TECHNISCHE UNIVERSITÄT WIEN
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Identification, characterization and visualization of indicators and reports for targeted decision support in manufacturing companies

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Wien, im Juli 2015

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Ich habe zur Kenntnis genommen, dass ich zur Drucklegung meiner Arbeit unter der Bezeichnung

Diplomarbeit

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Wien, im Juli 2015

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Christoph Höpfl

Abstract

As the title suggests already, the following thesis is about “Identification, characterization and visualization of indicators and reports for targeted decision support in manufacturing companies”.

The structure and the sequence of this thesis hold strictly to the assignment of tasks, which can be seen in the title.

Firstly, it is dealt with the question, why a reasonable structured information system is of immense importance of a modern manufacturing company. Furthermore, indicators are examined in more detail and the difference between the different types of indicators is illustrated. By this derivation important key figures or indicators are identified.

In the next section metrics are characterized. Indicators differ significantly among themselves in their use and composition. For this reason, *“Performance Measurement Systems”* are briefly discussed, which are composed of individual metrics and combined to form a kind of *“head-indicator”*. The so called *“Key Performance Indicator”*.

At this point, a kind of criteria catalog is introduced, with which it is able to characterize and classify specific indicators or performance measurement systems.

The next paragraph of this work is to determine the appropriate visualization of these indicators or performance measurement systems. Especially at the level of the shop floors and superior hierarchy level an appropriate visualization is of utmost importance. Here, the dashboard plays an important role. With the help of a dashboard the visualization is primarily done in the shop floor.

In the visualization there are a few rules that must be followed. In this connection, for example, play the correct selection of graphs and images, as well as the contrast, font size, font and color an important role.

Furthermore, this thesis deals with the superior hierarchy level of the shop floor. In this level, the manufacturing execution system finds its use. In this case, this system will be briefly explained. In addition, it is explained shortly by using a practical example.

In the last chapter, well-known figures are taken up again. They are identified and characterized with the previously introduced criteria catalog. In addition, a possible visualization is shown.

In the beginning of this work, there was a lot of literature, which could be used. This was especially the case with the key ratios and indicators. However, German and English literature differs in some definitions of different types of indicators. The large amount of literature was no longer available in the second part (Visualization) of the work. There are only a handful of authors who have dealt with this topic. Also it can be seen that these authors made use of each other and they often rotate "in a circle".

Also the research on the “Manufacturing Execution System” turned out difficult. This system is supplied for the most part only by external companies. Often only the provided brochures could be read. The actual implementation of this system was a trade secret.

Summary in German

Die vorliegende Diplomarbeit beschäftigt sich mit der *„Identifikation, Charakterisierung und Visualisierung von Indikatoren und Berichten für gezielte Entscheidungsunterstützung in Fertigungsunternehmen“*. Dieser Titel gibt bereits sehr guten Aufschluss über die Thematik, welche es im Laufe dieser Thesis zu bearbeiten gilt.

Diese Diplomarbeit wurde in Zusammenarbeit mit dem Fraunhofer Austria durchgeführt. Die thematische Ausrichtung dieser Diplomarbeit war so ausgelegt, dass sie zu den Ergebnissen eines großangelegten Forschungsprojektes mit einer Reihe von Partnern aus Industrie und Wissenschaft beiträgt. Dieses Teilgebiet, an dem Fraunhofer Austria beteiligt ist, beschäftigt sich mit intelligenten Produktionsprozessen. Hierbei sollten Anforderungen für ein Entscheidungsunterstützungs- und Überwachungssystem für produktionsrelevante Prozesse in produzierenden Unternehmen erarbeitet werden. Im Rahmen dieses Projektes waren zwei Diplomarbeiten durchzuführen, wobei Vorliegende den zweiten Teil darstellt. Erstere beschäftigte sich mit dem Titel: *„Modellierung einer Systematik zur Erfassung und Kategorisierung entscheidungskritischer Kennzahlen und Reports in produzierenden Unternehmen.“* Da sich diese Arbeit bereits sehr mit der Identifikation beschäftigte, wird dieses Thema in vorliegender Arbeit kürzer gehalten.

Struktur und Abarbeitungsreihenfolge halten sich sehr an die im Titel beschriebene Aufgabenstellung, da diese bereits eine strukturierte Themenführung beinhaltet.

Zunächst soll kurz die Frage geklärt werden, weshalb ein vernünftiges Informationssystem von sehr großer Wichtigkeit in modernen Produktionsbetrieben ist und weshalb aus diesem Grund ein gut strukturiertes Controlling unabdingbar wird. Nur durch das Controlling können Kennzahlen bzw. Indikatoren richtig verarbeitet und in geeigneter Form an das Informationssystem weitergeleitet werden. Dieser Teil soll jedoch nur als Hinführung und Einleitung zum eigentlichen Thema der Indikatoren verstanden werden. Es dient zum Gesamtverständnis dieses doch sehr komplexen und umfangreichen Themas.

Das darauffolgende Kapitel wendet sich dem eigentlichen Thema vorliegender Arbeit, den Kennzahlen, zu. In diesem Abschnitt werden Indikatoren anhand von Definitionen und der Darstellung verschiedener Funktionen und Typen charakterisiert.

Da oftmals alleinstehende Kennzahlen nichts bzw. sehr wenig über eine bestimmte Situation aussagen, bilden mehrere Indikatoren, welche in Verbindung gesetzt werden, sogenannte Kennzahlensysteme (Performance Measurement Systems). Diese werden wiederrum in einem gesonderten Kapitel beschrieben und verschiedene Kennzahlensysteme genauer charakterisiert.

Im Kapitel sechs wird ein Kriterienkatalog aufgestellt. Dieser weist die Ergebnisse auf, welche in den vorherigen zwei Kapiteln über Kennzahlen und Kennzahlensysteme gesammelt und in einschlägiger Literatur recherchiert wurden.

Da sich diese Arbeit auch mit der Entscheidungsunterstützung in Fertigungsunternehmen beschäftigt, befasst sich Kapitel sieben mit der Thematik, bestimmte Kennzahlen bzw. -systeme, den verschiedenen Hierarchiestufen in einem Unternehmen zuzuordnen. Dabei wird auf das „Top-down“ und „Bottom-up“ der Kennzahlengenerierung, die Beziehungen zwischen den Kennzahlen und die Gefahr des „absolut blinden Vertrauens“ auf eben diese eingegangen.

Das nächste Kapitel stellt mit der Visualisierung den zweiten großen Hauptteil dieser Diplomarbeit, neben den Kennzahlen, dar. Dabei wird auf die verschiedenen Grundlagen der Visualisierung und Visualisierungsmöglichkeiten eingegangen. Kennzahlen und ihre Darstellungsformen bringen relevante Informationen näher an den dafür zuständigen Mitarbeiter. Da in der Praxis oftmals Defizite in der Visualisierung herrschen und diese vielfach als zweitrangig erachtet werden, wird versucht den momentanen „State of the Art“ in der Literatur bzgl. Visualisierung wiederzugeben und dieses auf die Praxis zu übertragen. Zudem wird kurz auf die „Manufacturing Execution Systems“ eingegangen, welche den Versuch darstellen, Kennzahlen und ihre Visualisierung mithilfe von großangelegten Computerprogrammen zu erfassen. Dieses System wird kurz anhand eines Beispiels erläutert.

Leider wurde das vorliegende Forschungsprojekt während der Bearbeitung dieser Diplomarbeit gestoppt. Dadurch entfällt der Abschnitt, welcher die Ergebnisse aus der Literatur konkret mit denen in der Praxis arbeitenden und an diesem Projekt beteiligten Unternehmen vergleicht. So werden im nächsten Kapitel drei Standard-Kennzahlen verwendet. Dabei werden diese durch den zuvor aufgestellten Kriterienkatalog charakterisiert. Auch eine jeweils geeignete Visualisierungsmöglichkeit wird aufgezeigt. Hierbei wird auf die Kennzahlen „ROI“, „Scrap Rate“ und „Cycle Time“ zurückgegriffen, da diese in nahezu jedem produzierenden Unternehmen angewendet werden und sich teilweise auf unterschiedlichen Hierarchiestufen befinden.

Contents

1 Introduction

This work was part of a larger research project of Fraunhofer Institute Vienna. It represented the second part. The thematic focus of these diploma theses was designed that it contributes to the results of a large-scale research project with a number of partners from industry and academia. This branch dealt with intelligent production processes. A decision support and monitoring system for production-related processes should be developed in manufacturing companies.

The first part dealt with the "*modeling of a scheme for the collection and categorization decision critical key figures and reports in manufacturing companies*", whereat the second part was about "*Identification, characterization and visualization of indicators and reports for targeted decision support in manufacturing companies*".

Like the title suggests, this thesis deals with the identification, characterization and visualization of key figures. The sub-region, from which this thesis has its source, focuses on intelligent production processes. Here, demands for a decision supporting and monitoring system for production-related processes in manufacturing companies should be developed.

In addition to the identification and characterization of relevant key figures, the main focus of this work should be on identifying possibilities of indicator and report visualization and how it matches to the objectives of the decision makers.

The following points are particularly important:

- Literature and concept analysis of key figures visualizations
- Visualization developments of the identified indicators
- Basis of decision for targeted decision support.

1.1 Problem statement

Like the title suggests, this work deals with the identification, characterization and visualization of key figures.

However, the detailed processing of the identification of appropriate indicators was a major component of the antedate thesis and was thus processed more accurately in that one.

A major problem, when working with key figures, represents the manifold literature. There is a lot of literature and also a lot of different opinions on this subject. For this reason it is difficult to present a compact overview. In particular, the different

interpretations of definitions in different languages make it difficult to work with key figures literature.

When it comes to indicators, discussions on the achievements of departments and resources are no longer guided by beliefs, but by analytically derived requirements. Corporate management, based on key figures, seems almost ingenious. This appearance is unfortunately deceptive. Because of that, other problems arise. The proper use of indicators is often a challenge. The correct assignment of indicators at different levels of the hierarchy plays an important role as well as the orientation of the company in the industry branch. Is it really sure that other indicators used in different levels of hierarchy, for example in the management level or on the shop floor? Or is it enough to adapt these indicators on each hierarchy? The problem repeatedly arises in the fact that companies often do not know exactly what specific indicators testify or how they are composed at all. Regularly, the opinion is expressed that indicators, which are used in different companies, cannot hurt the own one. However, this is a misconception.

Not everything can be unified. Different companies require different metrics. Companies need to be much more aware of what indicators they can afford and what they cannot afford, and what conditions are necessary.

For example, indicators can be valuable to give a first indication of trouble. But wrong is the automatism, many companies are working, when it comes to indicators. [1]

Because of that, in this thesis the different and most common key figures are identified. In addition, indicators are defined and characterized by its features.

In the further work with indicators, decision makers need an effectual tool for the effective and efficient management and for the control of operational processes. Though, the information and control systems used in practice do not often show the desired effect. By implementing a monitoring system as a specification and control tool as well as a suitable visualization of key figures, deviations can be identified, realistic planning data can be determined and key figures can be represented in a transparent way.[2] Key figures are information which has been compressed to a number. However, numbers have an abstract character or are abstract information for the human brain. They must be analyzed before their information content can be grasped. However, it may not be inferentially expected that customers or employees have sufficient analytical skills to gather all the necessary mathematical relationships.

[1] cf. http://www.pf-mi.de/angewandte_forschung_wissenschaft/wann_kennzahlen_schaden.htm#f1 [read on: 17.03.2015]

[2] cf. http://www.tcw.de/management-consulting/produktion/monitoring-systeme-und-visualisierung-201, [read on: 01.03.2015]

In order to provide the requested information, which lies behind the shown key figures, it is useful to visualize and prepare them in a receiver-oriented way.[3]

1.2 Methodological approach and structure of this thesis

Based on existing, general approaches and process models in the literature, an individual approach model of an indicator is shown from its formation to its visualization. This is done by an empirical approach. This approach is guided by theory and literature.[4] For this reason, literature comparing is done in this work, because German and English literature differs often very significantly.

First of all, two chapters, *"Information system"* and *"Controlling"*, have to be introduced. In this way, the tasks, which key figures take in the control system of a company, can be properly understood. Information systems supply in the context of controlling a contribution for the rationality assurance of corporate governance. Only with an intact information system, aims of the companies' administration can be achieved and verified in the single controlling departments.[5] These first two chapters can be considered as an introduction to the actual topic "key figures". Only when key figures can be ranged correctly in context, the task of metrics can be fully understood.

In these first chapters, the origin of the key figures is discussed briefly and why they are arranged in the controlling, which is very important for the whole information system of a company. Without metrics, there can be no controlling. Whether budgets are monitored or projects are managed. It is always about key figures.[6] It's the same with the information system. Without a properly functioning controlling, no information system can be constructed, which is needed for economic and strategic objectives achievements.[7]

The chapters four, five, six and seven are devoted entirely to the key figures. In chapter four a characterization of the figures will take place and how they can be distinguished from each other. In chapter five the performance measurement systems will be discussed further, which are formed from individual indicators. Also,

[3] cf. Pollmann (2007), p. 64 f.

