput Time
O101	4	12
O102	5	8
O103	3	10
O104	2	4
O105	1	6
	∑ 15	∑ 40

Average working time:

$$\bar{t}_{WT} = \frac{15}{8} = 1.88$$

Average throughput time:

$$\bar{t}_{TP} = \frac{\sum_{i=1}^{n} t_{TP,i}}{\text{n}} = \frac{40}{5} = 8.0$$

Proportion of working time PWT:

$$PWT = \frac{1.88}{8.0} = 0.235 = 24\%$$

In this example, the utilization in the production area is 24%; therefore, low.

4.3.3.3. Delivery on Time

The importance of production dates has significantly increased with networked production. There is high-time dependency due to overall timing across production lines and across companies in the production network.

The schedule variance is the difference between the planned target dates based on scheduling and capacity planning and the detected actual dates based on the confirmations of production orders. Negative lateness will be posted with an earlier completion and *vice versa*. In order to avoid consolidation of positive and negative schedule variances, the amount of schedule deviations is summed up, or there is squaring and root extraction of values.

The *simple average schedule deviation* $(\overline{SASD})$ is calculated from:

$$\overline{SASD} = \frac{1}{n}\sqrt{\sum_{i=1}^{n}(t_{act} - t_{plan})^2}$$

n – number of confirmations t_{act} – time actual t_{plan} – time planned

Positive and negative deviations do not offset each other; they are first squared and the square root is then extracted.

Example:

Table 5: Time Deviation in Production Orders

Production Order	$Time_{plan}$ (h)	$Time_{actual}$ (h)	Time Difference squares
O101	100	110	100
O102	109	106	9
O103	108	115	49
O104	112	108	16
O105	115	125	100
O106	118	120	4
∑	662	684	278

The simple average deviation is:

$$\overline{SASD} = \frac{1}{n} * \sqrt{278} = \frac{16{,}67}{6} = 2{,}78$$

The simple average deviation is about 2.78 hours.

To find out whether the work content of production orders leads to over- or under-proportional increase in lateness, the calculation of weighted average lateness is defined as follows:

$$\overline{WASD} = \frac{1}{n}\frac{\sum_{i=1}^{n}\sqrt{\left(t_{act,i} - t_{plan,i}\right)^2} * x_{PO,i}}{\sum_{i=1}^{n} x_{PO,i}}$$

$\overline{WASD}$ – weighted average schedule deviation

$t_{act,i}$ – confirmed actual time PO_i $t_{plan,i}$ – time planned PO_i

$x_{PO,i}$- weighting factor, for example the production quantity of the production order

Example:

Table 6: Actual Plan of Time Deviation with Weighting Factor

PO	T_{plan} (h)	T_{actual} (h)	I Difference	II Difference squares	III Difference square root	IV XPO	III* IV
A101	100	110	-10	100	10	10	100
A102	109	106	3	9	3	3	9
A103	108	115	-7	49	7	10	70
A104	112	108	4	16	4	4	16
A105	115	125	-10	100	10	10	100
A106	118	120	-2	4	2	2	4
∑	662	684				39	299

The *weighted average schedule deviation* is:

$$\overline{WASD} = \frac{1}{6} * \frac{299}{39} = 2{,}55$$

The weighted average deviation is 2.55 hours.

The weighted average schedule deviation is considerably higher than the simple average schedule deviation. This is because purchase orders with small work content or complexity (weighting factor) were reported much more punctually than orders with a higher weighting factor.

It is within the scope of the tasks of the controlling to find out the reasons.

4.3.3.4. Quality of Goods

Product quality plays an important role for customers. Quality features are not only damage or missing functionality, but also usability and service. Repairs are usually not paid by the customer and also lead to loss of confidence. Therefore, the entire material process must be examined to detect the points at which the product quality can be adversely affected.

Measurement of the entire value stream is necessary to detect errors in the shortest period of time possible and thus avoid the delivery of defective products. Delivery quality therefore sums up the entire process and is defined as follows:[127]

Delivery quality [%] = (1 – error rate vendor) * (1 – error rate in production) * (1 – error rate handling) * (1 – error rate assembly) * (1 – error rate transport)

Error rate is basically calculated by division of the number of errors through the total number of objects, i.e. actions.

Approaches to improving delivery quality are shown in the following table:

Table 7: Dependencies and Improvement of Delivery Quality

	Vendors	Production	Logistics	Production Control	Customer Transport
Delivery Quality	Error rate of vendor	Error rate in production	Error in handling	Wrong assembly, material in stock	Quote of transport damages
Dependent on	Procurement processes, vendor processes	Production line set up, beginning performances (learning curve), maintenance	Product variants, number of handling operations, sorting process	Product variants, lay days	Service enterprises, transport route, passage of risk
Starting point to increase the delivery quality	Adaptation of effort for a quality check, supplier development	Standardization, qualification, education	Reducing the number of handling operations, standardization	Reduce reconciliation, reduce interfaces	Service development, increase in standards of quality

Source: Gottmann, J., 2016, p. 177.

Since the structures in terms of logistics and production are constantly changing, checking the delivery quality is a constant subject of consideration. New technologies, new partners, new customers and last, but not least, new products, require constant updating of the quality management system.

126 Gottmann, J., op. cit., p. 175.

4.3.3.5. Reactivity and Flexibility in Variant Production

In this context, the company should be able to quickly adapt its production processes to changes in the company environment. Reactivity is influenced by various measurable indicators. These indicators are compiled as follows:[127]

- Procurement: replenishment lead time in delivery processes
- Production: every part every interval (EPEI) and overall equipment effectiveness (OEE)
- Logistics: material availability, internal lead time
- Production control and organization: lot size.
- Customer process: transport routes.

The replenishment lead time from suppliers is particularly optimized with the installation of the “Collaborate Planning, Forecasting & Replenishment” (CPFR) system.

CPFR is a business model between trade and industry to predict sales performance in trade or the development of demand in order to optimally plan the flow of goods. Collaborative means that legally independent partners carry out a concerted plan.

In the classic doctrine, stocks were built up to achieve high product availability, whereby the economy was significantly affected by inventory and capital costs. As part of the networked production, this objective is achieved through coordinated planning based on framework contracts.

CPFR is achieved by the following steps:

1) Framework agreement. The cooperation scope and the performance criteria for measuring success and the definition of business processes are hereby set. This includes provision of resources and their skills, executive bodies and establishing information exchange.
2) Creating a common business plan. Order data are set with the lead time for orders, contract minimum and order intervals for this purpose.
3) Definition and calculation of the demand forecast.
4) Identification of variances and solving the variances in real-time communication.

127 Ibid, p.178.

5) Detailing a demand forecast into a purchase forecast.
6) Identifying variations in the order forecast and exception handling in the order forecast in real-time communication.
7) Triggering the purchase order.

This results in an improved response behavior by an increased rate of reaction to changes in demand, the reduction of stock-outs and lower costs.

In the century of the fourth industrial revolution, with company networking and the use of cloud technology, many companies use the opportunity of standard procurement processes for purchasing an application on cloud technology from service providers.[128]

Every Part Every Interval

The key figure EPEI[129] indicates the period during which it is possible to produce the entire product range. Regarding a specific product variant, the key figure EPEI can be used to calculate the time needed to produce the product variant again.

Within stock production of series products with variations, this key figure plays a role when it comes to achieving a uniform supply of variant-related production lines by optimizing the sequencing of variant-specific production orders in the previous production lines.

This means production cycle necessary for the production of all variants with their specific periodic quantities should be minimized.[130]

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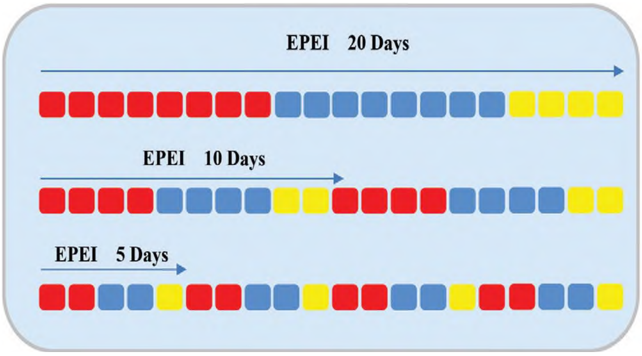
128 "Intelligent shopping does not only mean shopping at the lowest price. It learns the spending habits of your company and uses this knowledge to negotiate better. The point is to be linked with a diverse network of quality suppliers to quickly find partners for cooperation, reduce your cost of goods and services while minimizing your risks. Also important is contracting and procurement in accordance with the existing regulations." SAP solution ARIBA. http://de.ariba.com/lösungen/987/einkaufen. Retrieved on May 5, 2016.

129 EPEI represents the frequency of production of different parts or services provided within a fixed repeating schedule. It is typically reflected in days or partial days and represents the time interval between successive complete wheel revolutions or runs.

130 A well-known procedure for sequence planning in variant production is the Toyota Goal Chasing Method. This procedure is used in the automotive industry and the main logic is to produce the variant with the biggest actual difference between the required quantity and produced quantity within a production cycle. The technical prerequisite is availability of flexible production systems with a minimum setup cost when changing the product variant to produce.

Figure 26: Every Part Every Interval (EPEI)



Source: Adapted from Syska, A., 2012, p. 12.

This key figure becomes especially interesting in sales order-batch production. The basis are now average variation-related customer requests. The figure above provides an overview of the EPEI. The lower the EPEI value, the more flexibly the production can respond to changing customer requirements.

With the use of the EPEI (Every Part Every Interval), as the time passes until the same product variant is produced, the organization is aligned with fixed time periods in which the same product variants are produced. Smoothing of the production will be achieved by the realization of every part every interval. The smoothed production avoids interim storage stocks and temporal idle time of production capacities. Therefore, the production reaches high efficiency in the organization.

Example for the calculation of the EPEI

For the calculation of the EPEI, customer-requested units per day are multiplied with the time per unit in the first step. This results in total processing times per day.

Table 8: Example of Every Part Every Interval (EPEI)

Product Variant	Daily Quantity required	Production Time per Unit [Min]	Production Time Daily quantity [Min]	Set Up Time for Daily quantity [Min]
A	400	**1.2**	480	0.5
B	600	**1.4**	840	0.4
C	200	**1.3**	260	0.3
D	300	**1.5**	450	0.6
E	500	**1.6**	800	0.2
SUM	2,000		2,830	**2.0**

The set-up time within a single production cycle is required for tool changing. The tools are wearing out and must be replaced, especially in the metal-cutting production.

The production is organized in several production cycles. This means that the whole quantity needed for product variant A will not be produced first, followed by the quantity for product variant B, etc. To be able to deliver, different product variants will be produced iteratively in several cycles. After each cycle, a part of the product variant quantity will have been produced. To calculate the production quantity of each cycle, the total quantity of about 2,000 pieces could be divided into 20 pieces. Thus, the total quantity needed of about 2,000 pieces will be produced with 100 cycles. Each cycle will deliver 20 pieces. To find the production quantity for each cycle, the total quantity could be divided by 100 cycles.

Solution

Product Variant	**Daily Quantity Required**	**Daily Quantity Each Cycle**	**Production Time Each Variant Each Cycle**
A	400	**4**	**1.2 * 4 = 4.8**
B	600	**6**	**1.4 * 6 = 8.4**
C	200	**2**	**1.3 * 2 = 2.6**
D	300	**3**	**1.5 * 3 = 4.5**
E	500	**5**	**1.6 * 5 = 8**
SUM	2,000	**20**	**28.3**

100 cycles will produce the required 2,000 pieces. Each cycle produces 4 pieces of product variant A, 6 pieces of product variant B, etc.

With the production time of about 7 minutes plus setup time of about 20 minutes, the time needed for one production cycle is as follows:

$$Production\ Time_{\ cycle} = \frac{2{,}830\ total\ time}{100\ cycles} + 2\ setup\ time = 30$$

After each production cycle, a subset of daily requirements is available for each variant. The total production item for each production cycle can be calculated as follows:

$$EPEI = Production\ Time_{\ cycle} = \left(\sum_{I=1}^{n} t_{pr,i}\right) + t_{st,i}$$

$$t_{pr,i} = production\ time\ variant\ i$$

$$t_{st,i} = setup\ time\ variant\ i$$

Every part every interval means that, after the production time of a cycle, every variant is available with a subset of the required daily quantity. In this example, the result is:

EPEI = 28.3 + 2 = 30.3

In one production cycle, it is not necessary that 4 pieces of A are produced first, 6 pieces of B second, etc. It is also possible to switch to another product variant, which is defined with the Toyota Goal Chasing method as mentioned in the note above.

It is the task of the controller, in collaboration with engineers, to determine the minimum for EPEI (Every Product Every Interval) by an optimal production organization based on technical procedures.

4.3.3.6. Degree of Innovation

The degree of innovation quantifies the novelty of innovation and places them in relation to the existing products and processes. A distinction is made in terms of novelty between the applied technologies and importance for the market. Furthermore, the impact of innovation on internal organization and external environment should be measured. Radical innovations are a significant novelty in both the market and technology. By contrast, incremental innovations are a small novelty in all innovation dimensions.

Controlling has to make sure that the innovation portfolio is compatible to corporate strategy. Converting ideas to realization requires high levels of inter-functional co-ordination and integration.[131]

131 Vitezić, N., Vitezić, V.: A Conceptual Model of Linkage Between Innovation Management and Controlling in The Sustainable Environment. Journal of Applied Business Research, 31, 1; p. 175-184, 2015, p. 178.

At the project level, the controlling approach differs in particular degrees of freedom enjoyed by the project team. Due to strong control of innovation projects, the controlling blocks restrict innovation success. Development projects with high innovation levels are often not feasible.

In such projects, the *role of controlling is to support the project team in the selection of suitable methods for project controlling*. Measuring the level of innovation is usually possible only with the calculation of ratio key figures. An empirical study that includes questioning the management about the level of innovation activities is conducted first. Thus, costs and benefits are an important segment to be analyzed in research and development (R&D) department.

Expenditure on research and development is reflected in the following characteristics:[132]

- Financial expenses for research and development
- Number of innovative products (radical innovation means a new product which generates its new market)
- Headcount in innovation projects
- Progress degree = reached milestone since project start / total number of milestones
- Time to market = time duration from product idea until market entry
- Relative process time shortening = process time shortening / total process time
- Innovation cost intensity = expenses based on product- and service innovation / total revenue

Time to Market, Target Achievement and Innovation Portfolio

The turnover of the products launched on the market is less than 3 or 5 years. The meaning of such an innovation ratio is the so-called "Time to Market". It defines how much time a company needs from an idea for a new product until successful positioning of the product on the market. The Benchmark Center of Europe in Cologne discovered that 1/3 of the products needs more than two years of time to market. A top-performer has high profitability in comparison to the investment in the new product.

Target achievement refers to the expected results of ongoing innovation projects. Advantage: simple determination (survey among the project leaders),

132 Kunau, O., Möbus, S. A., Petsching, M., Schniering, N.: Kennzahlen im Controlling von Service-Innovationen. In: Gleich, R./Schimank, C. (Eds.): Innovations-Controlling, Der Controlling-Berater, Band 13, Freiburg, 2011, p. 87-160.

can be divided according to the level of development of the projects (idea, concept, feasibility, business plan, market launch). The benchmarking center in Europe discovered that top-performers keep within 3/4 of all projects on the budget and schedule.

4.3.3.7. Overall Efficiency in Production

The key figure overall equipment effectiveness (OEE) which has been introduced in section 2.1.2.3. has been further developed by Winkler, Seebacher and Oberegge.[133] The result of their development is analyzed. It is a perfect example of applicability of process-oriented production controlling and therefore business model-oriented production controlling considering the production process as a business.

The *overall production efficiency* OPE is defined as follows:

$$OPE[\%] = \frac{\sum_{t=1}^{n} N_t}{\sum_{t=1}^{n} K_t} * 100$$

$$\sum_{t=1}^{n} N_t = \text{Net Production Time} \qquad \sum_{t=1}^{n} K_t = \text{Production Capacity}$$

Waste in the production process (for example: downtime, loss of speed, empty transport…) has to be taken into account for the calculation of efficiency. Waste is calculated as surplus material in stock with the usual definition of intermediate stock (α):

$$\alpha = \sum_{i=1}^{n} x_i \sum_{t=1}^{n} t_{x_i}$$

The consideration of waste (w) leads to the definition of OPE_w:

$$\text{Overall Production Efficiency:} \quad OPE_w[\%] = \frac{\sum_{t=1}^{n} N_t^2}{\sum_{t=1}^{n} K_t * (\sum_{t=1}^{n} N_t + \alpha)} * 100$$

133 Winkler, H., Seebacher, G. and Oberegge, B.: Effizienzbewertung und -darstellung in der Produktion im Kontext von Industrie 4.0, (2017). In: Obermaier, R.: Industrie 4.0 als unternehmerische Gestaltungsaufgabe: Betriebswirtschaftliche, technische und rechtliche Herausforderungen, Wiesbaden, 2017, p. 219.

Example:

Net productive time:	80 min.
Production capacity:	100 min.
Waste:	3 PCs with 5 min for each PC.

$$OPE = \frac{80}{100} * 100 = 80\%$$

$$OPE_w = \frac{80^2}{100 * (80 + 15)} * 100 = 67\% \qquad \propto = 3 * 5 = 15$$

The waste reduces the overall production efficiency from 80 to 67%.

Additionally, the overall production efficiency, logistic efficiency, has to be taken into account. It is defined as follows:

Efficiency Production Process: $$\boldsymbol{EPP}\,[\%] = \frac{\sum_{c=1}^{n} \boldsymbol{a_c} - \sum_{c=1}^{n} (\boldsymbol{d_c} + \boldsymbol{l_c} + \boldsymbol{e_c})}{\sum_{c=1}^{n} \boldsymbol{a_c}} * 100$$

a = availability (transport capacity of transport equipment i)

c = capacity (transport capacity i)

Waste of:

d = downtime

l = loss of speed

e = empty transport.

Example:

A production has an availability of 98% (a).

The influencing <u>factors</u> are as follows:

d = 0,01 (unexpected downtime),

l = 0,02 (loss of speed),

e = 0,05 (empty transport).

The factors together reduced the EPP of about 8% to 90%.

$$EPP = \frac{98 - (1 + 2 + 5)}{100} * 100 = 90\ \%$$

It is evident that more waste of transport capacity leads to lower efficiency.

OPE and EPP together define the overall efficiency of the production system. Therefore, the OPE and EPP are multiplied by a weighting factor:

Total Production System Efficiency: $\boldsymbol{TPSE = OPE_w * w_P + EPP * w_{TR}}$

w_p – weighting factor OPE w_{TR} – weighting factor EPP

Example:

With a weighting factor of w_p = 0,6 and w_{TR} = 0,4, the result related to the previous examples is as follows:

$$OPE_w = \frac{80^2}{100*(80+15)} * 100 = 67\% \qquad w_p = 0{,}6$$

$$EPP = \frac{98-(1+2+5)}{100} * 100 = 90\ \% \qquad w_{TR} = 0{,}4$$

$$\mathbf{TPSE = 67 * 0.6 + 90 * 0.4 = 40.2 + 36 = 76.2\ \%}$$

Winkler *et al.*[134] propose using the cost of production and transport equipment as basis for setting the weighting factors for OEE and OPE. The costs to be taken into account are depreciation costs of equipment and labor costs recorded in the production and transportation processes.

134 Winker, H. *et al.,* 2017, p. 231.

SUMMARY

With regard to the ongoing increasing market dynamics, companies have to adapt to technical and methodological terms in accordance with the current fourth industrial revolution. Obviously, the dynamics of business processes will have an impact on corporate planning, company management, and, therefore, controlling. Corporate management and controlling have shifted from a functional to a process-driven approach. Classic operational, function-oriented organization is just a part of a company-wide joint venture organization and autonomy-oriented management will be further developed into a service-based approach to business processes. A business function is usually understood as processing of business objects and business processes. A process is a sequence of operations or repetitive activities in which information is processed (input) to reach a goal-oriented result (output). It is characterized by a higher-level interaction between people, machines, materials, and methods along the value chain to achieve an objective. The business process is used to achieve the objectives derived from the company's strategy. Process orientation in a company means understanding the basic attitude that considers the functioning of the entire company as a combination of processes. Each activity can be regarded as a process and improved accordingly. There are some requirements for processes which should be considered, such as: effectiveness of tasks and objectives, performance efficiency, controllability, and adaptability. Each business process has a life cycle that consists of modeling, implementation, and optimization through restructuring. Companies tend to be competitive and try to optimize processes. In other words, this means a gradual and sustainable increase in company's competitiveness by aligning the processes with customers' requirements. Therefore, the focus is on customer-driven processes in the company.

If we understand controlling as a sub-system of the management and a coordination function, controlling is not viewed as a bundle of tasks, but as a process. The controlling process starts with analyzing the production process, understanding the process, planning and monitoring the process. Thus, service quality of the controlling is the central part of this concept of controlling in general and production controlling in particular. Process quality is a prerequisite for achieving the desired quality of results – processes and outcomes are closely linked. Through accurate measurement of a key performance indicator (KPI) from the processes, some conclusions may be drawn about the results of the processes.

A wide spectrum of business controlling tools is available that can be used for process-oriented production controlling. At the level of cost accounting, activity-based costing records and basic accounting data are used. The value stream analysis is recommended in particular for the control of production processes and process design methods. The effectiveness and efficiency of the

production system is based on process indicators which can be combined into a performance measurement system. The Process Scorecard could be used as an efficient tool for controlling purposes. The necessary availability of process data in real time can be ensured by the manufacturing execution system (MES).