[4] cf. http://www.iur.ruhr-uni-bochum.de/imperia/md/content/iur/homepage/lehre/forschungsmethoden.pdf, p 8. [read on: 17.03.2015]

[5] cf. http://www.enzyklopaedie-der-wirtschaftsinformatik.de/wi-enzyklopaedie/lexikon/informationssysteme/Betriebswirtschaftlich-administrative-Informationssysteme/Controlling--Informationssysteme-im [read on: 17.03.2015]

[6] cf. http://www.controllingportal.de/Fachinfo/Kennzahlen/Bilanzkennzahlen-zur-Bilanzanalyse.html, [read on: 21.03.2015]

[7] cf. http://www.wirtschaftslexikon24.com/e/controlling-informationssysteme/controlling-informationssysteme.htm, [read on: 21.03.2015]

the time evolution of these systems is presented. In chapter six, again a closer look is taken at the performance measurement systems, especially in their field of application. This field is in this thesis the hierarchy level of the production floor. Through these characterizations a kind of criteria catalog is created, which will be used in chapter nine to evaluate specially selected indicators or key figures.

In chapter eight of this thesis, theoretical possibilities of visualization are communicated and demonstrated, according to the latest knowledge. Therefrom, suitable visualization options in the different levels of the hierarchy levels are derived.

In the last chapter nine, the generally gained knowledge should be applied to single key figures. Above all, the theoretical knowledge is transferred and used. Individual key figures, so to speak, “go” through the entire thesis, from their value in the controlling department up to their visualization.

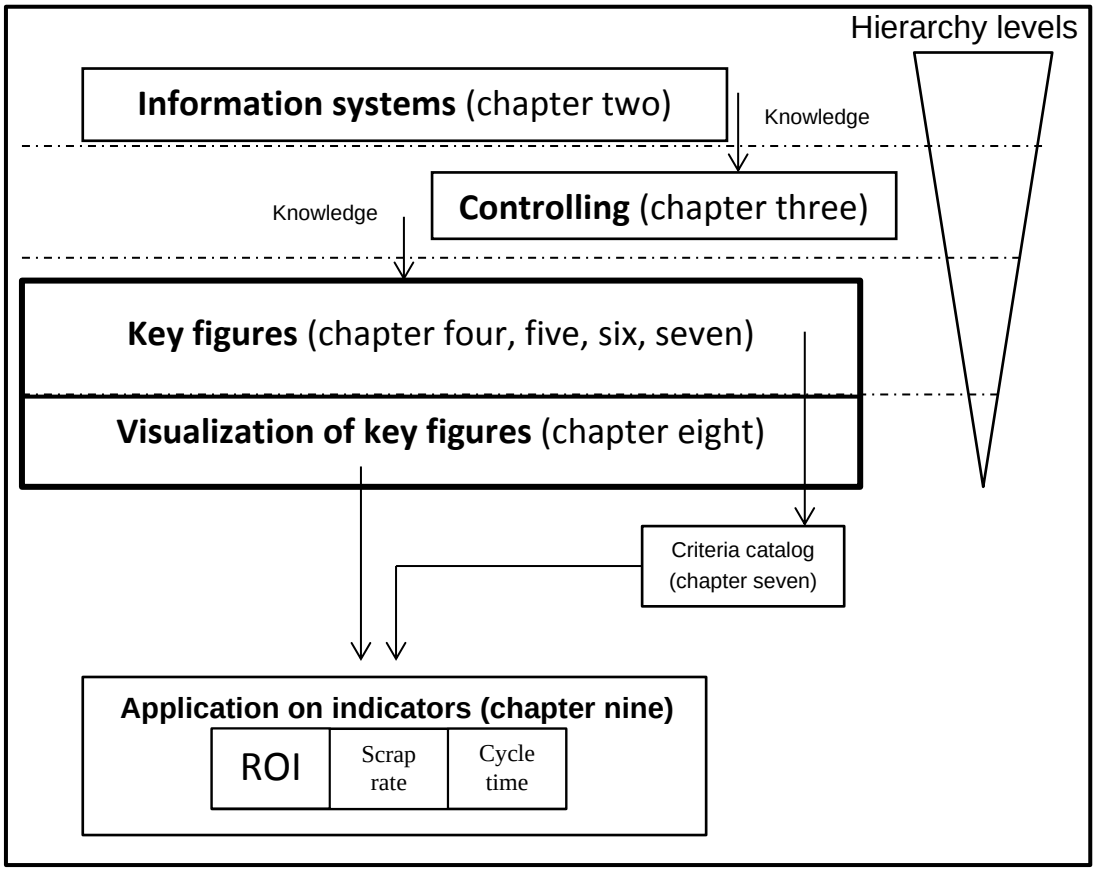

Image 1: Structure of this thesis

2 Theory and fundamentals

In the following chapter, basic concepts should be clarified. To understand the work with key figures and performance measurement systems, it requires more than knowing about their structure or their aim, which they pursue.

It should be understood that a functioning information system is involved when working with key performance indicators and performance measurement systems. In this chapter, tasks, the needs and the provision of information systems are made understandable.

First, the concept and the function of information and information systems in the business environment are generally described. Information has become a critical factor for any organization. Especially in the analysis and design of service processes, the factor information plays a major role.[8]

2.1 Term of information and information systems

First of all, the concept of information should be clarified. Nowadays an often encountered definition of information in the economic parlance is be quoted by WITTMANN. He described information as a purposeful knowledge. *"Knowledge should be used to achieve a purpose and to create a maximum of distribution*."[9]

The next paragraph refers to the concept of information systems. Usually they can be understood as "human-machine-systems". The technical elements of these systems are for example hardware-establishments, data or software. The human system-elements are the ones who are responsible for the business or development, or the ones who use the system. Operational information systems support the performance and the exchange relations within the company itself as well as business and environment.[10]

Another definition is that an information system is the amount of all internal or external regulated information-connections within a company. In addition, technical and organizational facilities for information gathering and-processing are included. You can say that an information system is the formal part of the whole operational communication system.[11]

Depending on the position and responsibility of a decision-maker, the type and degree of compaction from the required information change. Whereas the view in the

[8] cf. Salman (2004), p. 25.
[9] cf. Wittmann (1959), p.14.
[10] cf. http://www.informatik.uni-kiel.de/uploads/media/grudl_wi_II_4_07.pdf, [read on: 25.05.2014]
[11] cf. http://wirtschaftslexikon.gabler.de/Archiv/9241/informationssystem-v13.html, [read on: 25.05.2014]

strategic management level is directed to the entire company or business sectors for planning future business dealings, the operational levels usually have to make decisions according to a defined flow chart. The split into different hierarchy levels and types of information is shown in image 1.

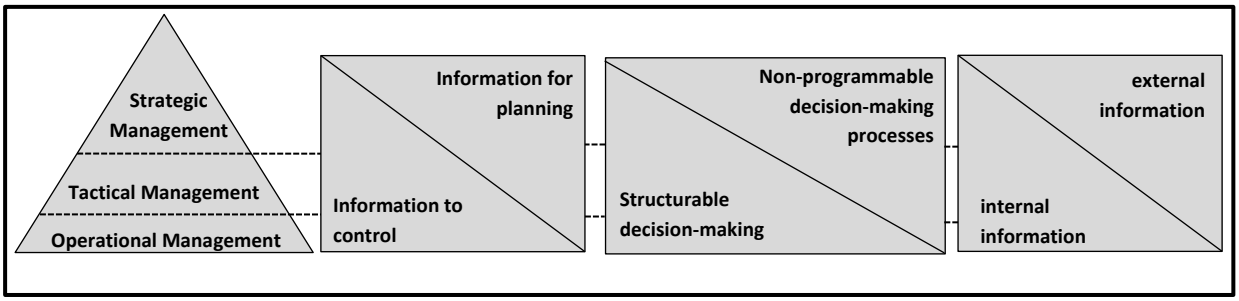

Image 2: Information and its task on different levels of the company[12]

2.2 Tasks of information systems

Information systems in the industrial sector involve various tasks. The common functions of these systems are the acquisition, the permanent storage and the processing of internal or external information.

The targets of these systems are, that you allocate

- the correct information
- in the right pattern
- in the proper dimension
- in the right spot
- at the right time
- to the accurate quality.[13]

2.3 Life cycle of information economy

The aim of managing the information economy is the production of informational economic balance between information supply and information demand. Like most of the balanced, the information economy is also dynamic. This means that supply and demand of information must be readjusted to each other again and again. Change one of the parameters, e.g. the information demand, so a new balance is sought. This results in the life cycle of the information economy.

[12] cf. Lucey (2005), p. 260.
[13] cf. http://www.enzyklopaedie-der-wirtschaftsinformatik.de/wi-enzyklopaedie/lexikon/daten-wissen/Grundlagen-der-Informationsversorgung/Informationsbedarf, [read on: 25.05.2014]

Basic elements are:

- Management of information-demand and -supplies
- Management of information sources
- Management of information resources
- Management of information provision
- Management of information use[14]

Subsequent, the most important ones are described

2.3.1 Information-need

A decision process is based on information. An information-need specifies which specific information will be provided for arbitration. It is defined by the person or group, who makes decisions.[15]

It is almost inaccessible to reach the previously defined targets precisely. Often, there is quite a big gap between the achievements of the result and the target. However this has not to be bad. If you can discover and interpret the cause of that phenomenon, you can often reach a learning effect, which can affect the business positively in the future, related to plan and economics.

Because of that, you have to develop and define indicators, which can precisely measure the strategically and operative targets on the different shop floor areas.[16]

A well-known accurate quotation, which can be often heard or read in the controlling- or management-literature, is from DRUCKER: *"If you can't measure it, you can`t manage it."*[17] This means, that everything a business does not assess or measure, you cannot regulate or develop further in an aim-oriented way.

2.3.1.1 Short explanation of information-need

The information need is the foundation for the information demand and happens in the information-need analysis. Different parameters can be retrieved to systematize and record that demand. Some examples for acquisition parameters are: recipient (e.g. for whom this information is intended), ambition for the decision (e.g. for which is this information used), sort of information (e.g. aggregated information), quality (e.g. estimates), amount (e.g. completeness), etc.[18]

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[14] cf. http://www.newbooks-services.de/MediaFiles/Texts/8/9783642158308_Excerpt_001.pdf, p. 17f. [read on: 30.05.2014]

[15] cf. http://www.enzyklopaedie-der-wirtschaftsinformatik.de/wi-enzyklopaedie/lexikon/daten-wissen/Grundlagen-der-Informationsversorgung/Informationsbedarf, [read on: 25.05.2014]

[16] cf. Barth / Hartmann / Schröder (2007), p. 466.

[17] Drucker (1999), p. 32.

[18] cf. http://www.enzyklopaedie-der-wirtschaftsinformatik.de/wi-enzyklopaedie/lexikon/daten-wissen/Grundlagen-der-Informationsversorgung/Informationsbedarf, [Gelesen am 30.05.2014]

These constants supply an entire description of the information demand. Simultaneous they define the profile of the decision maker. In order to fully grasp the information-need, it requires a structured approach to ensure a certain degree of completeness. This proceed can be divided in different phases.[19]

For example:

- definition of the problem
- analysis of the information demand
- information gathering
- assessment and usage of information.[20]

2.3.1.2 The idea of information-need

For a significant statement there is a need of measure and interpretation. Information is the key for doing that in a proper way. The information need is specified by type, quantity and quality of the information, which is needed by a person to fulfill the task in a certain time. Through a breakdown of a fulfilling task you can identify two different categories of information need.[21]

The two different categories are [see image 3]:

- objective information need:
  This part specifies the information, which is important to accomplish the existing problem.
- subjective information need:
  Primary this part is determined by the decision maker itself. It is also based on the individual evaluation of the involved person. It is his decision whether the information is relevant for the determination or not. Furthermore it is determined through experience, education, etc. of the decision maker.[22]

2.3.2 Management of information-demand:

Information demand or information inquiry is the trigger for the lifecycle of infonomics. The main aim is that you provide the information-demanders with the appropriate and comprehensive information-supply. The whole framework of information demand and need has to be contemplated in a sophisticated way. A requirement for that management is a precise knowledge and description of the information demand,

[19] cf. http://www.enzyklopaedie-der-wirtschaftsinformatik.de/wi-enzyklopaedie/lexikon/daten-wissen/Grundlagen-der-Informationsversorgung/Informationsbedarf, [Gelesen am 30.05.2014]
[20] cf. http://www.enzyklopaedie-der-wirtschaftsinformatik.de/wi-enzyklopaedie/lexikon/daten-wissen/Grundlagen-der-Informationsversorgung/Informationsbedarf, [Gelesen am 30.05.2014]
[21] cf. Picot et al. (2003), p. 81 f.
[22] cf. http://www.enzyklopaedie-der-wirtschaftsinformatik.de/wi-enzyklopaedie/lexikon/daten-wissen/Grundlagen-der-Informationsversorgung/Informationsbedarf, [Gelesen am 03.06.2014]

which has to be covered. A suitable approach has to be selected out of a various number of information needs assessment methods.[23]