The Process Scorecard can be used as a measure because it focuses on the strategic agenda, selection of a small number of data items, mix of financial and non-financial data, and indicators that have to be balanced with the goals and objectives. Strategic corporate management methods are used for strategic process analyses: benchmarking, SWOT analysis, and business process outsourcing. Benchmarking is the process of comparing best practices at the international level. Benchmarking could be used in strategic and operative process controlling. SWOT is used for the analysis of the company's market position compared to customers' requirements and available resources in the company. It focuses on process-related strengths and weaknesses, opportunities and threats. The concept of outsourcing relates to the question, which process and sub-process should be outsourced or insourced to obtain experience and enhance the company's knowledge. Operational process controlling can no longer rely on traditional cost accounting calculations, particularly cost object accounting. The value stream ratio system should be used with the key targets: cost, time, quality, flexibility and innovation. Key performance indicators for value stream controlling are cost per unit, throughput time, delivery on time, quality of goods, reaction and flexibility in variant production, degree of innovation, and overall production efficiency.

QUESTIONS

1. Explain the meaning of a process-oriented company and process requirements that should be considered.
2. What are the objectives of business process management and what does its life-cycle consist of?
3. What are the success factors and value drivers in process oriented production controlling?
4. Using one example, explain the main characteristics of the Process Scorecard and the controller's role.
5. What are the most commonly used methods of strategic process analysis? Explain the benefits of each.
6. Which indicator systems and other systems are used in the operational process controlling?
7. List and explain the performance indicators of value stream controlling.

5. Production Business Model Controlling

Due to increasing market dynamics and the associated competitive pressure, the development of product and process innovation no longer guarantee the survival and growth of a company. All aspects of the current business model must be scrutinized to identify new ways for achieving company's goals. However, successful business models are no coincidence. A systematic approach to the development of business model innovation is required for long-term competitiveness, especially in established companies.

The business model innovation basis will be analyzed first in this chapter followed by the explanation of the business model design phase.

In the second section, the following process optimization methods are presented in order to use them in business model optimization:

- value balance production process
- production value added
- value drivers and value management.

The third section of this chapter covers the topic of value production for the calculation of value added of the production process and therefore a specific production model, which is the final result in business model-oriented production controlling.

5.1. Business Model Innovation

Business model-oriented thinking and business model-oriented controlling have a central objective: *drive innovation*.

In economics, the term was introduced by Joseph Schumpeter with his theory of innovations. He recognized innovation activity as an independent productive factor and showed that innovation has an influence on the growth of business economics. Innovation is mainly defined as a change or novelty resulting from human creativity in a new idea, new products, services, systems, processes, policies, programs. It is defined here as a *list of new production functions*. Innovation is a deliberate and targeted process of change towards something first, "new". Economy and society change when production factors are combined in a new way.

In many "business model" definitions, the focus is on the benefits for the customer and the organization. The business model defines the relevant activities which must be performed in the company to achieve business model success.

The keen interest in business model innovation and the associated controlling originates from the expansion of competitiveness of the BRIC countries. Therefore, it is necessary to expand to these new markets.[135] Moreover, the EU's development strategy requires sustainable management which will be achieved by using a specific toolset and steering, i.e. clearly set targets, planning and measurement systems. In a word, sustainable innovation and controlling.

5.1.1. Business Model Innovation Perspectives

A business model is a result of a business idea. The criteria of a business idea are a product or a service that should be offered to the market and the target customer, the organization of product manufacturing and marketing as well as the corresponding controlling model.

A business model will be robust if it has the following characteristics:

- **Uniqueness:** The business model should not be imitated by the competitors.
- **Bargaining resistance:** The target groups: customers, vendors, and cooperation partners should not be able to negotiate a result, which neutralizes the benefits of their own business model and transfers it to the target groups.
- **Flexibility:** The business model should strengthen or increase the flexibility of the organization.
- **Non-substitutable:** It should be possible to substitute the new product in a short and medium time period.

The three main perspectives: customer, organizational, and financial, define a business model innovation and are explained in the following text.

5.1.1.1. Customer Perspective

Customer benefits originate from qualitative and quantitative characteristics of the new product. Qualitative characteristics include novelty, design, product image, and customizability (configuration) of the product. Quantitative characteristics are product price, customer benefits through cost savings or revenue effects at the customer side, as well as the product service that increases customer value.

135 Casadesus-Masanell, R., Zhu, F.: Business Model Innovation and Competitive Imitation: The Case of Sponsor-Based Business Model, Working Paper, 2013. University of Southern California, Los Angeles, 2013, p. 7.

Target customers are an integral part of the business model. If the customers are confident, the result is long-term customer loyalty which enables success of the innovation.

In reality, there is a variety of business models which are successfully marketed due to their characteristics. Coffee marketing by Starbucks was not successful because the company had developed new coffees. It was rather the marketing of a coffee-drinking lifestyle in the company's branches with its own design of coffee-houses.

The following table provides some examples of customer segments created by business models.

Figure 27: Examples of New Customer Segments

Customer Segment	Examples
People on a Long Work Trip	Southwest Airlines „mobile commuters“
Consideration of Changing Customer Requirements	Senseo Coffee „speedy cup of coffee“
Aggregation of Small Market Niches	IKEA „handyman in all income brackets“
Formation of new Customer Segments	The Body Shop „Ecology and Care“
Reduction of Over-Engineering	Canon „printer and copier“
New Value Proposition	Amazon „online-selling“

The examples in the previous figure show that a new business model is generally based on innovation. There are different types of innovation; technical innovation and the resulting product functionality. Another form of innovation can be developed in the exchange of supply relationships. This is especially true when the customer is involved in the compilation of a product range with their own products. Online trading innovation reduces the time required for the purchase of a product for which the customer does not need a personal consultation. A vision implies that reordering is done automatically by reaching one missing stock or the minimum stock in private households.

A central point in the customer's perspective are CRM – *customer relationship concepts*:[136]

- **Personal assistance.** The customer is personally advised by a salesperson or customer service representative.
- **Key account management.** Organizational classification of the product group and support of a key account manager or fixed assignment of a sales representative to large customers to get customer-specific know-how about his projects and related product requirements in the future.
- **Automated self-service.** Customer profiles are created in communication with the customer, usually by using online portals in the IT system. Thus, the customer perceives the online service as a kind of a personal relationship.[137]
- **Online community.** In an online community, members can get information and news and share their experiences.

Innovation and business models have been developed using information technology in particular. An example is providing the customers a possibility to develop design proposals, which are included in IKEA's production "myIKEA". Customers whose proposals have been realized have a share in the revenue of these products.[138]

5.1.1.2. Organizational Perspective

Organizational perspective consists of resources and activities. Resources are physical resources (production facilities, factories, production equipment, IT systems), intellectual resources (brands, expert knowledge, patents), financial resources (cash, investments, equity), and human resources (experts, generalists). Activities include manufacturing execution (automation to improve quality), problem solving (customized solutions for standard problems, which differ in the case of actual use in the actual customer scenario), and networks. Continuous updating and development of online presence is necessary for optimization of usability, especially in business models.[139]

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136 Osterwalder, A., Pigneur, Y.: Business Model Generation – A Handbook for Visionaries, Game Changers and Challengers. Hoboken, New Jersey (USA), 2010, p. 28.

137 An example of interaction through an online portal is the SAP Learning Hub. SAP Learning Hub provides immediate, cloud-based access to a vast selection of SAP learning content – and to their innovative, interactive learning rooms. And when you add SAP Live Access, you can carry out class assignments, prepare for customer engagements, or just experiment with live, fully configured SAP training systems. https://training.sap.com/de/en/.

138 Bieger, Th., zu Knyphausen-Aufseß, D., Krys, Schr.: Innovative Geschäftsmodelle. Konzeptionelle Grundlagen, Gestaltungsfelder und unternehmerische Praxis. Springer, Heidelberg, 2011, p. 44.

139 Osterwalder, A., Pigneur, Y., op. cit., p. 24.

Resources and activities play the key role in the development of new business models. Another question of organization refers to collaborations; strategic alliances and joint ventures. With the development of cloud technology in particular[140], cooperation in the buyer-supplier relationship has increased.

Cooperation motives apply to the following objectives:

- **Optimization and economies of scale.** The subject of optimization is sharing resources and associated cost savings.
- **Risk reduction.** Collaborations are very common in the development of new technologies with a correspondingly high proportion of basic research. For example, in the automotive industry, many collaborations have been closed to the development of electric drives, although the companies are competing on the product market.
- **The transfer of know-how and market entry.** A meaningful collaboration is, on the one hand, the result of specific product innovation knowledge of the company. On the other hand, an innovative company is a newcomer in this market segment. Cooperation with already established companies in the market segment leads to a win-win situation. The innovative company gets access to the market, and the customers of cooperative partners, the other company, benefit from the transfer of knowledge.[141]

The issue in all these motives for cooperation is the extent of outsourcing and insourcing. Process outsourcing was discussed in the previous section 4.2.2.3. Regarding business processes, the public cloud is mainly used for routine processes performed continuously. Furthermore, collective understanding of performance is required, i.e. it determines how much each partner contributes to the total value.[142]

140 Cloud computing relies on sharing resources to achieve coherence and economics of scale, similar to utility over a network. Cloud platform also known as Platform-as-a-Service (PaaS), is a system that delivers over the Internet (and as a utility) the easy-to-deploy infrastructure and services needed to develop, prepare, and run applications, as well as other services, including application integration and portals.

141 A successful product in the collaboration between industrial business partners aiming to increase the efficiency of the procurement process is the ARIBA product, which is part of SAP's business suite. ARIBA was founded with the mission to reduce company expense. Actually, two million companies are using ARIBA, which is the world's largest market place for business-to-business transactions via the Internet. The efficiency in the use of this software is based on the sharing of the platform for which each participant pays only the usage time. On the other hand, the service provider can invest in a fast and efficient technology through a number of users and therefore make great profit. This new business model of sharing computer facilities has been generated using cloud technology.

142 Wirtz, B.: Business Model Management – Design, Instrumente, Erfolgsfaktoren von Geschäftsmodellen. 3rd edition, Springer, Gabler, Wiesbaden, 2013, p. 133.

5.1.1.3. Financial Perspective

In terms of financial perspective, the issue is the value that can be generated with the business model.

In terms of revenues, it revolves around the question of whether, and to what extent, are the customers willing to pay for the services of the business model. From the customer's point of view, there is a fixed-price tendency, so the risk is transferred to service provider. In innovative business models, however, the service provider does not have any experience with development costs, and billing therefore tends to be resource-related. While material goods can be calculated more reliably, the degree of uncertainty in services is significantly higher.

Regarding the costs, a reliable calculation is possible if resources, activities, and cooperation necessary for the business model have been configured. The increase of automation generally leads to economics of scale. Synergies could be created if activities for multiple services – such as marketing – are merged, which is called economics of scope.

Basically, business models can be cost-driven or value-driven. *Cost-driven business models* focus on cost minimization, whenever possible. Examples of a cost-driven business model are budget airlines Southwest Airlines and Ryanair.

Value-driven business models place the focus on value creation. Value creation is based on customer requirements. In the consumer market, customer benefits relate to product characteristics, especially through marketing. Benefits especially include luxury products, for example, sports car brands like Ferrari or Lamborghini that also promise a personal status to the owners of such vehicles.[143]

The market-oriented view of a value-driven business model is not followed in this book. The focus is on innovative production processes. The increase in value added for the company is an innovation in production processes in the context of smart production and related supply chain processes. Although customer satisfaction is a prerequisite for the products success and thus the business model success, the measurement of innovation success is value added for the company.