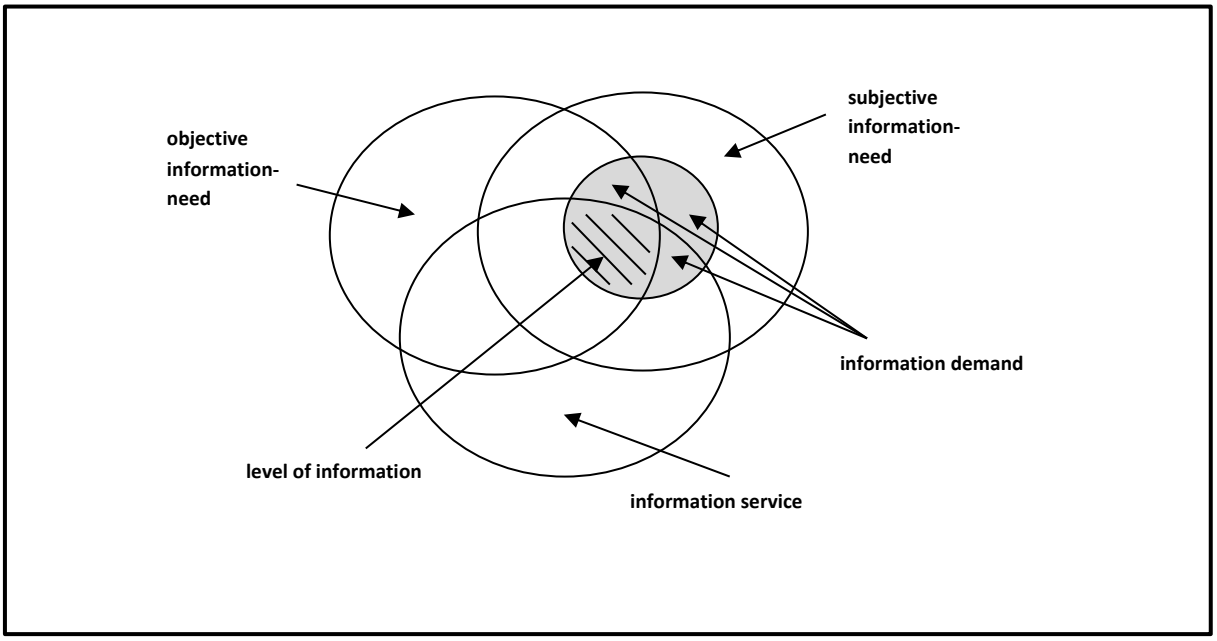

Image 3: Objective and subjective information need.[24]

The requested subjective information need differs generally more or less high from the objective one. The target achievement should be the approximation of the subjective and the objective information need. Sometimes this can be really tough. It becomes more difficult the more complex and unstructured the underlying problem or task is. Often the amount of information, which is actually asked, is only a subset of the previously expressed information demand.[25] Because of that, there is a specific difference between the two words of information need and information demand. The information demand is only part of the subjective information need, which is asked by an individual.[26]

It is uncommon, that the information offer is completely striking the subjective and the objective information need. The effective information supply resp. knowledge is only the intersection of the information need and the information offer.[27]

[23] cf. http://www.newbooks-services.de/MediaFiles/Texts/8/9783642158308_Excerpt_001.pdf, p.19., [read on: 30.05.2014]
[24] cf. Picot et al. (2003), p. 82.
[25] cf. Picot et al. (2003), p. 81 f.
[26] http://www.newbooks-services.de/MediaFiles/Texts/8/9783642158308_Excerpt_001.pdf, [read on: 27.05.2014]
[27] cf. Picot et al. (2003), p. 81 f.

The goal, which is worthwhile, is the balance between information need and information supply.[28] All the more subjective and objective information needs are striking, the better can be achieved an optimum. In order to approach these two types of information the use of different methods is eligible. On the one hand, there should be possibilities for the person in charge to express his information demands, on the other side content-related aspects of the task and goal achievement should be considered.[29]

2.3.3 Information provision

Main components of the corporate information systems are the operational performance measurement and reporting systems. These have to provide the company's management and staff with the necessary information. A description of the information supply situation is generally preceded by a design of information systems. [A specific definition and explanation on the performance indicators and measurement systems takes place in Chapter four.]

An explanation of the information supply situation precedes normally a design of information systems.[30]

A suited excerpt that often reflects the situation in many companies today is the quotation of MICHEL: *"Die Informationen, die wir bekommen, brauchen wir nicht, und die Informationen, die wir brauchen, bekommen wir nicht"*[31]. This German statement by MICHEL means about: the information that we receive, we do not need and the information we need, we do not get.

Nowadays lots of business owners' are addicted to the technical euphoria. They think that in the information age, these problems can be solved internally by the purchase of the latest technology. Technically you have never been as well equipped as it is today. It seems that systems can measure and evaluate everything. Because of that phenomenon many companies think they have to make a note on any incident. Often disillusionment follows to this technical euphoria. This occasion leads to the paradox: "lack of abundance".[32] Lack of abundance means just the above statement by MICHEL. There is an abundance of information, but a lack of the right one. Blame for this dilemma is just the provision of information that is supposed to bring improvement first. They should help to provide the right information, at the right time, to the right person [see image 4].[33]

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[28] cf. http://www.newbooks-services.de/MediaFiles/Texts/8/9783642158308_Excerpt_001.pdf; [read on: 04.06.2014]
[29] cf. Picot et al. (2003), p. 81 f.
[30] cf. Gladen (2003), p. 1.
[31] Michel (1999), p. 127.
[32] cf. Gladen (2003), p. 1.
[33] cf. Gladen (2003), p. 1.

Many times firms face a variety of data and information, which is difficult to distinguish between “genuine” and “false” information. Often it brings no added value. Besides, it contributes that not all requested information has an importance to the recipient. To sum up, one can say that companies sometimes suffer from an overload of information.[34]

Because of this, the industrial economics recognized early to distinguish between knowledge and information. Only if knowledge satisfies the information-need of the recipient, knowledge will become information [see image 4].

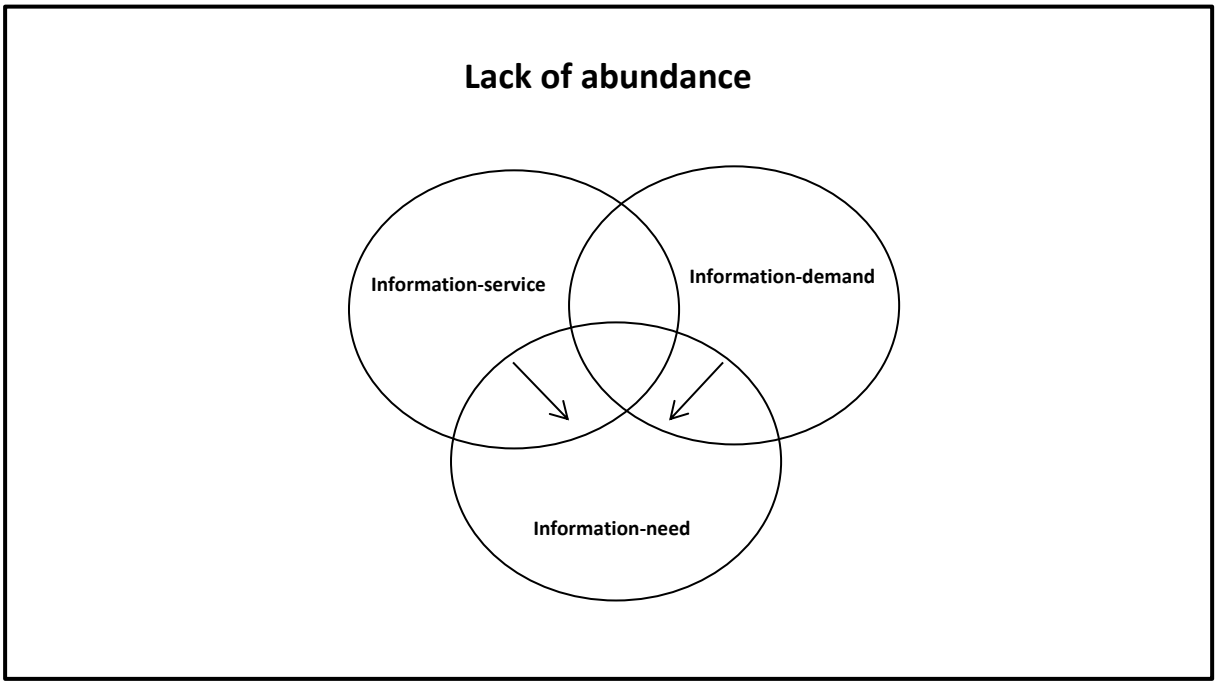


Image 4: Relationship between knowledge offer, knowledge demand and information needs.[35]

Some reasons for “lack of abundance” are:

- Managers complain about the controllers, that they only produce a “cemetery of numbers”. For GLADEN, the reason is, that reports are too detailed instead of concentrated, too operative instead of strategic and too past-oriented instead of future-oriented information.
- Managers get too many reports. So to speak, they “drown” in paperwork
- The fast progress of modern information technology (such as the internet)
- Some managers are to prestige conscious and the employees are victims of that attitude.[36]

[34] cf. Gladen (2003), p. 1 f.
[35] cf. Klaus Hufschlag (2008), p. 35.
[36] cf. Gladen (2003), p. 2 f.

Economic inefficiency is the inescapable path of this lack. For the shaping of information systems, information need is a keyword. Everyone is interested in the company's success. And this success of the information activities is measured by the performance of the information need. An imperfect information provision can be recognized that the available knowledge, the knowledge demand and the information need do not cover. It should be that only knowledge is offered and requested, which the information need corresponds.[37]

[37] cf. Gladen (2003), p. 3.

3 Controlling

To demonstrate what role the information system plays in corporate governance and how the controlling is involved in the provision of information, we use the system-theoretical representation of the management task. This means, if a company has a complex system it is useful to decompose the system into subsystems. Such a decomposition of a system into subsystems is called system differentiation.[38]

There are four subsystems of the management system. The subsystem controlling is a special one and is explained below:

- Organization
- Personnel management
- Planning and control
- Information system
- Controlling[39]

The subsystems organization, personnel management, planning and control and information system are caused by the system differentiation. This system differentiation demands, as each decomposition of a system into subsystems, the requirement of coordination between the resulting subsystems. Thus, an optimal task performance or achievement of the basic system can be ensured. This coordination task between the individual subsystems is indeed an element of the operational management system, but belongs to none of the individual subsystems. It is made rather a new subsystem. This is the subsystem “Controlling”. However, this subsystem is different from the others because it is not an isolated system. It includes in a certain degree the other systems and considers them overlapping. This is due to the fact that coordination between systems can be carried out by an isolated system of these systems only imperfectly. Controlling embodies at first a subsystem of the operational management system. Insofar, the controlling represents in a company a leadership or management task. The control system is used as a communication system and has the important task of coordination between the various subsystems. This fact makes it necessary to describe this subsystem in more detail.[40]

The term controlling took the starting point in the U.S and goes back to the second half of the 19th century. After the global economic crisis, it experienced a big boom. Already at the beginning, the tasks of controlling went beyond the normal duties. According to an empirical investigation in large U.S. companies, other important

[38] cf. Peters / Brühl / Stelling (2005), p.18.
[39] cf. Gladen (2003), p. 5.
[40] cf. Peters / Brühl / Stelling (2005), p.31 f.

tasks were added to the controlling. In the early forties the tasks of controlling were beyond only the task of accounting. As part of the corporate planning, controlling was associated with information and coordination tasks. However, controlling could not create an own business portion. The tasks of controlling are widely integrated in the activities of management department or in the specialist departments.

Despite all the difficulties of classification, the controlling has widespread above all in Germany. In the beginning, especially the large companies created the first controlling working places. This took particularly place in the late sixties. Then, controlling was introduced in the middle and small businesses at the beginning of the eighties.[41]

Mainly large and medium-sized companies are often faced to rapid changes and little room for maneuver. That is why companies need a powerful system of coordinated planning, control and monitoring instruments.[42]

In the next chapter, the general understanding of tasks and contents of controlling is to be considered in more detail. This seems appropriate, since the complexity of the environment, which is faced by companies, continuously rises. The information policy of new enterprises is forward, not backward looking. Nowadays information is a crucial performance factor for organizations.[43]

3.1 Definition

“Jeder hat seine eigene Vorstellung darüber, was Controlling bedeutet oder bedeuten soll, nur jeder meint etwas anderes.”[44] This statement means as much as, everyone has their own idea about what controlling means or should mean, but only everyone means something different.

The Term controlling is still not completely defined. It means as much as rules, rule and control. However, it does not mean revision or control. It goes far beyond the words and phrases. In the administration, controlling is therefore a system of rules. This system is designed to ensure the achievement of operational and business objectives. Therefore, controlling is not a temporary process. Rather, it is defined as a permanent power in the company and refers to all areas of business activities.

Between two components of controlling can be distinguished:

- **Instrumental component:** New and further development of the existing classic accounting tools.

[41] cf. Schaefer (2008), p. 12 f.
[42] cf. Wuppertaler Kreis (1999), p.7
[43] cf. Beck (1998), p.13
[44] Preißler: Controlling, p.10.

- **Guide component:** This component has the claim of “self-control”. In practice this type of control is gaining more and more importance. By this is meant, that every leader, who is responsibly to achieve an outcome, should check for him, if the result has been achieved or missed.[45]

This prior approach is only one attempt to describe the controlling in companies. It is characterized by a variety of very different approaches, which form the definition. “Generally Accepted Controlling Principles” have not been determined yet.[46] Because of this lack of generally accepted rules, there are many approaches.