In addition to technical or organizational innovation, it must always be taken into consideration which customer expectations can be fulfiled and whether an appropriate return on both sides – buyers' and suppliers' – founded the attractiveness of the innovation.

143 Konter, M.: Business Model Innovation. Entwicklung und Controlling innovativer Geschäftsmodelle. Diplomica Verlag, Hamburg, 2013, p. 29, and Ehret, M., Kashyap, V., Wirtz, J.: Business Models – Exploring value drivers and the role of marketing, In: Industrial Marketing Management, volume 42, issue 5, 2013, p. 713-743.

5.1.2. Business Model Design

Business model design is a process that creates, actualizes or reorganizes business models. Nowadays, the challenge is to design a successful and sustainable business model. The scope of tasks is similar to design thinking and focuses on business engineering as well as business reengineering. Business process reengineering includes radical redesign of core business processes. This section provides analysis of the main phases: *idea finding, idea valuation, prototyping, and decision*.

5.1.2.1. Idea Finding

Idea finding cannot happen directly by a standardized way of thinking; it consists of creative thinking processes. Opportunities for idea finding are observation and experience, searching (for example, in scientific journals, the Internet), expert interviews, exchanges of ideas (in communities), and at conferences.

The basic methods are creative techniques: brainstorming, morphology, the 6-3-5 method, and mind mapping.

a) Brainstorming

With the help of a moderator, many ideas are collected and recorded in the shortest possible time. The focus is on spontaneity. The introduction of crazy or fantastic ideas is allowed. Ideally, the participants write their ideas, send them to each other and develop them further. Criticizing ideas is not allowed, in order to prevent an interruption of the creative process. Advantages of this method are the following: *brainstorming is carried out without great expense, employee motivation is high, as they are involved in the brainstorming process, there is mutual inspiration, many ideas in a short time and the possibility to obtain unusual ideas.* However, there are disadvantages; many ideas ultimately remain unnoticed; it is not a structured method and brainstorming is unsuitable for complex problems. This method is therefore only suitable for simple problems, such as finding a name or searching for slogans.

Example:

a) What part of city life do I find interesting? The participants of a brainstorming session share their ideas: population – parties – activities – age structure – jobs – City Council – business – religions – nationalities – Parliament – etc.

b) Clustering – The collected ideas are structured. Individual ideas or suggested solutions are summarized under focus terms: Politics, Economy, Leisure, Social Issues, Education.

b) Morphology

Morphological analysis is a creative heuristic method for a full grasp of complex problem areas and consideration of all possible solutions without prejudice. The problem analysis and the question can be generalized. Morphological analysis uses the morphological box, which is a multidimensional matrix.

Determining characteristics, attributes, factors, parameters, dimensions are listed in a matrix column. It should be ensured that the characteristics are independent and operational. All the possible values of each characteristic are then written on the right. The result is a matrix in which each combination of characteristic values is a theoretically possible solution. However, this method cannot produce radical innovations, because the space of possible properties by the selected matrix dimensions is limited by the outset.[144]

The procedure involves the following five steps:

1. Definition and analysis of the problem.
2. Determination of characteristics.
3. Determination of possible characteristic values.
4. Definition of the combinations.
5. Alternative assessment and selection of solutions.

c) The 6-3-5 Method

The 6-3-5 method stands for: *6 participants develop 3 ideas and write them on a paper which will be passed 5 times.* All participants will receive each other's ideas and have the task of developing the 3 initial ideas. A disadvantage is the rigid procedure that restricts creativity. This method is only suitable for small and medium-sized problems.

For example: Each of the 6 participants receives a piece of paper with 3 x 6 squares. In the first round, each participant writes down 3 ideas. After a set period of time, the paper is passed on. Then the participants pick up the ideas of brainstorming leaders and develop them further. Ideally, after 6 rounds, 108 ideas are created.

144 Mittelmann, A.: Morphologischer Kasten. In: Wissensmanagement/Methoden und Werkzeuge. URL: http://www.artm-friends.at/am/km/WM-Methoden/WM-Methoden-285.htm.

d) Mind Mapping

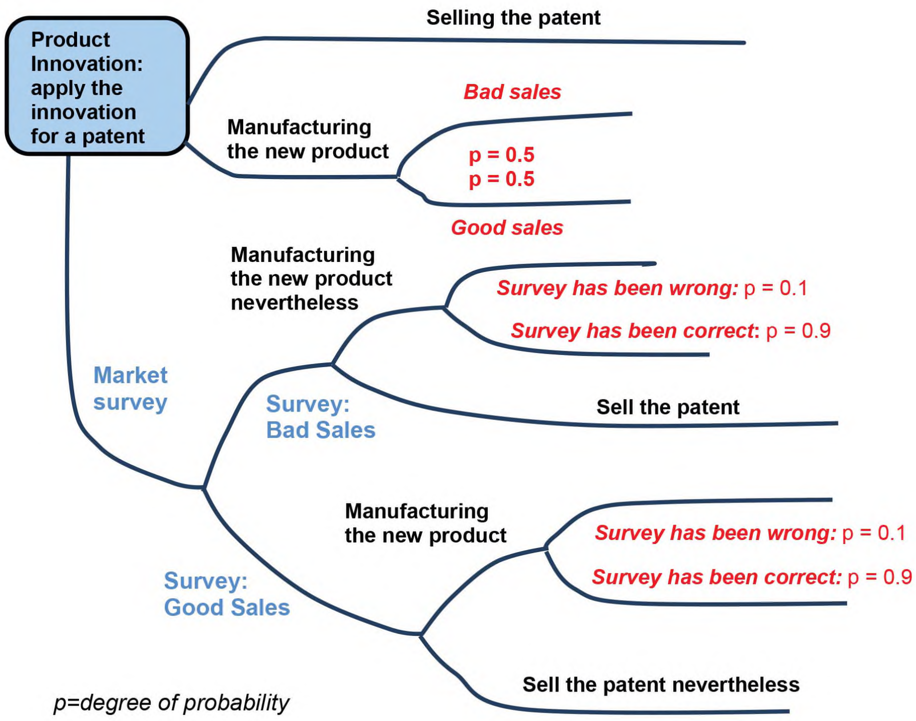
Strategic and unstructured problems can be structured using the mind mapping approach. Structuring is done by *designing a tree in which a problem is gradually broken down from general to specific.* The problem is dissected here using a tree structure.

An example of a product innovation scenario is provided below:

A company has developed a product innovation which is a new product. The rights to the innovation patent could be sold. On the other hand, the product could be manufactured, which needs an investment in new production facility. The third opinion is to engage a market research institute that results in the engagement cost, but increases the reliability of the company's decision.

The possible alternatives are demonstrated in the following figure.

Figure 28: Mind Mapping for Product Innovation



The probability of occurrence of all decision alternatives has to be calculated using the theory of probability. It is interesting that many computer applications support the mind mapping process. One of these solutions is called “MindManager”. The advantages of using such a tool are listed in the marketing information as follows:[145]

- *MindManager supports the creative brainstorming process that helps one's own thinking and understanding and facilitates decision-making.*
- *MindManager increases productivity of each individual and the team. The visual and dynamic way of work meetings, presentations, and personal task management can be made more transparent and faster. Numerous interfaces of common Microsoft applications allow MindManager to have a central cockpit in which distributed information are brought together in a time-saving manner.*
- *MindManager simplifies the information and knowledge management in teams and companies. Distributed information and valuable knowledge are easily put into mind maps, understood in new contexts and are always centered and up to date. Therefore, understanding and communication are significantly improved.*

Regarding the scenario of business model development and optimization using the supporting tools, the mind mapping method seems to be the best choice.

5.1.2.2. Idea Evaluation

After the development of various options in the context of ideas, a feasibility study must be carried out. In the context of innovation, a macro-analysis of the industry environment and micro-analysis, which is the industry itself, must be performed.

The macro-environment of a business model is characterized by the following factors: *technology, regulations, economy, ecology, and society*. The political, legal, and economic environment provide the framework. It includes the economic progress of a country which promotes innovative business models; this could also be a restriction.

145 Mindjet GmbH, Alzenau, URL: https://www.mindjet.com/de/produkte.

Another important factor is ecology. It relates on the one hand to the available resources, and on the other hand to the legal framework through the existing environmental law. A suitable example is insufficient supply of charging stations for vehicles equipped with an electric drive for greater distances.[146]

While general factors will be examined through macro-analysis, micro-analysis relates to the sector market volume and market potential. With the focus on the market potential, the possible innovation success will be investigated. Porter's situation analysis refers to the power of customers and the suppliers (buyers' market, sellers' market) and the possible threat of substitute products and potential competitors. The most popular model is Porter's industry structure analysis. A comprehensive and systematic review of all competition-related factors can be carried out in the product innovation environment. If the opportunities and risks are identified, the business model will be adjusted if necessary.[147]

5.1.2.3. Prototyping

Prototyping of a business model leads to the *harmonization of business model components.* Contradictions can be identified and eliminated. The objective is to calculate different variants of the business model considering the environmental influence. An analogy is the well-known stress testing, in which the reaction of the model to changing conditions is calculated to find out whether the model is resistant.[148]

Prototyping involves the following phases:[149]

- **Hypothesizing**. Relations are defined and formulated in a hypothesis that the relations between the components can be measured in the model. Thus, in view of a new product – a sports car – the components of the model might be marketing, functionality of the product, expectations and requirements of the customer and customer behavior.

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146 The national platform for electric mobility with working group III for charging infrastructure and grid integration was detected in the 2015 annual experts' report: *To achieve a successful market run-up in Germany, the political players together with the manufacturers of vehicles and the potential operators and investors in charging infrastructure have to increase the attractiveness of electro-mobility and make it a priority. The existing approaches to charging infrastructure are heterogeneous and a vehicle in an accelerated ramp is no longer sufficient. Simplicity of use and payment and unrestricted access to charging infrastructure in the public space needs to be improved*. In: Ladeinfrastruktur für Elektorfahrzeuge in Deutschland, 2015.

147 Porter, M. E.: Wettbewerbsstrategie: Methoden zur Analyse von Branchen und Konkurrenten. 12th edition. Campus Frankfurt/New York, 2013, p. 37.

148 Stress Test denotes a test measuring of responses to stress, such as increased stress and strain of physical or psychological nature. A stress test is a risk management tool in the financial industry. A distinction is made between micro-stress tests, which are used by financial institutions, or by supervision institutes such as BAFIN (*Bundesanstalt für Finanzdienstleistungsaufsicht)* of the European Central Bank (ECB).

149 Konter, M., 2013, p. 138.

- **Test design.** Definition of test cases carried out in the context of prototyping.
- **Testing.** Performing simulations relating to changing variables of the test model.
- **Analysis.** Use of IT applications to summarize the results based on case studies.
- **Knowledge Management.** Summary of each simulation and the related hypothesis, test cases, results, and consequent actions.

Konter, M. provided an illustrative example:[150]

> *Product innovation in high-quality sports cars cannot be linked to cost leadership strategy, otherwise the promise of a high-quality luxury vehicle would be difficult to accept by the customer. Customers in the middle-income brackets generally cannot pay for such a product and therefore do not count into the target group of this product. In this regard, a high-priced differentiation strategy is useful.*

The results of prototyping are solving problems and leading to the decision on business model design. The decision process is accompanied by other strategic analyzes, for example, benchmarking, SWOT analysis and business process outsourcing, which have been studied in this book in section 4.2.2.

Business model development results are the basis for continuous model improvement with process optimization. If deviations in the model occur in the context of analysis of the cause and localization of the problem, further analysis of the business model will be performed.

5.2. Controlling the Business Model Innovation – Value Production

With the market launch of new technologies in the fourth industrial revolution and the resulting availability of integrated ERP systems linked globally via the Internet technology of the 21^{st} century, new perspectives have opened for production controlling. The requirements for powerful process information systems for controlling purposes are fulfilled by the outstanding processing speed of in-memory computing.

Many industrial companies cannot record the high volume of logistics processes online in the IT system. The update must be made asynchronously the

150 Ibid, p. 41.

following night. This time lag between the data and the production and logistic processes makes real-time production controlling impossible.

A production controlling system must be able to represent modern, complex, and globally networked production structures. Only with the control of such structures is the production controlling effective and efficient. It is effective in terms of availability of the technology for providing current and decision-oriented information, and efficient in terms of data reliability.[151]

The impact of internal processes on the company's financial success has confronted the company's production area with the question: What is the potential contribution of a production process or a production model to corporate value?[152] By developing value drivers and value management, a company increases its value by cash flow and value added.

5.2.1. Cash Flow in the Production Value Management

Alfred Rappaport formulated in 1986: A company increases its value by achieving cash flow, which leads to interest payment higher than the expected cost of capital. In other words, cash flows must provide a higher return on capital than alternative investments.[153]

A value-oriented production generates sustainable cash flow. Cash flow is calculated on the basis of the payments from a production model and the related costs of the model. Value-based management is a sustainable process to be implemented in the company. Value orientation goes beyond the shareholder value approaches originally associated with these governance tools, as the increase in enterprise value also benefits other stakeholders of the company, such as the staff.

5.2.1.1. Defining Cash Flow

Free cash flow is defined by operating cash flow plus the cash flow from investing activities. With the proceeds of the free cash flow, companies can pay dividends or buy back shares. The free cash flow shows how much money is actually left for the company's shareholders. This indicator *cannot* be manipulated through accounting tricks in contrast to the balance sheet valuation by classic accounting rules.

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151 Bauer, J.: Produktions – Controlling und – Management mit SAP ERP. Effizientes Controlling, Logistik- und Kostenmanagement moderner Produktionssysteme. 4th Edition. Springer-Vieweg, Wiesbaden, 2012, p. 27.

152 Kaplan, R. S., Norton, D. P.: The Balanced Scorecard: Translating Strategy into Action, Harvard College, 1996, p. 341.

153 Rappaport, A.: Creating Shareholder Value: A Guide for Managers and Investors: The New Standard for Business Performance. 2nd edition, Free Press, New York, 1998, p. 32.

The operating cash flow is defined as follows:

$$CF_{op} = rev_{pl.PRM} - C_{pl,PRM} - dpr_{PRM,y}$$

Legend:

$CF_{op} = Cash\ Flow\ from\ operating\ actions$

$PRM = Production\ Model$

$c_{pl.PRM} = Cost_{pl.PRM}$

$rev_{pl.PRM} = Revenue_{plan.PRM}$

$dpr_{PRM,y} = Amortization\ (depreciation)_{PRM,year}$

Cash flow is the key indicator for calculating the value of the production process, production, and results from cross-linking of alternative production possibilities of that business model.

Therefore, this concept is elaborated further in the following chapters describing smart production.

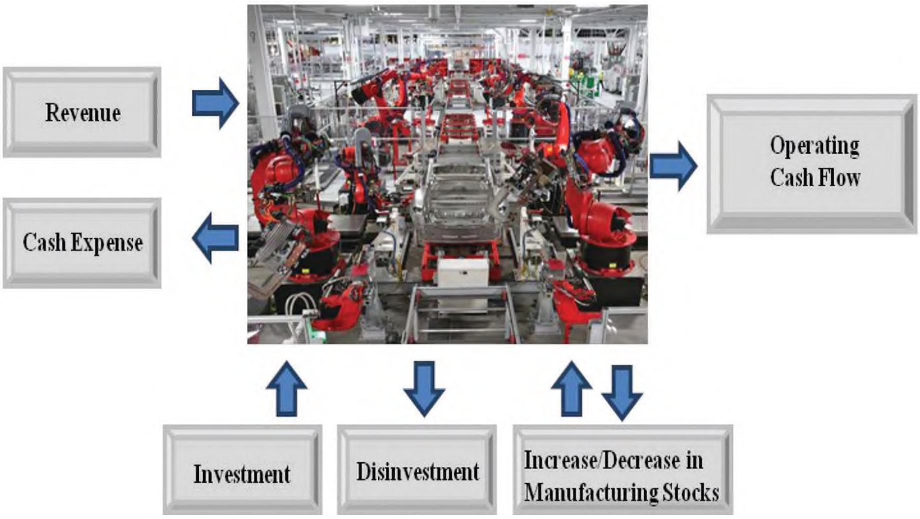
5.2.1.2. The Value Balance of the Production Model

Value balance is the basis for calculating operational production cash flow. On the one hand, there is the focus on resource consumption in the production process, and on the other hand, production result must be valuated with regard to its contribution in operating cash flow.

Value added is generated from the revenues from external customers. The reduction in product costs adds value if the products can be sold at the same price. This includes production maintenance costs, but also payments for production services from external partners and, where appropriate, licenses.

An increase in value represents investment in the production process and the production model respectively. Disinvestments imply the opposite. The same applies to the expansion and reduction of manufacturing stocks. This refers to the value of the production model balance sheet. On the other hand, the objective of the lowest possible material stocks must be evident, since they adversely affect the dynamics of the production system and represent capital tie-up.

Figure 29: Value Balance Production Process



Source: Modified from Bauer, J., 2012, p. 344.

5.2.2. Production Value Added

An interesting view on value-added products is obtained by analyzing the share of farmers in the USA. It is detected that the share of one-dollar spending in shopping food decreased from 46% in 1913 to less than 20% in 2006.[154] The reason is changed consumers' behavior. People are buying "ready to eat" and "ready to cook" products, while the farmers are selling raw vegetables. The production of value-added products, which means value-added processing, offers the farmers a larger share of the food dollars. Value-added products from the point of view of the farmers are – for example – producing and selling jam instead of strawberries. Another example is addition of services like advertising and consulting to the products that provide added value to the customers.

Production value added depends on production excellence and the possibility of cash flow accumulation in the present and future time.

154 USDA Economic Research Service. In: https://extension.umd.edu/agmarketing/value-added-products.

5.2.2.1. Production Excellence

Production excellence focuses primarily on agile production and optimized operational processes. The basis for production value added is production excellence, which is defined by the BMW group as follows:

> *At BMW Manufacturing, continuous improvement is something our team takes very seriously. We believe it's a key difference that distinguishes BMW from the competition — and flexibility throughout the production process is an essential factor in improving productivity and efficiency. By implementing the Value-Added Production System (VPS), BMW is adding maximum value while minimizing waste in all production and support area processes. From supplier to dealer, from product development to production itself, VPS is helping ensure total customer satisfaction in a timely, efficient, quality-focused manner. Since its global launch within the BMW Group in 2006, VPS has played a vital role in continuous improvement. Here at BMW's only North American manufacturing facility, VPS principles are being applied and assessed every day — and the results have been impressive. The impact of the Process Excellence / Continuous Improvement initiative has been a 25% improvement of the operating cost structure, totaling more $225 million. Because of this comprehensive approach, VPS activity has helped introduce new behaviors and guidelines from the top down, eliminating the need for costly additional support programs and projects.*[156]

The example shows that the basis for successful production models is set only with the cooperation of all production factors, especially the employees. Qualification and motivation were mentioned in section 4.2.3.2. Since the focus in this book is on the financial aspect, the importance of this aspect will not be developed further.

5.2.2.2. Discounted Cash Flow – Equity Method

Discounted cash flow is the concept that production value calculation lies in the accumulation of the forecasted cash flows over the forecast period and the realized cash flows over the reporting period. The amounts of charges are mentioned in the previous section. The calculated cash flow is discounted over the period and results in discounted cash flow.

For the calculation of discounted cash flow, direct and indirect detection can be applied. *The direct method, i.e. the equity method*, will be explained in this section.

155 BMW Group, plant Spartanburg (USA). In: https://www.bmwusfactory.com/manufacturing/building-a-better-bmw/value-added-production-system/

The present value of incoming cash flows will be calculated. Cash flows for the equity method include dividends, withdrawals, repayments of capital, and corporate tax credits. In this book, the calculation of operating cash flow is based on the forecast of production model revenues and costs. This concept is only possible with availability of a smart production landscape and an IT solution, providing real-time production data in real time, thus allowing forecasting in a short time.

It is assumed in the equity method that all surpluses are distributed, which means no reinvestment. Creditors' claims are also fulfilled.

The discounted cash flow method (DCF), unlike the discounted cash flow approach, is a process in which predominantly future surplus, referred to as cash flow, including interest on the company's debt, are discounted using the interest rate of weighted average cost of capital.

Using the direct DCF determination (equity method), discount rate determination is done differently. With the equity method, only cash flows (net receipts or distributions) are discounted to equity holders (owners). The cash flows to be discounted include dividends, withdrawals, capital repayments and corporate tax credits. It is therefore assumed that all surpluses have been distributed and the claims of the lenders have already been satisfied.

The business model value is calculated as follows:

$$BMV_{EQM} = \sum_{i=1}^{n} \frac{CF_t^{EC}}{(1+i)^t} + \frac{RV_n}{(1+i)^t}$$

$BMV_{EQM} = Business\ Model\ Value_{Equity\ Method}$

$CF_t^{EC} = Cash\ Flow_{time\ period}^{Market\ Value\ of\ Entity\ Capital}$

$(1+i)^t = (1 + interes\ rate)^{time\ period}$

$RV_n = Residual\ Value_{number\ of\ periods}$

Future projections of cash flows and determination of the required rate are mentioned in literature as difficult and inaccurate. However, the key advantage lies in the ability of a smart factory with an IT solution called in-memory computing: the availability of current production key figures in real time reduces the risk of inaccurate data forecasting, because it can be constantly adapted to the current progress. Through the establishment of a smart factory, alternative production options can be used quickly.

Technical aspects of smart production and in-memory computing were discussed in the previous chapters. This discussion takes place in view of the current development of the new SAP S/4 HANA[156] IT system.