Controlling is indeed interpreted differently in specific. However, on the general statement all agree. It can be explained by the support of the management of the company through information. In a specific way it is the result-oriented management of enterprises by facts and figures. Subtasks are:

- Planning
- Control
- Information supply
- Goal-oriented coordination

Further, controlling does not always mean work through the above-mentioned sub-items stubbornly. Also it means to look for alternatives and to consider a variety of influencing factors and integrate them into the result. To do this purposefully in companies, the different hierarchical levels must have the conviction, which they are able to work more successfully with controlling than without.[47]

In the literature controlling is very often divided into two sections. One section is the operational part. The other is the strategic one. Operational controlling describes the short-term planning, monitoring and controlling. The goal is to enable corrections for deviations from corporate performance. The detection of opportunities is the task of strategic controlling. It should secure the long-term existence of the company.[48]

But why is a uniform definition of terms so hard? One explanation is that the functional and institutional point of view is often mixed. If namely the institutional part is meant, the functions of the controller are described.[49]

“*In practice, people with the title “controller” have functions that are, at one extreme, little more than bookkeeping and, at the other extreme, de facto general management.*”[50]

[45] cf. Wuppertaler Kreis 1999), p. 7.
[46] cf. Schaefer (2008), p. 17.
[47] cf. Baier (2008), p. 21 f.
[48] cf. Vollmuth (2010), p. 6
[49] cf. Baier (2008), p. 21 f.

The functional part is described in the literature as a partial function of the management process. Here, the term usually includes the steering, control and regulation of processes. Controlling takes place when corporate management and controller work closely together.[51] In this context an often cited book is by SCHWEITZER/FRIEDL. They systematized the controlling definitions to “classical” controlling concepts. In their opinion the various controlling concepts are divided in the following classifications [s. image 4].[52]

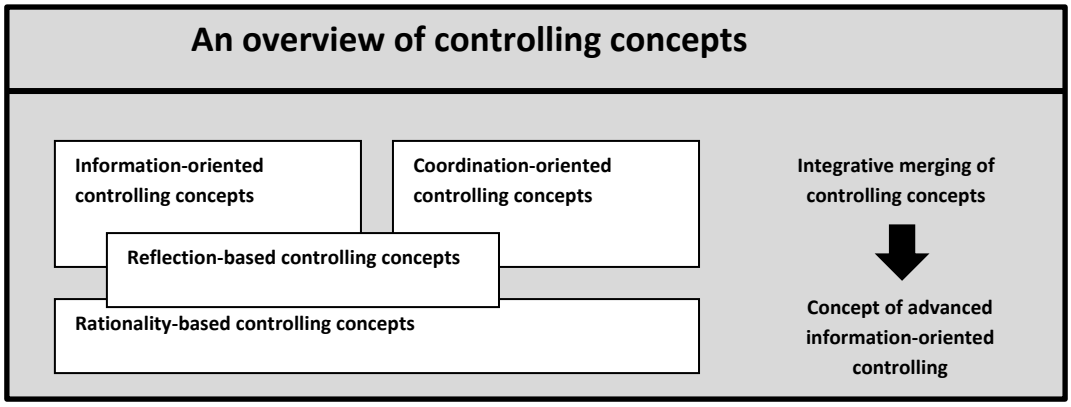


Image 5: Controlling classifications[53]

However, in this work the different controlling concepts will not be discussed in more detail. It should only be shown a broad overview of the current state of the definition in literature.

3.2 Tasks

Tasks of the controller cannot be generalized every time. You have to adjust them, for example, to changes in the environment or frame conditions. Of course, the tasks of the controller also depend on the size of the company. In large ones, controlling is usually divided into different area, such as marketing controlling, innovation controlling or financial controlling. Controllers are specialized for this purpose on various divisions and report their values to the next higher level or directly to the management. In small or medium-sized companies the controlling tasks are often adopted by the management itself or the accounts department. But nevertheless the main tasks of the controller remain the planning, management and control of corporate goals. To all intents and purposes a controller stands available as a consultant for the management and department heads. However, the advisory function is very different from each other. While the controller assistances the

[50] Anthony, Control Systems, p. 28.
[51] cf. Baier (2008), p. 22.
[52] cf. Schaefer (2008), p.17 f.
[53] cf. Schaefer (2008), p. 8.

management of the definition and achievement of targets, he supports the heads of departments through proposals and plans for the implementation of corporate objectives.[54]

Controlling works best when controllers and managers fully cooperate. So to speak, the manager is responsible for the result, the controller for the transparency of results.[55]

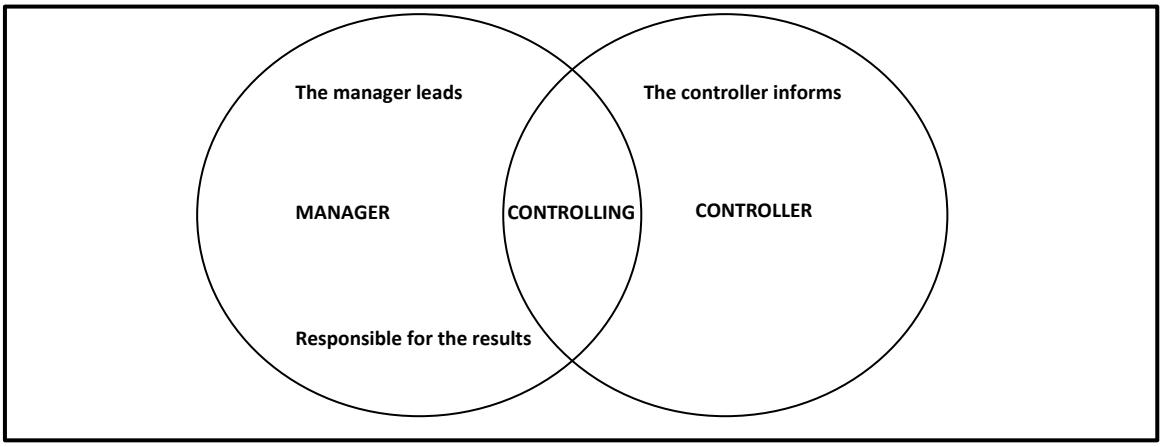


Image 6: Relationship between controller and manager[56]

After PIONTEK the tasks of controlling are divided into three main tasks. These three fields are the provision of information, tasks of adaption and coordination tasks.

Here is the information system at the core of each controlling system. As described in chapter 2.1 a functioning information system is of central importance. Forecasts in times of turbulent environments get increasingly difficult or almost impossible. It is necessary to know exactly the developments in all areas of the company. It must also be recognized where and in what order of magnitude variations have emerged from the plan. This is important to be able to take timely countermeasures. In a company there are always discontinuities. However, these usually occur no more unheralded. Rather, they have a longer history, which could already be seen on closer observation. Thus, countermeasures are ready quickly. In general, an information system must ensure as a service to the decisions striking management a demand-oriented information supply. On the basis of this, the controller must ensure that information is timely provided, is available in the necessary compression and is problem-oriented.[57]

It can be concluded that controlling is a subsystem of a company's greater guidance system [s. image 6]. With ever more complex businesses, it was necessary to set up

[54] cf. http://www.controllingportal.de/Fachinfo/Grundlagen/Aufgaben-des-Controllers.html, [read on: 15.07.2014]
[55] cf. Baier (2008), p. 23.
[56] cf. Baier (2008), p. 23.
[57] cf. Vgl. Piontek (2004), p. 5.

subsystems, because an all-comprehensive system was no longer adequate. The various subsystems include organization, personnel management, planning, monitoring and information system. Here, the subsystem “information system” has the task to provide the other subsystems with information. To prevent the specialized subsystems from “a life of their own”, they must be coordinated by another system. For the coordination of the individual subsystem to the guide system the subsystem controlling is in charge.[58]

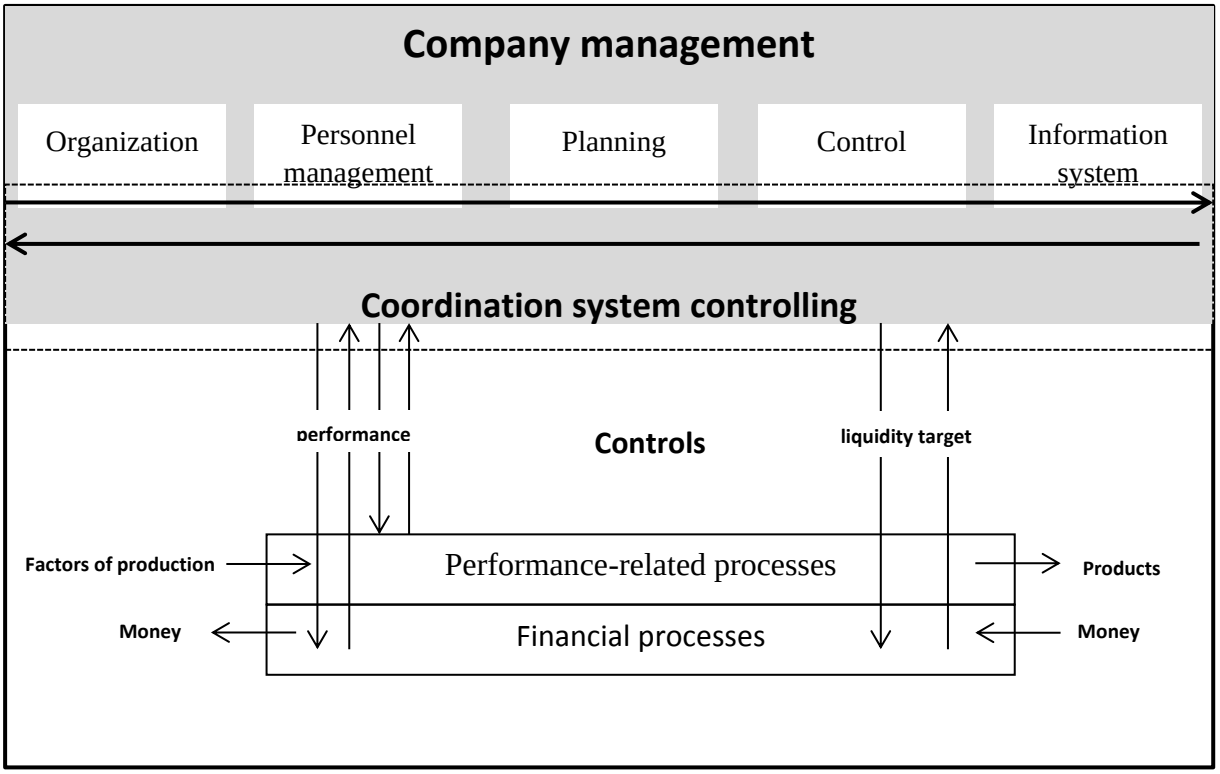


Image 7: Information system and controlling as subsystems of the guidance system[59]

3.3 Controlling instruments

In order to perform controlling as part of a company, a controller has a variety of different “tools”. They are called “controlling instruments”. With them, specific goals and actions can be developed as well as organization and implementation tasks of planning, control and information processes. These instruments are naturally held in accounting. In that field they have their strongest distribution. However, you should not limit these tools only to these parts.[60]

[58] cf. Gladen (2003), p. 5 f.
[59] cf. Gladen (2003), p. 5.
[60] cf. Baier (2008), p.120.

In this context, one could distinguish between operational and strategic controlling instruments again.[61] With little research on this topic you will see shortly that there are a variety of control instruments for each subarea. Some are better for certain areas while others are less suitable.[62]

In the next chapter, there is no reason to enumerate or identify the individual instruments. Rather, only an overview of each sub-region will be given in which these instruments are in use.

3.3.1 Instrument of financial accounting

Financial accounting is one of the externally oriented corporate accounting. In addition to the financial accounting, the financial statement is also another major component of business accounting. These occur in the function as an information provider. For this reason, they must be accountable to third parties and to comply with certain requirements. All economically significant transactions between the operating company and the environment are recorded in the financial accounting. These are recognized according to their numerical values and listed in chronological order, using appropriate booking techniques. All transactions that lead to a change in the amount and composition of assets and capital are treated as economically significant.[63] Financial accounting is therefore still the main instrument of accounting.

The most important tasks of financial accounting include the close, complete and correct record of all business transactions. These serve as a basis for preparing the financial statements. Further proof of the wealth and capital must be provided in a company. The changes in the course of a fiscal year will be also included. On the basis of this, the financial assessment of the company is created. Another object is the evidence of the economic activity. In this case income and expenses for the period are compared. This proof can carry out a profitable and capital-economic analysis.[64]

With the recording of all business transactions the official financial statements can be formed at the end.[65] Figures are essential for good management and control of a company. However, a problem is that the individual partial areas of accounting convey different qualities of numerical information. A major disadvantage of external accounting is that it is solely focused on the past. In the past, this backward-looking information was sufficient. One had only to do with manageable markets, long product life cycles and constant prices. Nowadays a future-oriented perspective is

[61] cf. Vollmuth (2010), p.7 ff.
[62] cf. Baier (2008), p.120.
[63] cf. Peters / Brühl / Stelling (2005), p.181 f.
[64] cf. Wuppertaler Kreis (1999), p. 8 f.
[65] cf. Wuppertaler Kreis (1999), p. 8.

essential. In a time of complex contexts, rapidly changing markets and individualism, other instruments are needed.[66]

There are mainly required short-term profit and loss accounts. This is a crucial advantage of modern accounting. For the control of the company short-term results are needed, which are constructed according to certain patterns. For this, part results from individual divisions are needed. For in-company billing, the cost and performance accounting is responsible. First, the cost and performance accounting is backward looking, because it determines the internal results. Is the controlling pursued consequently by the management, measured variables are placed in the form of defaults. A further instrument is the instrument of indicators. They are, in addition, to the nominal / actual comparison essential. Nowadays these indicators have been increasingly developed to whole performance measurement systems. These instruments are credited to the internal accounting, which will now be described in more detail.[67]

3.3.2 Instrument of cost and performance/management accounting

Accounting may be called as a central information gatherer and information provider. Accounting is mainly divided into two areas. The allocation is made in the “financial” accounting and “cost and management” accounting.