5.2.2.3. Discounted Cash Flow – Entity Method

In the previous approach, debts are first subtracted from the sum of investments and stock-based cash flow is discounted. With this approach, the entire investment is discounted and the debt is then subtracted. Due to discounting, the entire investment, the weighted average of capital cost, is used as interest rate:

$$BMV_{ENM} = \sum_{i=1}^{n} \frac{CF_t^{WACC}}{(1+WACC)^t} + \frac{RV_n}{(1+i)^t} - DEBT$$

$$BMV_{ENM} = Business\ Model\ Value_{Entity\ Method}$$

$$CF_t^{WACC} = Cash\ Flow_{time\ period}^{Weighted\ Average\ of\ Capital\ Cost}$$

$$(1+i)^t = (1+interest\ rate)^{time\ period}$$

$$RV_n = Residual\ Value_{number\ of\ periods}$$

$$DEBT = Debt\ Capital$$

$$WACC = i_{Equity} * \frac{Equity}{Overall\ Capital} + i_{debt} * (1-tax) * \frac{Debt}{Overall\ Capital}$$

$$tax = tax\ rate$$

The WACC takes into account the possibility of deducting interest on borrowings.

Both methods (Equity and Entity Discounted Cash Flow) are based on a future constant capital structure. A long-term forecast of the future capital structure is difficult. One of the solutions is the so-called *adjusted present value (APV).* Initially, in the APV method, market value is calculated on the basis of fictitious full self-financing of the business model. Therefore, cash flows are discounted at equity cost. Tax savings for of debt interest deductibility are added in the next step. The market value of total capital is obtained from this sum. The market value of debt is subtracted in the third step. The market value of debt is calculated from the quoted price of fixed-income bonds.

156 Compare to Chapter 2. SAP S/4 HANA: Accelerate real-time responsiveness with SAP HANA in-memory database services. Process high-speed transactions while analyzing fresh data on the fly to take action in the moment and manage large database volumes cost-effectively using multitenant database containers and dynamic tiering across multi-tier storage. https://hana.sap.com/abouthana.html.

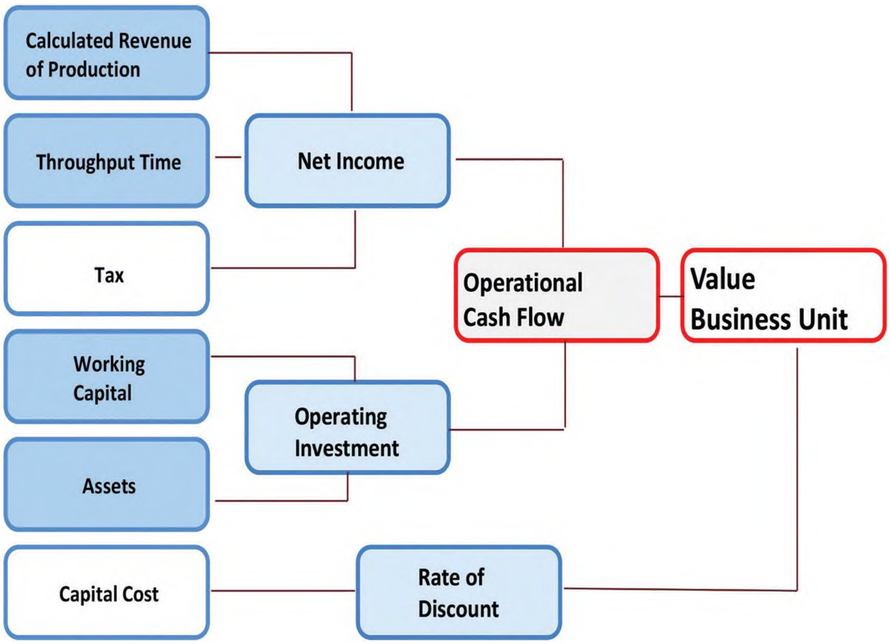
The established methods of company value calculation are based on average values and constant values and the associated disadvantage. The availability of real-time information, not only from production, but also from financial supply chain management (FSCM) can help reduce these drawbacks. SAP Financial Supply Chain Management (FIN-FSCM) optimizes the financial and information flows within the company and between business partners. SAP Financial Supply Chain Management contains the following components: collection management, dispute management, and market risk analyzer.

5.2.3. Value Drivers and Value Management

The cash flow is affected by the so-called "value drivers". The term value drivers derives from the discussion of the shareholder value concept which, in the first place, generally refers to *all factors and parameters whose growth increases company value for shareholders.* Value management is rooted in the concept of value and its aim is to reconcile all the stakeholders' views balancing between needs and resources.

Macro-value drivers are collected by farmers according to Rappaport in the figure below.

Figure 30: Macro Value Driver



Source: Bauer, J., 2012, p. 201.

Bauer notes that taxes and capital costs do not affect the value of production. This view is not followed in this book with its focus on flexible business models in smart production. The flexibility of networked production structures through a relocation of the production locations generates a potential tax advantage, which is a decision criterion. Production process distribution to internal and external partners also influences capital requirement.[157]

5.3. Economic Value Added and Return on Capital Employed

Economic value added (EVA)[158] is a well-known concept established in financial theory in general. It represents real profit *versus* paper profit, i.e. it is the after-tax cash flow generated by a business minus the cost of the capital deployed to generate that cash flow. EVA underlines shareholder and company value and is adopted as a measure for business planning and performance monitoring.

EVA motivates managers to create shareholder value, still a very important target of leading companies' strategies. Shareholders invest to gain return on engaged capital. Thus, return on capital employed (ROCE) is one of the key profitability indicators that measures how efficiently a company is using its capital. It is calculated as a relation between earnings before interest and tax (EBIT) and capital employed. ROCE is commonly used by investors to determine whether a company is suitable to invest or not.

$$\mathrm{ROCE} = \frac{\mathrm{EBIT}}{\text{capital employed}}$$

A higher ROCE implies a more economical use of capital; ROCE should be higher than the capital cost. Both EVA and ROCE are efficiency indicators and of interest to controllers for measuring profitability and overall company success.

In the concept of business-oriented production controlling, ROCE is used as a measure of production efficiency taking into account all success factors which contribute on return of employed capital for production cycle purposes.

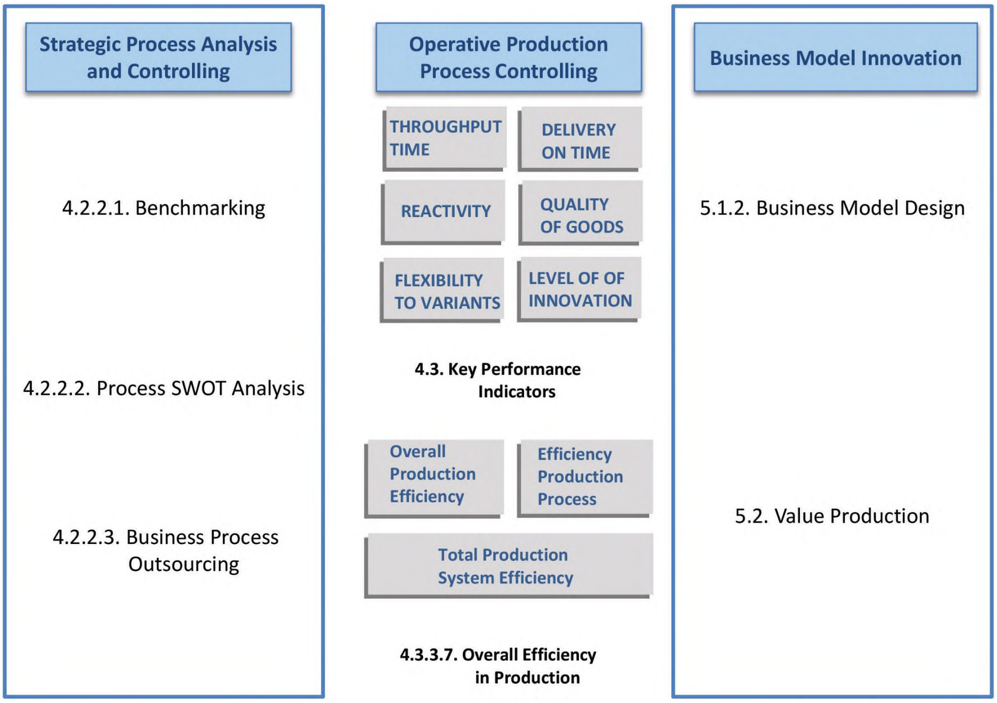
Business-oriented production controlling is focused on three points of view:

- **Strategic business model controlling** based on strategic process controlling
- **Operational business model controlling** based on value business model and business balanced scorecard
- **Business model innovation controlling** based on value driver and cash flow.

157 Bauer, J., op. cit., p. 347.

158 EVA is a registered trademark of Stern Steward&Company and has been implemented in numerous companies to motivate managers to create shareholder value. If EVA is positive, the company creates shareholder wealth. Negative EVA indicates that shareholder value is destroyed.

Figure 31: Production Controlling in the Digital Age



The essence is reflected in the conclusion that the tools for business model-oriented production controlling have been developed on activity-based costing. This refers to process analysis and process controlling. The field of application of production controlling that emerged with the fourth industrial revolution is a new field of research. It will be a further development of supply chain controlling.

A concluding, interesting and pioneering compilation of key figure management in business model-oriented production controlling can be found in the calculation of ROCE in Werner[159] The ROCE calculation in this textbook is modified in accordance with success factors in the new digital environment.

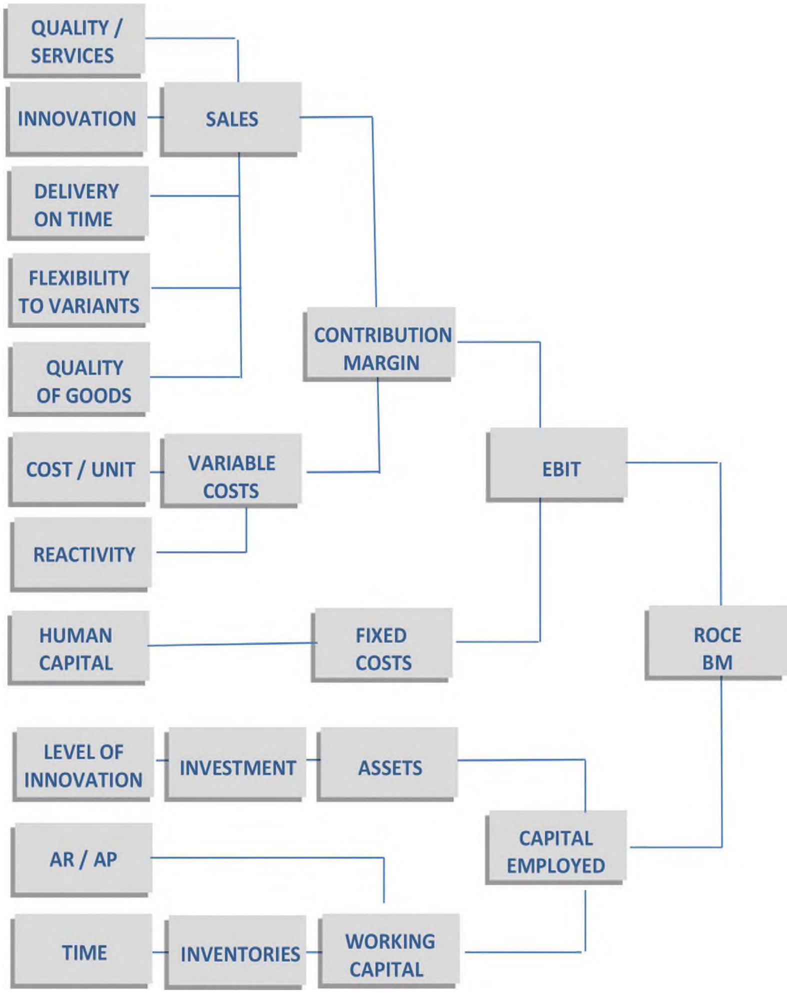
Business model success and the corresponding revenues significantly depend on the quality of service. In times of high competition and comparable products by different vendors, quality of service is the key competitive factor. Also, the possibility of different variants based on production costs for mass production influences the purchase decision. The same applies to the possibility of sparking customer interest in innovative products.

159 Werner, H.: Kompakt Edition: Supply Chain Controlling. Grundlagen, Performance-Messung und Handlungsempfehlungen. Springer Gabler, Wiesbaden, 2014.

The minimization of variable costs is a key task in smart production. In a networked production, in addition to the availability of production capacity, optimal allocation of production orders to resources is the basis for best practice.

When a business model can be calculated on the basis of success factors shown in the following figure in real time, it leads to a decisive competitive advantage.

Figure 32: Return on Capital Employed Model



The controlling methodology in the combination of process-oriented production controlling, supply chain controlling, and corporate controlling supported by IT applications will successfully meet the challenge of the digital era.

SUMMARY

Increasing market dynamics and the associated competitive pressure encourage the development of products and processes. However, innovations no longer guarantee the survival and growth of a company; thus, the current business model must be scrutinized to identify new ways of achieving the company's goals. Business model-oriented thinking and business model-oriented controlling have a central objective: innovation drive.

There is a wide range of innovation perspectives connected with market conditions and one cannot determine a single specific perspective decisive for innovation success. Combined technical, organizational, and product-specific functions create innovation. In addition to technical or organizational innovation, it must always be taken into consideration which customer expectations can be fulfilled and whether an appropriate return on both sides – buyers' and suppliers' – founded the attractiveness of the innovation. Business model design is the process that creates, actualizes or reorganizes business models and the main phases are: idea finding, idea evaluation, prototyping, and decision-making.

A production controlling system must be able to represent modern, complex, and globally networked production structures. Only with the control of such structures is the production controlling effective and efficient. It is efficient in terms of data reliability and effective in terms of availability of the technology for providing current and decision-oriented information. A value-oriented production generates sustainable cash flow that is advanced in comparison with the traditional key figures of cost accounting. A key figure is controlling-oriented, because it shows whether a company is in the position to make a short-term investment in product- and process innovation. The value balance approach follows the business model orientation. This view differs from the purely technical production and cost-oriented view since the production process is understood as a business model.

The essence of production controlling is analysis of the production business. Production processes are not only examined in terms of their technical optimization. It is questionable whether market requirements, and thus customers' needs, are optimally fulfilled by the organization of the processes. These are the instruments of operative production controlling.

Production evaluation as a business is carried out using the methods of financial control of a value-adapted company. This means that financial return is not the only factor considered; indicators such as flexibility and innovation play a major role. The key figure in business model oriented production controlling is presented as a ROCE model.

QUESTIONS

1. Describe the relationship between a business model and an innovation and explain its perspectives.
2. What is business model design? Describe its main phases.
3. What is the potential contribution of the production model to corporate value?
4. Which are the value drivers (macro and micro) of production controlling?

Exercises

1 Calculation of Overall Equipment Effectiveness

The following production line data are provided:

Shift Length	8 hours (480 minutes)
Breaks	One break of about 20 minutes and one break of about 40 minutes
Downtime	30 minutes
Ideal Cycle Time	1 second
Total quantity	20,000 pcs.
Scrap	500 pcs.

Calculate the overall equipment effectiveness.

Solution

$$QR = \frac{19500}{20000} = 0.975$$

$$PA = \frac{390}{420} = 0.9286$$

Run Time = Shift Length – Breaks – Downtime

Planned Production Time = Shift Length – Break

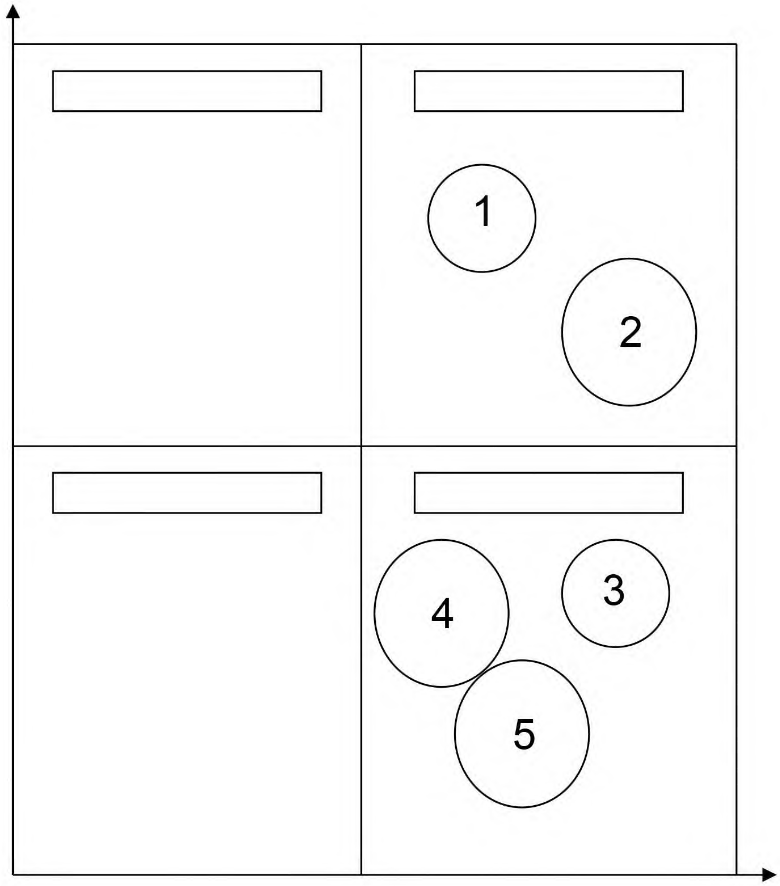
$$EFF = \frac{1\ second * 20000}{390 * 60\ seconds} = 0.8547$$

OEE = QR * PA * EFF = 0.975 * 0.9286 * 0.8547 = 0.7738

The overall equipment effectiveness is 77.4 %

2 Evaluation of a Portfolio Matrix Scenario

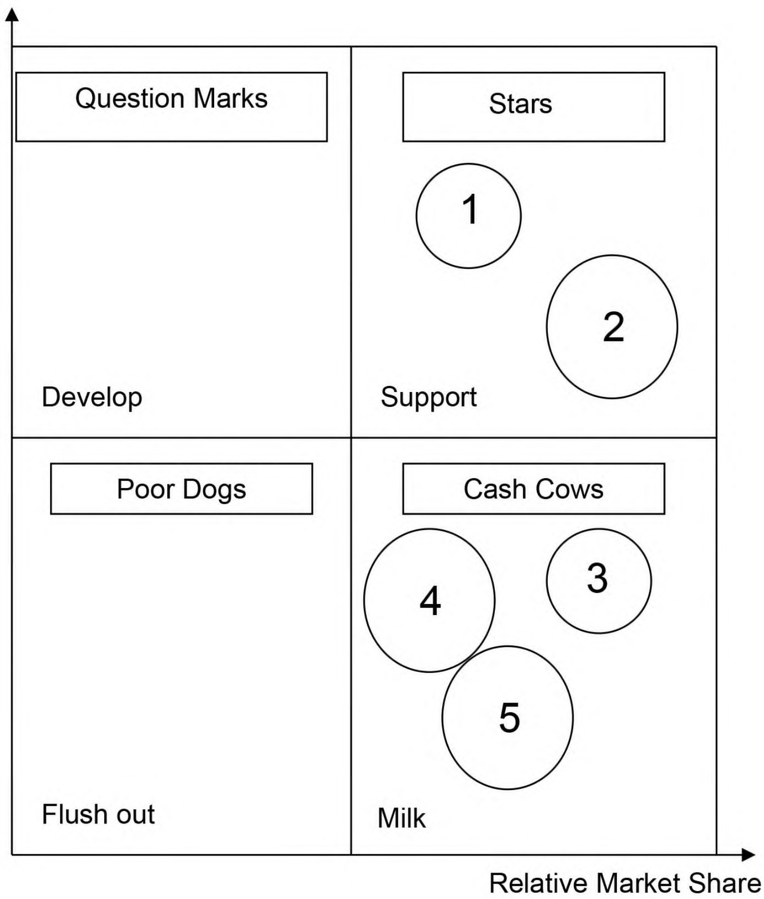
The production program of an enterprise is represented by the following portfolio:



2.1 Complete the portfolio.

2.2 Evaluate the situation and make proposals.

Solution



The enterprise does not have new products. The developments of such new products are missing. For the medium- and long-time survival of the enterprise, this will become a problem.

Cash cows are available. As long as the cash cows do not become poor dogs, the profit of the cash cows should be used to finance the development of new products.

The enterprise should make a decision on sustainable product development.

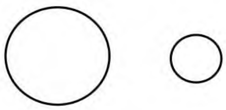
3 Positioning Products in a Portfolio Matrix

An enterprise collected the following data:

Product	Average market growth in the last 3 years (in %)	Own Market-share (in %)	Market share of the strongest competitor (in %)	Product revenue share in total revenue (in %)	Contribution margin of the product (in mil.)
A	10	15	10	12	- 1
B	15	5	15	8	- 1
C	15	3	15	5	+ 10
D	0	20	10	30	+ 2
E	- 10	30	15	20	- 8
F	- 20	5	10	20	- 2
G	10	8	40	5	- 2

a)

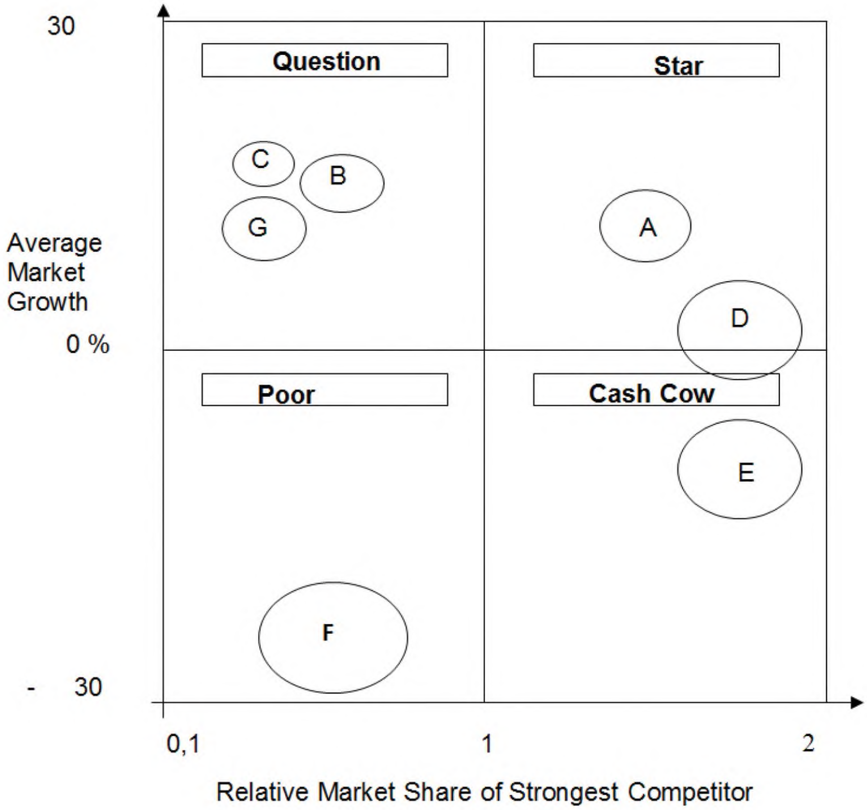
Calculate the relative market share based on the own market share and the market share of the strongest competitor. Position the products in the 4-Field-Portfolio Matrix and mark the share of the product with circle size.