As it stated before, in financial accounting, all business transactions of the company with its environment are considered, recorded and documented. The cost and performance accounting covers only the internal relations.[68] So, it serves to illustrate the actual performance process.

The following tasks are attributed to the cost and performance accounting.

- **Determination function**
  The costs and benefits should be as thoroughly as possible returned to the originator.
- **Prognostics**
  Operational decisions usually affect the company's future. Before such a decision is made there should be accurate information, how the decision can affect the costs and performance of the operation.
- **Default function**
  An essential task of management is to define the target or default values. Here, objectives, which should be achieved, are defined. At this point, the interface with the planning level takes place.

[66] cf. Schneidewind (2006), p. 42.
[67] cf. Wuppertaler Kreis 1999), p. 9 f.
[68] cf. Macha (2010), p.1.

- **Control function**
  At this point a target performance comparison takes place. For a satisfactory result, a continuous monitoring is needed. Only if requirements are kept, a performance can be successfully.[69]

The cost and performance accounting can also be seen as a “cybernetic circle”. In addition to planning, the actual situation and documentation are of great importance. The cost and performance accounting documents all cost and performance streams, which occur within the company [see image 8]. At the beginning there are tasks which should be realized. At this point an ideal situation should be determined. Now the actual performance process takes place. If these processes are completed, there is an actual-situation determination. The data is now given to the monitoring. At this point a target performance comparison takes place. If the value exceeds the tolerance, the management reacts in a certain way. However it turns out that despite intervention a large deviation continues, the planning of goals must be redefined.[70]

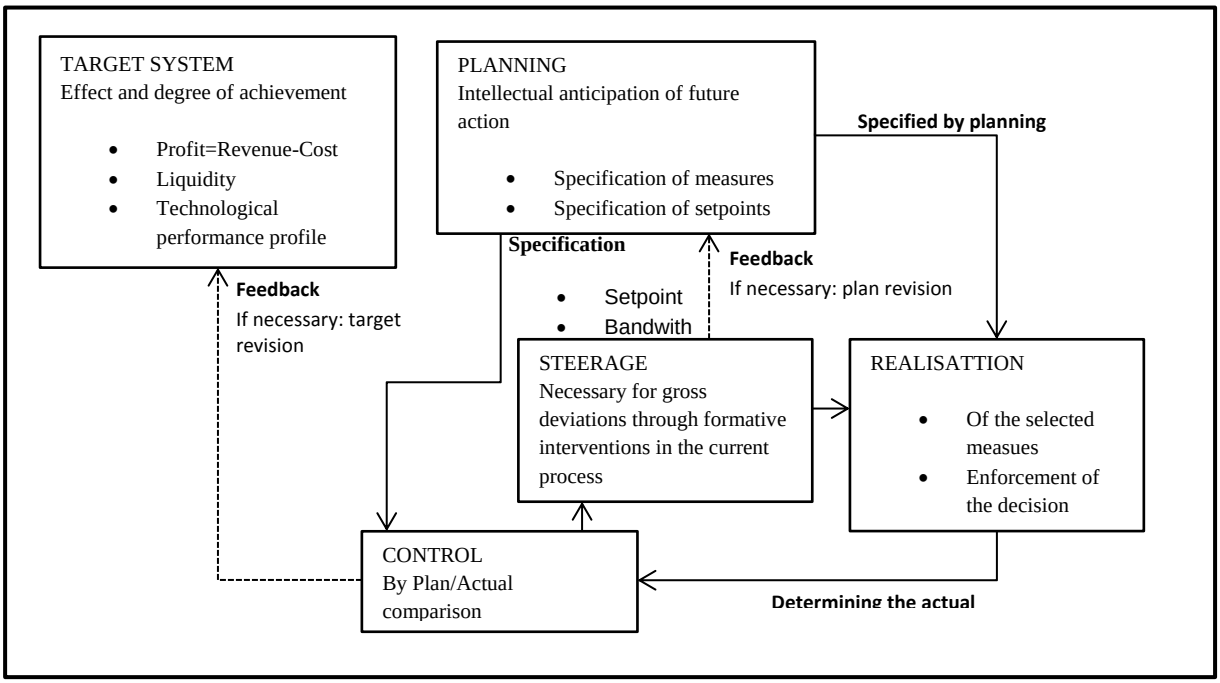


Image 8: Cybernetic cycle[71]

[69] cf. Wuppertaler Kreis 1999), p. 10 f.
[70] cf. Macha (2010), p.3 ff.
[71] cf. Macha (2010), p. 4.

3.3.3 Instrument of corporate planning

With a planning, several objectives are tried to reach. In almost all cases, however, a better understanding of the uncertain, unknown and rapidly changing future is sought. Then, there is the attempt to reach the best possible preview of operational events and adapt it to the dynamics of the environment. At the same time one has to consider possible changes in the requirements of different stakeholders. With all this, the target profit maximization and the security of existence are sought.[72]

The starting point is almost always the data that are obtained in the financial accounting and the cost and management accounting. With the aid of these data, a plan for the next period is created. In this stage, the income and the necessary expenses are planned. The planning happens with the payoff cycle of short-term result calculation. These target values are compared with the actual values from the result calculation. For the controlling the implementation and monitoring of such budget accounting is an essential field of activity.[73]

3.3.4 Instrument of the reporting

In the normal course of business a lot of information is caused. Controlling has general information and documentation task. To accomplish these tasks, reporting creates a connection between the origination and application site of the data.[74] After KÜPPER it includes: "*alle Personen, Einrichtungen, Regelungen, Daten und Prozesse mit denen Berichte erstellt und weitergegeben werden*".[75] This means as much as: "all individuals, institutions, regulations, data and processes are used to create and distributed reports."

The receiver of information is especially an internal position, but it can be also an external one. For the preparation and presentation of reports the information need is crucial. This should be fulfilled by the report at its best way.[76] Often, a special focus is on numbers and results of accounting and cost accounting. Depending on the temporal dimension, monthly, quarterly or annual reports can be arranged. These list the current data, comment and show deviations to previous periods.[77]

A controlling and receiver oriented information system has the task of information collection, processing and interpretation. Information must be made promptly and recipient individually available. They must also be of high quality and reliable. The compaction of the information varies depending on the company or receiver level.

[72] cf. Krupp (2013), p. 4.
[73] cf. Wuppertaler Kreis 1999), p. 12.
[74] cf. Geidner (2009), p.186.
[75] Küpper (2005), p.170.
[76] cf. Geidner (2009), p. 186.
[77] cf. http://www.controllingportal.de/Fachinfo/Grundlagen/Berichtswesen-Reporting.html, [read on: 05.06.2014]

However, it should always be the goal of a compression. Only really relevant information should be presented. This enables the decision to be accelerated. Therefore, the reporting system with its presentation of information and information processing is a key instrument in the management system of companies.[78]

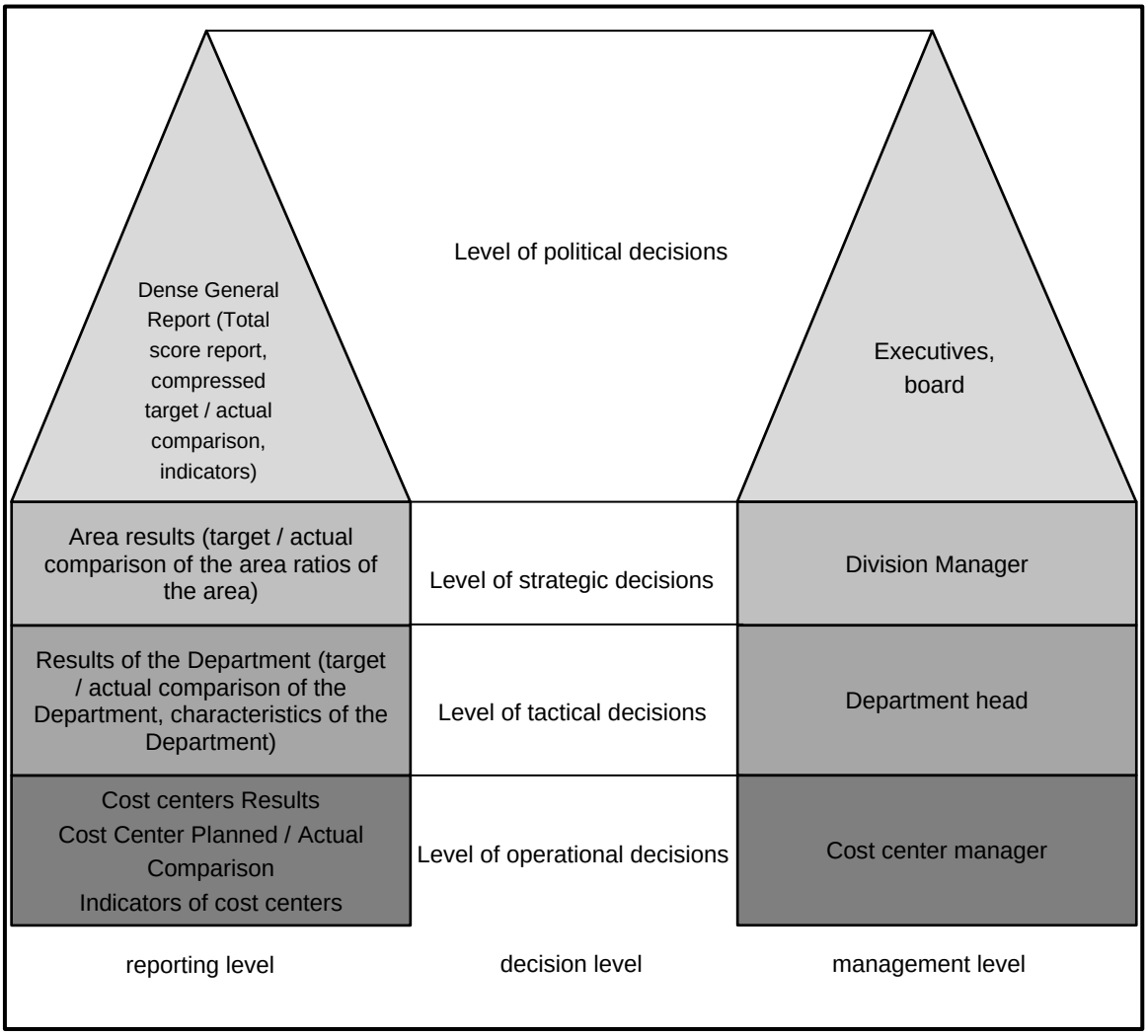


Image 9: Reporting hierarchy in the controlling[79]

Information today is often referred to the fourth factor of production. This knowledge consists of individual data, specifically from found facts. Information must be available. This means they must be collected, transformed and transmitted. The information system, which shall be established, should be seen as an integral part of the target, planning and control system of a company. A good controlling gathers, processes and presents data. This can reveal both, a strategic (e.g. early warning

[78] cf. Reichmann (2001). p .24.
[79] cf. Czenskowsky (2010), p.161.

indicators) and operational (e.g. indicators) character. Such reports are often target / actual comparisons and the subsequent root cause analysis of variance. Every business decision is actually the result of information provided. For this reason, the importance of building and maintaining these systems is apparent. As the main task of a controller, therefore, the installation of a goal-oriented and hierarchical information system can be seen. This includes data and presents it systematically to the receiver. The correctness of a decision depends largely on the quality and availability of information. Thus, the controlling has the difficult task of building a suitable information system, depending on company size. This should both meet the information needs of decision makers and on the other hand correspond to the principle of economic efficiency. The design must be recipient-oriented and economically.[80]

The following requirements are taken into account.

- Information, which is developed, must be current and correct. Manipulations must be ruled out.
- Lean, simply and economically (as little as possible, as much as necessary).
- A common source of information for the information system.
- Information must be objective and factual.
- Information, if possible, should be visualized and must be understandable.[81]

A common graphical representation of important operational performance factors and other indicators is the so-called "Dashboard". This is a kind of datasheet, in which one you can find a combination of different indicators. Thus, the report recipient has all important figures, for its range, at one glance.[82]

Another term that is often called in connection with the reporting system is the "Management Cockpit" or "cockpit chart". This instrument enables the display of visualization forms and degrees of compression of information. This system is based on large amounts of information, which is offered to the viewer in a clear and condensed form. This instrument can be used both in the top (strategic) management level and operational process level. In practice, dashboards and management cockpits accord to the technical implementation of addressee-specific information, which was processed. These are obtained primarily through the use of indicators and performance measurement systems. Working with dashboards and management cockpits are described in detail in Chapter 7 (visualization).[83]

[80] cf. Czenskowsky (2010), p.160.
[81] cf. Czenskowsky (2010), p.160.
[82] cf. Pollmann (2007), p. 68.
[83] cf. Arnold/Röseler/Staade (2005), p. 215.

3.3.5 Instrument of performance indicators

Performance indicators, their associated systems and the reports, which are based on them, are the core of almost each information systems. In the following chapter, a closer and more nuanced view of indicators is cast. Therefore, in this section only the properties of the indicators, as a controlling instrument, will be discussed.

Each controller works with indicators and performance measurement systems for the reporting. This approach cannot be waived. By applying of indicators, the ability is given to the management to recognize relationships as well as causes and effects of positive and negative factors. Indicators are summarized data which can be viewed as quantitative information. They are intended to provide information quickly and concisely about an economic issue.[84]

The data required for the operating indicators are mainly obtained from the financial accounting and the cost and performance accounting. These two areas are used as the main source of information for performance indicators. However, certain indicators need additional data that are not needed in this form in the accounting. Indicators serve equally for corporate management. By analyzing the indicators different forms of comparison are allowed:

- Time (income or expense over several periods)
- Intra-corporate (comparing one's numbers with comparable companies)
- Methods (comparison of different production)
- Target / actual comparison.[85]

A major problem of information processing is the sensible and meaningful summarization and comparison of the existing information material. Indicators serve not only the purpose to uncover absolute results and developments of the company afterwards. They can also be used for analysis, forecasts, plans, controls and checks. So they are an instrument for early warning, early detection and education. They can also be used for analysis, forecasts, plans, controls and checks. So, they are an instrument for early warning, early detection and early elucidation. They may serve as the following functions:

- As a benchmark and measure
- As a target size
- As a control number[86]

[84] cf. Czenskowsky (2010), p.183 ff.
[85] cf. Wuppertaler Kreis 1999), p. 12.
[86] cf. Czenskowsky (2010), p.184.

4 Key figures

Without metrics, there is no controlling. All kinds of monitoring for which the controlling is necessarily responsible, is done with the help of performance data or indicators. Because key figures represent one of the important controlling-instruments, they are particularly helpful to examine certain areas and situation, with scarce numerical values, more closely. Which key figures are important and at what intervals they should checked depend on many individual factors and should be decided independently.[87]

The following chapter is devoted to the subject of indicators and their applications in the enterprise. First, the most important concepts in the work with indicators are defined. Moreover, the various types of indicators are presented and how these can be systematized. Then it is shown how indicators can be used effectively to support the achievement of objectives in business. In the next sections the designation “key figures”, “indicators”, “business ratio”, “performance figure” mean nearly the same. In most cases, however, the expression “key figures” is used. Except the “Key Performance Indicators” (KPI’s) are described more precisely, because they occupy a special position. In the definitions of key figures German and English literature differs. In German there are indeed distinctions of the choice of words (key figures and indicators), which are explained more precisely in Section 4.1.1. In the English literature the distinction is less. Here, the expressions of indicators and key figures mean often the same. Also, no difference between the “objective” and “subjective” view is rendered in English as opposed to the German literature. For this reason, the auxiliary words “subjective” and “objective” are added to the expressions of indicators in this thesis, if it is necessary for a better understanding.

4.1 Definitions

To understand the main terms being worked with in the following chapters, they are explained briefly in the next section.

4.1.1 Concept of the key figures

“Wieder und wieder bitte ich: Non multa sed multum. Weniger Zahlen, aber gescheitere…“[88]. This quota means in the English language as much as: Again and again I ask: Fewer numbers, but more clever ones.

With this quote you see which claim is made on reporting and performance measurement systems. After GROLL performance indicators are numbers that

[87] cf. http://www.gruendungsnetz.brandenburg.de/sixcms/detail.php/bb1.c.297000.de [read on:
[88] Lenin, zitiert nach Stadler/Weißenberger 1999

provide information in a precise and concentrated form of important numerically ascertainable facts and developments within a company.[89] Performance indicators are that information which detects quantitative issues in a concentrated form. They serve specific needs of business analysis and management.[90]

Performance indicators support the management at all levels of a company. They allow a consistent monitoring and control of the set strategic and operational objectives. Through the use of indicators the quality and speed of communication can be improved among all stakeholders. Dynamics of companies are represented in a manageable way and complex processes and situations are made easy understandable.[91]

If it is possible, in the provision of information, the quantitative information is preferred to the qualitative one. Performance indicators should meet the requirements:

- Complicated operational issues, structures and processes mapped onto simple way
- Ensure as much as possible comprehensive and a quick overview
- To serve decision-making bodies in analyzes
- To switch off irrelevant data and help guide instances while current planning, implementation and control[92]

Performance indicators are often divided into three types. By this way of dividing, the two meanings for the term “performance indicators” can be seen.

- **Key figures in the broader sense:** This refers to quantitative information, which has been prepared for the specific needs of business analysis and management. This includes key figures and indicators.
- **Key figures in the narrow sense:** These are called measures. They are willfully strongly compressed and become absolute or relative figures. Through their concentrated form it can be reported about numerically ascertainable facts.
- **Indicators:** These indicators report a reality that can be mapped very difficult. For this reason, they seem incomplete or it is believed to be less important.[93]

To further address the third meaning. Indicators are not quantitative information obtained via compaction. Rather, they are qualitative statements about certain situations. These in turn lead to the inference of characteristics and changes for a different factor, which is considered important. So they are mostly not directly

[89] cf. Groll (1991), p. 11.
[90] cf. Arnold / Röseler / Staade (2005), p. 39.
[91] cf. Weber (1995), p. 227 f.
[92] Vgl. Gladen (2005), p.11.
[93] Vgl. Gladen (2005), p.11 f.

measurable or not observable facts. Customer satisfaction would be an example for those indicators.[94] In this case they are often called "soft factors". Here, these qualitative performance figures (indicators) are often called "soft factors". In contrast, the quantitative indicators (key figures) are referred to as "hard factors". They come mostly from the property, financial or income sector of a company and can be fixed to solid numbers.[95]

The focus of the measurement and assessment of the company's success has been measured in the past, only with "hard facts". This is for a large part of the companies, even today, still the case. Hard factors are usually evaluated and measured only from a financial perspective. However, nowadays the professional world agrees that success depends not only on hard factors. Rather, the soft factors play an increasingly important role. Image, employee motivation and customer satisfaction have at least the same importance as results from the financial sector. However, this can be difficult to measure. In order to quantify these benefits, special indicators are usually used. They are mostly called operational indicators. However, it must be previously set target values so that operational metrics are meaningful. Only by comparison with the actual values the achievement of the target can be verified. This type of measure is gaining more and more importance nowadays.[96]

In the next sections there will be no distinction between these two types (the “hard” and the “soft” ones). Performance indicators, key figures, indicators, etc. denote all the same. With ever-changing names, it would easily lead to comprehension difficulties. Moreover, the understanding of the difference should have been made clear.

Now follows a brief introduction to the KPI's. KPI's differ from conventional key figures because they already describe in concentrated or summarized way information about an issue. KPI's are generally intended to fulfill the following functions:

- Excitation function: Detection of abnormalities and changes
- Operationalization function: Goals are to be made concretely tangible and measurable by forming indicators.
- Default function: Delivery of critical targets as a specification for operational sections
- Control function: Simplify complex processes by reducing the key figures.

[94] Vgl. Gladen (2005), p.12..
[95] Vgl. Arnold / Röseler / Staade (2005), p. 39.
[96] cf. Brecht (2012), p. 53 ff.

- Monitoring function: Target / actual comparisons. Further analyzes for possible deviations.[97]

4.1.2 The four types of performance measurements in the English literature

However, in order to remind what the difficulties in the distinction of the individual indicators are, they will be discussed again in a slightly different way after PARMENTER. In this section, the English literature, which has substantial differences to the German one, is quoted. In particular, a distinction is made after the division of PARMENTER. Previously, in Chapter 4.1.1 the German literature, especially the book by GLADEN, served as a template.

So, it can be seen that key figures are a very comprehensive term. In addition to the previous division into hard and soft factors, a further division can be made. Often it is a problem that many companies do not really know what they measure. Very few companies measure what they want. The problem of all is that many do not know the difference. They are divided into:

- Key result indicators (KRI's)
- Result indicators (RI's)
- Performance indicators (PI's)
- Key performance indicators (KPI's)[98]

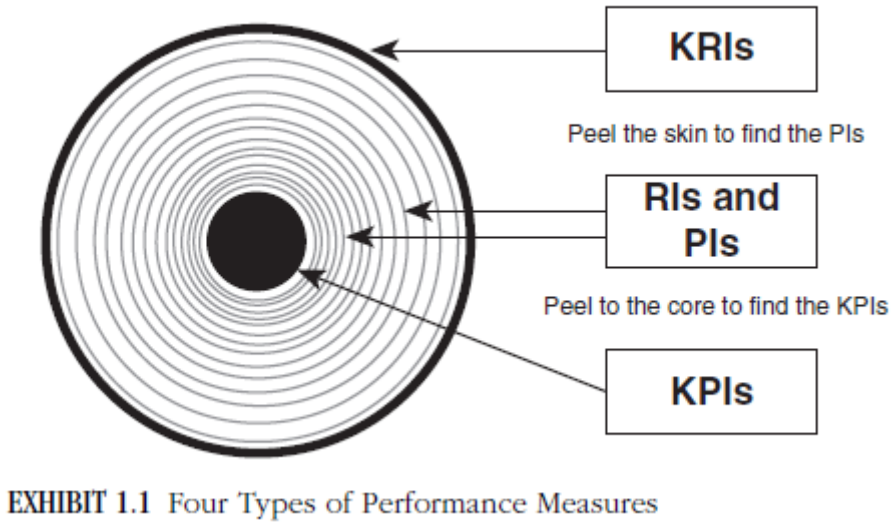


Image 10: Four Types of Performance Measures[99]

[97] cf. Arnold / Röseler / Staade (2005), p. 40.
[98] cf. Parmenter (2010), p. 1ff.
[99] Parmenter (2007), p. 2.

The following is a brief explanation of what the four different categories mean.

- **KRI's:** KRI's are often confused with KPI's. They comprehend customer satisfaction, net profit before tax, profitability of customers, employee satisfaction, return on capital employed, etc. KRI's are recognized by the fact that they always refer to results. Through it can be seen whether a company is on the right track or not. However, if the desired result should not enter, one cannot deduce what to do with KPI's. So they are not a suitable instrument for daily business. Rather, they are designed for long-term strategies. KPI's are there to tell you, how you have managed a critical success factor.[100]

- **PI's and RI's:** There are about 80 performance measurements which are located between the KRI's and the KPI's. This number 80 is estimated by PARMENTER and his point of view. The author gives no further details about what exactly these indicators are. These are the so called PI's and RI's. With the PI's alone you cannot do much. They are not the key to success. Rather, they help a team to adapt to the overall corporate strategy. The PI's have nothing to do with the financial. They only are added to the KPI's. They are disclosed with KPI's, e.g. on the scorecard for each division, department or team. So we can say that performance indicators help in the question of what to do. The PI's are therefore a step below the KRI's. They include, for example complaints from key customers, sales calls for the next week or late deliveries for key customers.
  The RI's measure in contrast to the PI's the financial activities. The RI's are just like the PI's below the KRI's. They can include, for example, the net profit on key product lines, yesterday's sales or utilization in the week. The RI's therefore represent activities that have been done or achieved.[101]

- **KPI's:** KPI's are a number of measures. These relate primarily to those corporate performances, which are assessed at the most critical for the current or future business success. Therefore, key performance indicators point to what measures must be implemented to improve performance in particular areas.[102]

4.1.3 Key Performance Indicators

In order to measure a company's performance, it requires appropriate measurements. Key Performance Indicators or Key Success Indicators (KSI's) help companies to measure progress for the to-reach business goals. KPI's represent,

[100] cf. Parmenter (2010), p. 2f.
[101] cf. Parmenter (2010), p. 3f.
[102] cf. Parmenter (2010), p. 4ff.

according to their definition, the critical success factors and need to be quantifiable. So, KPI’s mean a part of key figures. With them you can measure or identify productivity or a certain degree of a goal’s fulfillment. Directors, chief financial officers or sales managers need different KPIs. It's the same in the various management layers. Also different KPI’s are needed. [103]

In the literature the application of KPI's is still very controversial. When defining, the opinions diverge very far. In the following, the definition of KPI’s should be based on PARMENTER, because he describes the key performance indicators in a more specific way. He also distinguishes between the individual indicators. In others they are often simply used as a generic term.[104]

After countless interviews and workshops PARMENTER characterized KPIS's by seven points.

- They are nonfinancial measures. (They are not expressed in any type of currency.)
- A frequently measurement is required. It should be 24/7, daily or weekly.
- KPI's are handled by the CEO (Chief Executive Officer) or senior management team. This means that all employees need to understand why specific actions or measurements are required.
- Illustrate what measures must be taken by the competent staff.
- KPIs are metrics that are tied downward to a team.
- Have a considerable influence.
- KPI's indicate the most appropriate countermeasure.[105]

Image 10 illustrates the difference between "simple" measurements or indicators (which can be both financial and operational metrics) and key performance indicators graphically.

Unlike to "simple" indicators KPI usually report about a reality that can be mapped very difficult. They provide a numerical basis for the consideration and evaluation of cause-effect relationships.[106]

[103] cf. Arnold / Röseler / Staade (2005), p. 42.
[104] cf. Parmenter (2010), p. 6.
[105] cf. Parmenter (2010), p. 6.
[106] cf. Richert (2006), p. 31.