Solution

Relative market share of the products (in %)

Product	Relative market share
A	1.50
B	0.33
C	0.20
D	2.00
E	2.00
F	0.50
G	0.20



b)

Name the standard strategies for products A to F.

What are the reasons against the standard strategy for product F?

Do you see a problem in using the portfolio method?

Do you see a benefit from using portfolio as the controlling method?

Solution

Product A:	Investment strategy (transfer it to start)
Product B and C:	Investment strategy; if unsuccessful, disinvestment.
Product D:	Depending on the position in the life cycle of the product, investment or disinvestment.
Product E:	Absorption
Product F:	Disinvestment because of low chances of success.

A large portion of the total revenue and therefore a high contribution margin of this product are arguments against the use of the standard strategy for product F.

A problem within the portfolio method is the use of fixed standard strategies without a differentiated strategy recommendation as well as the focus on two variables.

For decisions on investment and finance, the method delivers a clear decision-making basis. The impact on future cash flows can be estimated.

4 Branch & Bound Method for Optimized Production Order Sequence

a) What are the prerequisites in the production area for the use of the Branch & Bound method for optimized production order sequence?

Solution

Using the Branch & Bound method, the production order sequence which causes the minimum of setup costs is used. The prerequisites are:

- Setup costs and setup times are known.
- Production equipment flexibility. It must be possible to produce different products on the same equipment.
- Flexibility in the time schedule of production orders, which means production to stock.

b) Calculate the order sequence with minimum setup costs.

The following matrix with setup costs is given:

From j to i	**1**	**2**	**3**	**4**	**5**
1	X	3	X	7	X
2	3	X	5	10	8
3	X	2	X	14	9
4	7	X	X	X	4
5	6	8	6	4	X

Calculate the optimized order sequence using the Branch & Bound method.

Solution

From j to i	**1**	**2**	**3**	**4**	**5**
1	X	1	X	3	X
2	0	X	0	6	4
3	X	0	X	10	5
4	4	X	X	X	0
5	3	6	1	0	X

From j to i	**1**	**2**	**3**	**4**	**5**
1	X	0	X	2	X
2	0	X	0	6	4
3	X	0	X	10	5
4	4	X	X	X	0
5	3	6	1	0	X

From j to i	1	2	3	4	5
1	X	2+0=2	X	2	X
		0			
2	0+4=4	X	0+1=1	6	4
	0		0		
3	X	5+0=5	X	10	5
		0			
4	4	X	X	X	4+4=8
					0
5	3	6	1	1+2=3	X
				0	

From j to i	1	2	3	4
1	X	0	X	2
2	0	X	0	6
3	X	0	X	10
5	3	6	1	**X !**

From j to i	1	2	3	4
1	X	0	X	0
2	0	X	0	4
3	X	0	X	8
5	2	5	0	X

From j to i	**1**	**2**	**3**	**4**
1	X	0+0=0	X	0+4=4
		0		0
2	0+2=2	X	0+0=0	4
	0		0	
3	X	8+0=8	X	8
		0		
5	2	5	2+0=0	X
			0	

Optimized order sequence:
order number {4 → 5 → 3 → 2 → 1 ..... → ..... 4 .....}

5 Throughput Time in Production

At a workplace in the production line, the following throughput and processing time has been measured for 5 production orders:

Order	Throughput Time	Processing Time
1	10	2
2	7	3
3	15	5
4	2	1

a) **Calculate the simple and weighted average throughput time**

Solution

Simple average throughput time:

(10 + 7 + 15 + 2) / 4 = 8.5 days

Weighted average throughput time:

(10 * 2 + 7 * 3 + 15 * 5 + 2 * 1) / (2 + 3 + 5 + 1) = 10.7 days

b) Which conclusions do you draw from the results of the previous exercise?

The weighted average throughput time is significantly higher than the simple average throughput time. This is the case when a production order with a lower production volume is brought forward.

While calculating the weighted average throughput-time, it can be detected whether processing time will be increased out of proportion or less than proportional. The reason is in the setup time. If the setup time has a high proportion of the total throughput time, the processing time increases disproportionately only with increasing order volume.

6 Free Cash Flow

The following plan data (million EUR) are known:

Year	**2019**	**2020**	**2021**	**2022**
+ Net Annual Income	125	90	116	113
+ Interest Expense	20	30	20	10
+ Changes in Provisions	15	5	10	10
- Changes in Receivables	18	17	15	0
+ Amortization (Depreciation)	30	30	25	25
+ Changes in Liabilities to Vendors	34	13	15	0
- Investment in Depreciation Amount	30	30	25	25
Total Cash Flow				
- Tax Saving (interest expense * 0.3)				
Free Cash Flow (FCF)				

Every year, a replacement investment will be carried out with the depreciation amount.

A constant debit equity ratio of 150% is expected. Therefore, the share of equity capital is about 40% and the share of outside capital is about 60%.

Value added tax is about 30%. Personal tax of the shareholders will not be taken into account.

Loan capital interest rate is about 5%.

Demand of the equity capital profit rate is about 11%.

Market value of the outside capital is about 630 mil. EUR.

Operational deposit surplus is paid completely as a dividend.

Calculate the enterprise value using the shareholder value approach.
To calculate the cash flow, you can use the table provided in the exercise.

Formula

Weighted average of capital cost:

$$k_{WACC} = r_{EK} * share\_EK + r_{FK} * share\_FK * (1 - tax)$$

EK = equity capital   FK = external capital   r = interest rate

K = net present value (value of the enterprise)

Discount factor: $(1 + k_{WACC})^t$

Present value free cash flow $\frac{FCF}{(1 + k_{WACC})^t}$

Future value = the last value of free cash flow / WACC

Overall capital value = sum of the present values from
year 2019 to 2022 + perpetuity

Value of overall capital – market value of equity capital = present equity value (enterprise value).

Solution

Weighted Average of Capital Cost:

$\mathbf{k_{WACC}}$ = 0.11 * 0.4 + 0.05 * 0.6 (1 – 0.3) = 0.065 **= 6.5 %**

Year	**2019**	**2020**	**2021**	**2022**
+ Annual net income	125	90	116	113
+ Interest Expense	20	30	20	10
+ Changes in Provisions	15	5	10	10
- Changes in Receivables	18	17	15	0
+ Depreciation	30	30	25	25
+ Changes in Liabilities to Vendors	34	13	15	0
- Investment in Depreciation Amount	30	30	25	25
Total Cash Flow	**176**	**121**	**146**	**133**
- Tax Saving (interest expense * 0.3)	6	9	6	3
Free Cash Flow (FCF)	**170**	**112**	**140**	**130**

If it is expected that the last cash flow will continue forever, the perpetuity is:

Future value = 130 / 0.065 = **2,000**

Present free cash flow value: FCF / 1 + WACC =

170 / 1.065 = **159.62** 112 / (1.065 * 1.065) = 112 / 1.134 = **98.77**

140 / $(1.065)^3$ = 140 / 1.208 = **115.89** 130 / $(1.065)^4$ = 130 / 1.286 = **101.05**

Sum of the present values = 159.62 + 98.77 + 115.89 + 101.05 = **475.31**

Overall capital value = 475.31 + 2,000 = 2,475.31

Equity capital = **2,475. 31 – 630 = 1,845.31**

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II List of Tables

III List of Abbreviations

App	Business Application
ABC	Activity Based Costing
AV	Availability
BI	Business Intelligence
BMV	Business Model Value
BP	Business Process
BPM	Business Process Management
BPO	Business Process Optimization
BPS	Business Planning and Simulation
BSC	Balanced Scorecard
CF	Cash Flow
CIO	Chief Information Officer
CNC	Computerized Numeric Control
COE	Center of Excellence
COL	Commonwealth of Learning
CPFR	Cooperate Planning, Forecasting and Replenishment
CPS	Cyber Physical System
CRM	Customer Relationship Management
DEBT	Debt Capital
DNC	Distributed Numeric Control
EBIT	Earnings before Interest Tax
EFF	Effectiveness
EPEI	Every Part Every Interval
ERP	Enterprise Resource Planning
EUR	Euro
FSCM	Financial Supply Chain Management
FMEA	Failure Modes and Effects Analysis

GmbH	Gesellschaft mit beschränkter Haftung (Ltd.)
HANA	High Analytical Appliance
IAO	Institut für Arbeitswissenschaft und Organisation (Fraunhofer Institute)
ICG	International Controller Group
IRT	Internal Replacement Time
ISO	International Organization for Standardization
ICV	Internationaler Controller Verein
IOSB-INA	Institute for Optronics, System Technologies and Image Exploitation – Industrial Automation
IT	Information Technology
KPI	Key Performance Indicator
LPI	Lean Performance Index
MES	Manufacturing Execution System
MTO	Make to Order
OECD	Organization for Economic Co-Operation and Development
OEE	Overall Equipment Effectiveness
OEEI	Overall Equipment Effectiveness Index
OF	Overlapping Factor
OPC	Open Platform Communication
PAR	Performance Audit Report
PDCA	Plan Do Check Act
PED	Process Efficiency Degree
PIMS	Profit Impact of Market Strategy
PO	Production Order
PPS	Production Planning and Control (*Produktionsplanung und –steuerung*)
PSC	Process Scorecard
PWT	Proportion of Working Time

RFID	Radio Frequency Identification
QR	Quality Rate
ROI	Return on Investment
ROCE	Return on Capital Employed
RWTH	Rheinisch Westfälische Technische Hochschule
RV	Residual Value
R&D	Research & Development
SASD	Simple Average Schedule Deviation
SAP	Systems, Applications and Products in Data Processing
SCC	Supply Chain Council
SCM	Supply Chain Management
SE	Societas Europaea
SIT	Short Interval Technology
SMB	Small and Medium-Sized Business Enterprises
SWOT	Strengths Weaknesses Opportunities Threats
S/4HANA	SAP for HANA
TCP/IP	Transmission Control Protocol / Internet Protocol
TP	Throughput (Time)
TS	Technical Specification
US	United States (of America)
VSM	Value Stream Mapping
VSRS	Value Stream Ratio System
WASD	Weighted Average Schedule Deviation
WT	Working Time
XML	Extended Markup Language

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