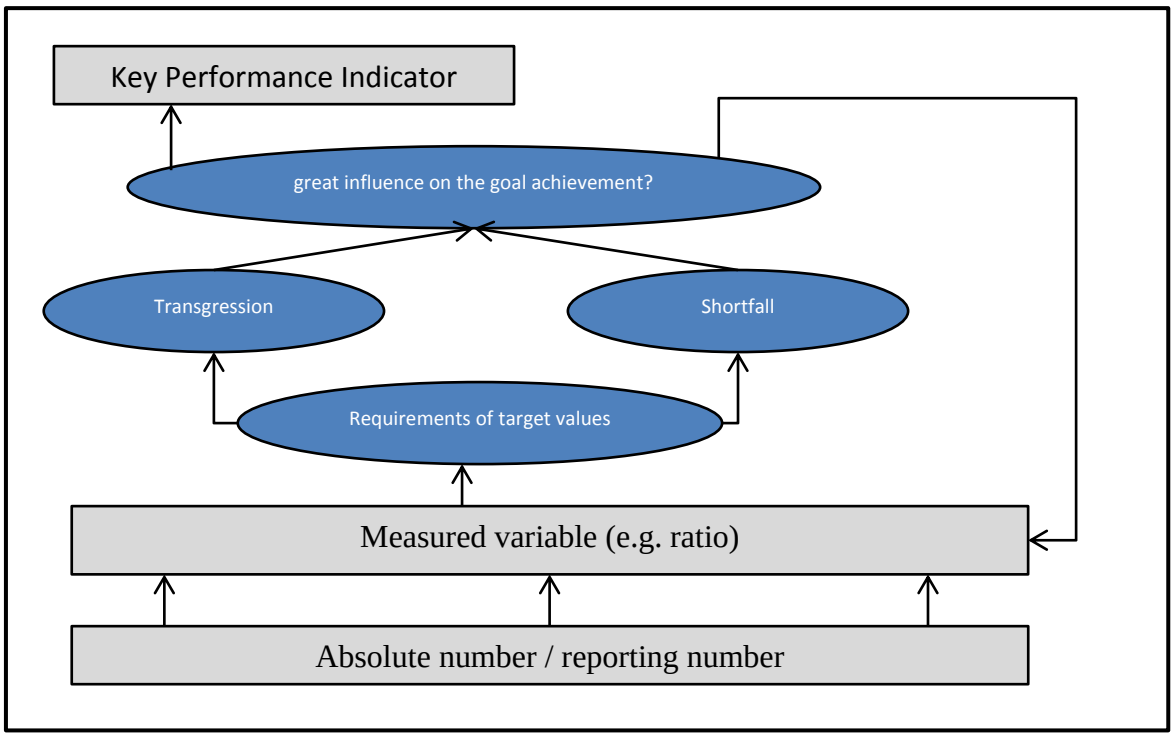


Image 11: Delimination of metrics and key performance indicators[107]

4.2 Functions of the key figures

Indicators should be considered on the basis of their quantification and their informative character as operating economic models. Within this model function they can be used depending on the decision phase as description-, discovery-, forecasting- and decision-model to assess the performance effectiveness of decisions and the degree of goal achievement. In their model function, the most important functions of indicators can be derived. These functions include the function of operationalization, the excitation function, the default function, the communication and control function and the control function.[108]

- **Function of operationalization:** This function deals with the formation of indicators, to measure operational objectives and their level of achievement. This function is of central importance. Based on it, statements about the operational successes are taken. It also represents the starting point of the next following functions.

- **Excitation function:** With this function, key figures are recorded continuously. This is especially for the detection of intra and inter-company changes. This is important for early detection of changes and the timely development of

[107] cf. Gaismayer (2004), p. 27
[108] cf. Hienerth (2010), p. 36f.

countermeasures. Analyses of key figures are often an impetus for operational rethinking.

- **Default functions:** Here, the critical measure values are set. These serve as a target for entrepreneurial activity and support operational decisions.

- **Communication and control function**: Key figures summarize economic issues. Hence, they reduce the risk of interference between communication transmitter and receiver. Key figures are therefore particularly suitable for the simplification of communication and control processes in companies.

- **Control function**: Through continuous target / actual comparisons, as well as assessing the effectiveness, efficiency and quality of service delivery, indicators also have a control function. Causes and causal relationships are analyzed and then, if necessary, appropriate countermeasures are implemented. Thus, key figures support decisions in the context of corporate governance.[109]

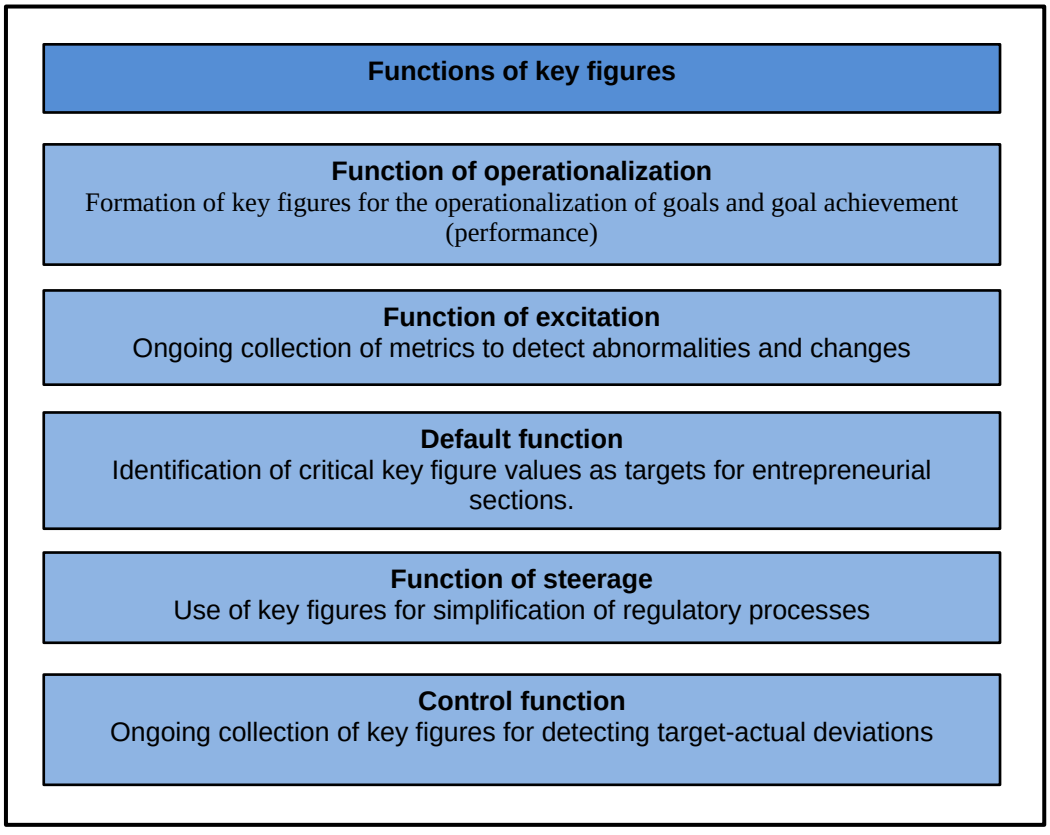


Image 12: Overview of the functions of key figures[110]

[109] cf. Hienerth (2010), p. 37.
[110] cf. Weber (1995), p. 188.

4.3 Types of indicators

As described earlier in chapter 4.1-4.3, key figures express particularly informative facts. Key figures are generally divided into absolute figures and relative figures. Individual values are referred to as absolute figures. This can be, for example stocks (cash on hand), sums or differences (profit).[111] However, some authors have the opinion that absolute numbers on its own, without comparison with other numbers, do not develop expressiveness. Therefore they could not be counted to indicators. This doubt is not given by relative ones.[112] In the so-called relative numbers or relationship figures two distinct but factually related variables are taken into relation. A size for different characteristics is made comparable over the denominator. Rates of return with different use of capital can be compared with each other. In contrast, absolute profit amounts are without any information and therefore hardly meaningful. Numerator and denominator can have the same dimension. However, it is not absolutely necessary. Rather, a meaningful relationship is important. Therefore, it cannot set arbitrary sizes in relation to each other. The counter sets the value to be measured. The denominator is a measure.

The relative key figures are generally divided into three types of indicators [s. image 13].

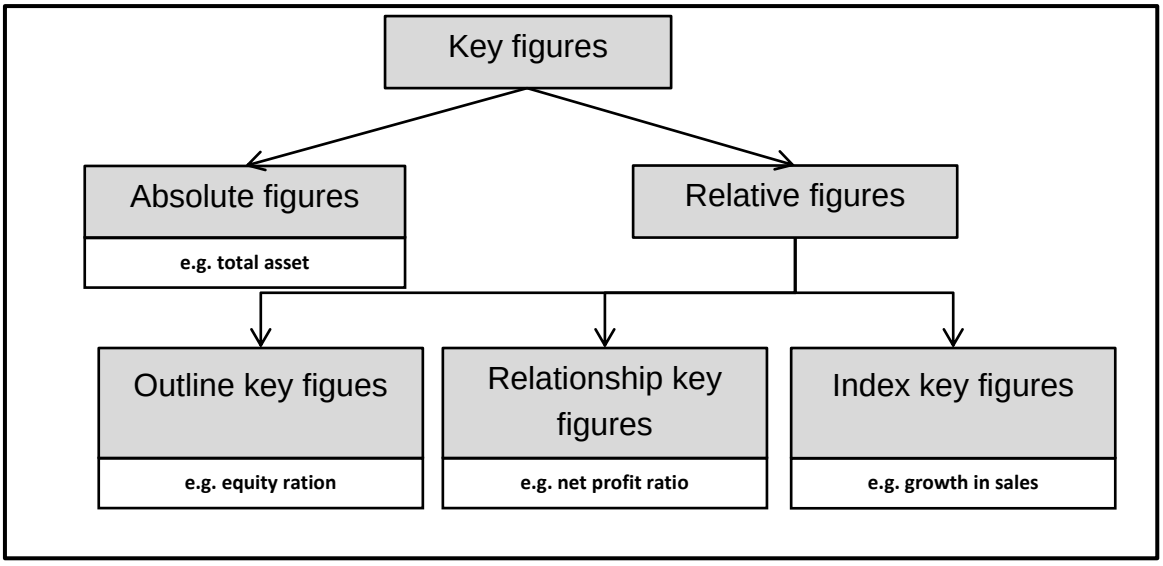


Image 13: Different types of indicators[113]

- **Outline figures:** These are often graphically illustrated in pie charts. They specify a portion of a size to a total amount (E.g. Equity / total capital). As can be seen, a material connection between the two variables should be given.

[111] cf. Dellmann / Pedell (1994), p. 106.
[112] cf..Gladen (2003), p. 16.
[113] cf. Gladen (2003), p. 17.

Both sizes are the same dimension. Thus, the weight of the meter size can be estimated.[114] Especially this is a help for the managers, because they can see the degree of fulfillment of objectives (e.g. market share).

- **Relationship figures:** These key figures establish a relationship between unequal numbers, which are suspected that they have a cause-effect relationship. Numerator and denominator have almost always different dimensions. Often it is not clear which size should be in the denominator or the numerator. If this is the case, the effect key figure is in the numerator and in the denominator is the cause key figure. The interpretation is facilitated if a positive related key figure (such as cost effectiveness) rises at a desirable development in the value. Examples of this would be Per capita revenue, profitability, economy feasibility, etc.
- **Index figures:** These are metrics with which, for example, a time series or a time variation of data can be displayed in a clear manner. Examples would be a price index, cost index, etc. At the beginning of the period under observation, the initial values are set to 100 as an underlying. Now all the other numbers from the time series are taken into consideration with the base 100. They are all expressed as a percentage. Thus, developments can be presented more clearly. Furthermore, no absolute figures must be disclosed.[115]

The subsequent image provides an overview of the possibilities of key figure systematization. In part, it has already been discussed in the text. In some cases there are additional terms.

[114] cf. Dellmann / Pedell (1994), p. 106 f.
[115] cf. Gladen (2003), p. 16 f.

Systematization feature	Types of business figures						
Business function	purchasing	warehouse management	production	sales	HR	finance	
Statistically methodological aspects	absolute numbers				ratios		
	single numbers	sums	differences	average values	relationship numbers	outline numbers	index numbers
Quantitative Structure	aggregates				portion sizes		
Temporal structure	point of time sizes				period sizes		
Content structure	value sizes				volume sizes		
Cognitive value	key figures with						
	autonomous value				dependent value		
Sources in Accounting	key figures of the						
	balance sheet		accounting		expenses, results of operations and cost accounting		statistics
Elements of the economic principle	input		result		standards of relations between input and result		
Territory of the statement	total operating metrics				part operation metrics		
Planning considerations	target indicators (forward-looking)				actual indicators (backward-looking)		
Number of participating companies	single operating metrics		enterprise metrics		industrial sector metrics		total operating metrics
The range of determination	standard metrics				business specific metrics		
Power of the company	cost-effectiveness metrics				key figures about financial security		

Table 1: Possibilities for the systematization of operating indicators[116]

[116] cf. Hienerth (2010), p. 38.

Type	Formula	Example
Key figures species by quantitative structure		
Type A	absolute numbers as whole or partial size	Turnover, employees, total assets, fixed assets
Type B	Relative numbers as $\frac{total\ size}{total\ size}$	Turnover per employee
Type C	Relative numbers as $\frac{section\ size}{total\ size}$	Ratio of equity to total capital
Type D	Relative numbers as $\frac{total\ size}{section\ size}$	Ratio of equity to total capital
Type E	Special forms of total or section sizes	optimal lot size, order quantity
Key figures species by the content structure		
Form 1	Amount or $\frac{quantity}{quantity}$	Employees, percentage of women and men
Form 2	Value or $\frac{value}{value}$	Sales, return on equity
Form 3	$\frac{quantity}{value}$	price elasticity
Form 4	$\frac{value}{quantity}$	Turnover per employee
Key figures species by the temporal structure		
Variant a	Time amount or $\frac{time\ moment\ amount}{time\ moment\ amount}$	Total assets, equity ratio
Variant b	Period or $\frac{period}{period}$	Net income, cost of materials, personnel expenses ratio, return on sales
Variant c	$\frac{time\ moment\ amount}{period}$	Stock turnover in days
Variant d	$\frac{period}{Time\ moment\ amount}$	return on equity

Table 2: Quantitative, content and temporal structure of indicators[117]

[117] cf. Meyer (2011), p.24.

5 Performance measurement systems

There is a difference in terminology. Performance measurement systems do not denote the same as key figure systems. For a performance measurement system not only conventional decision variables are selected. Rather, in this system, also the soft factors play a role, such as customer and employee satisfaction. In addition, criteria like caused costs, time, quality and number of new customers of a company are of importance. They are used to assess the effectiveness and efficiency of the operation. The performance appraisal stands at the center of strategic planning.[118]

The term “performance measurement system” is mainly used in the strategic enterprise level because of the consideration of "soft" factors. Whereas the term "key figures system" is especially used in the operational level because of the consideration of the "hard" factors.[119]

In the following work, however, there is no longer a strict distinction between key figure systems and performance measurement systems, because the term “performance measurement systems” represent a development of the indicator systems.

5.1 Classification of performance measurement systems

For the classification of performance measurement systems, different features are used. In the literature a distinction is made mainly by the characteristic scale of *MEYER* [see image 18]. Furthermore, in addition to this catalog, there are other features listed, especially in the more recent management literature. These are class, quantifiable, dimension, shape representation and connection characteristics.[120]

These features will now be discussed in more detail in the following chapters.

5.1.1 The connection between the key figures

An isolated view of single figures (the characterization of individual ratios took place in chapter 4) usually leads to inconsistent and contradictory statements. Often, this makes a concrete statement about a development impossible. To avoid this, measures are related to each other. A distinction is made between three types. A

[118] cf. http://www.controllingportal.de/Fachinfo/Konzepte/Performance-Measurement.html, [read on: 09.10.2014]
[119] cf. http://www.controllingportal.de/Fachinfo/Konzepte/Performance-Measurement.html, [read on: 09.10.2014]
[120] cf. März (1983), p. 23.

distinction is made between the logical, empirical and hierarchical relationship types.[121]

- **Logical relations:** In this field, a distinction is made again between definitional and mathematical connection. Is the Relationship between the figures based on a conceptual distinction, such as turnover, it is spoken of a definitional context. However, the relationship is based on mathematical rules, such as ROI, it is spoken of a mathematical relationship.

- **Empirical relations:** Empirical relations apply in contrast to the logical relationships in the operational reality as confirmed. They are considered relevant to the decision. They are mapped in the form of stochastic or deterministic working hypotheses. The deterministic relations are used for reasons of simplicity and because of subjective decisions.

- **Hierarchical relations**: It requires an internal target hierarchy to represent a ranking between the different metrics. A distinction will be held again. There is a distinction between factual-hierarchical and subjective-judgmental indicators contexts. Objectively-hierarchical relations point to an objective ranking, which is made by the operational reality. Subjective-judgmental indicators' contexts, however, are mostly based on targets of certain divisions or persons. They lead to primary and secondary key figures.[122]

[121] cf. Hienerth (2010), p.39.
[122] cf. Hienerth (2010), p.40.

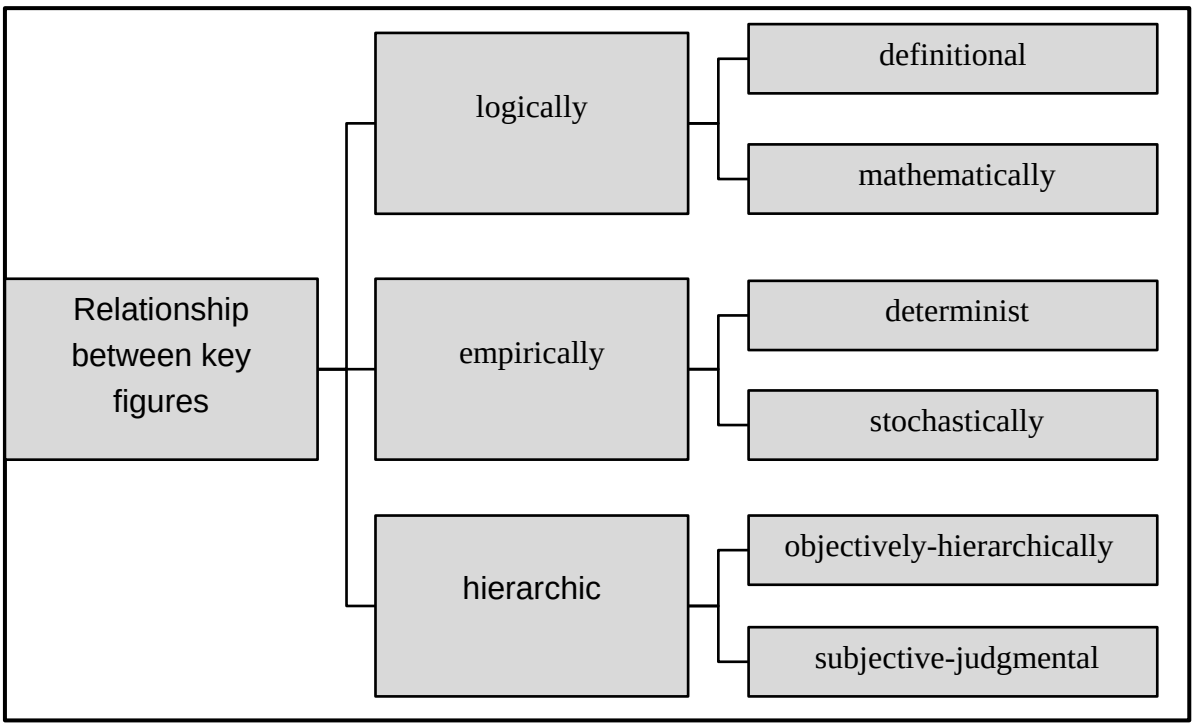


Image 14: Relations between key figures[123]

5.1.2 Definition of performance measurement systems

Companies, together with their tasks, are becoming increasingly complex. Individual key figures may not adequately describe the situation and reflect the facts. To solve this problem, several key figures must be used simultaneously in a systematic way. In a mere accumulation of key figures it is difficult to derive a clear analysis. Is the present key figure amount less with structure, problems may arise. The danger is that the respective user arbitrarily selects key figures and interprets them to his favor or individual goals. Due to the complexity also the acceptance of such key figures collections decreases.[124]

The term “key figures system” describes the amount of sorted key figures. Key figures show the connections between various sizes and mediate economically meaningful statements about the companies and their parts. Performance measurement systems or key figures systems can be derived for analysis purposes and for control purposes.[125] The individual elements are therefore in a factually meaningful connection to each other. They supplement and explain. They are also aligned to a common overarching goal. Crucial for a performance measurement system is the selection of one or more key figures that act as a "peak". One can distinguish between multiple key figure systems. There are classification systems,

[123] cf. Hienerth (2010), p. 39 f.
[124] cf. Preißler (2008), p. 17.
[125] cf. Gladen (2003), p. 91.

computing systems and mixed forms. These consist of computing and classification systems.[126]

5.1.2.1 Computing / mathematical systems

In computing systems there is always a head-key figure. From the top all measures or key figures are brought mathematically and logically in connection to each other. The formula for the most important indicator is gradually broken down and divided. Here, its conclusion is analyzed.

This head-key figure is a fundamental statement about the company. Starting from the top-level indicators and other key figures are formed. The complete decomposition resembles a tree diagram or a pyramid. One of the most well-known computing systems is the “Du Pont System of Financial Control”. A disadvantage of this system is that not all key figures are initially related. Sometimes there must be introduced the so called auxiliary-indicators, which provide no additional information.[127]

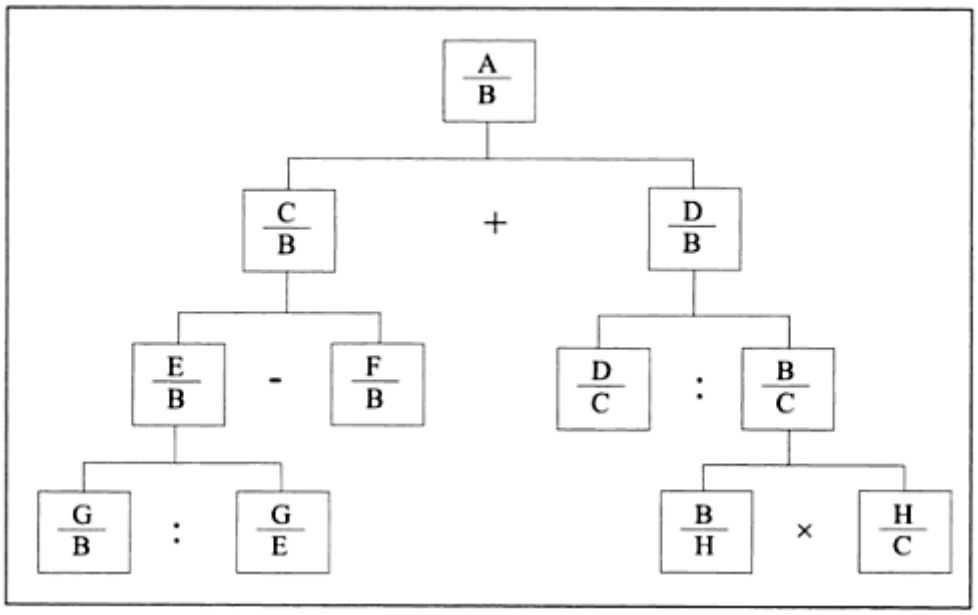


Image 15: Example of a computing system[128]

5.1.2.2 Classification systems

Classification systems are performance measurement systems in which key figures are not related by arithmetic operations. They are structured properly and logically linked together by various circumstances. With these systems, limits of computing systems can be overcome. Key figures will be added to the system, which cannot be

[126] cf. Preißler (2008), p. 17.
[127] cf. Preißler (2008), p. 18 f.
[128] cf. Preißler (2008), p. 18.

linked together in a mathematic-logically way. Classification systems thereby show a higher flexibility. There is only one major drawback due to the higher flexibility. The quantitative connections between the indicators are not explicitly shown. In some cases, they remain completely unclear. In addition, oftentimes a certain subjectivity of key figures selection cannot be avoided.[129]

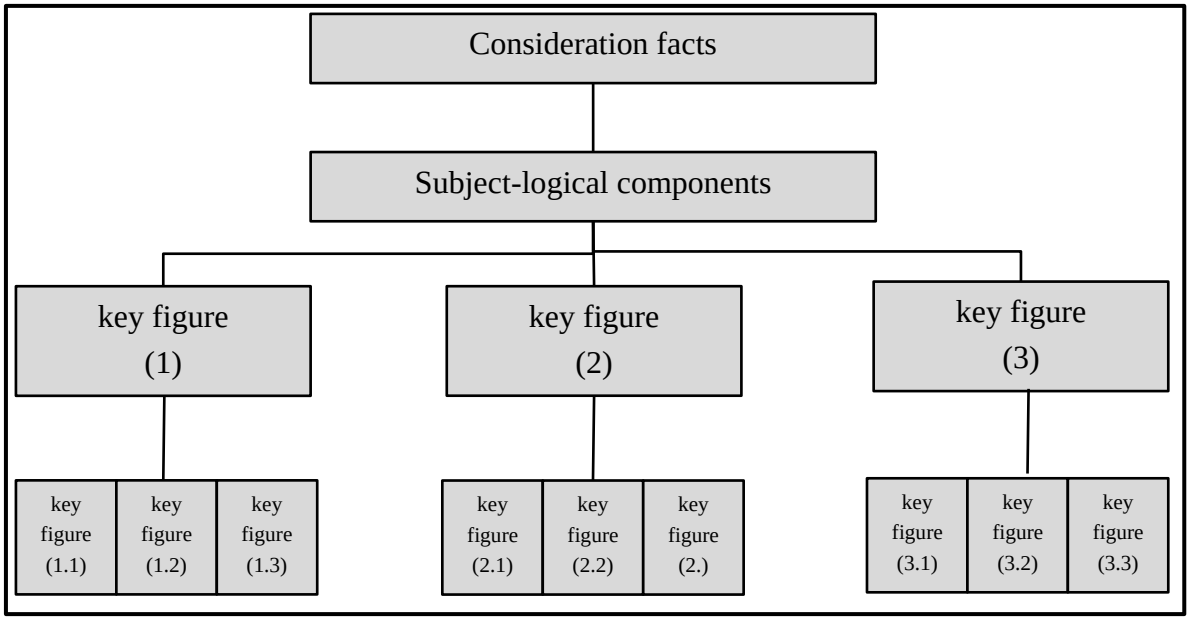


Image 16: Example of a classification system[130]

5.1.2.3 Mixed form of classification systems and computing systems

Performance measurement systems can include both characteristics of a computing and a classification system. The characteristics of key figures in the mixed form usually have characteristics of both systems. Advantages of both systems can be used. At the same time the shortcomings can be circumvented. This ensures that many relevant indicators are included and the formation of unnecessary auxiliary-indicators is avoided.[131]

[129] cf. Gladen (2003), p. 120 f.
[130] cf. Gladen (2003), p. 120.
[131] cf. Preißler (2008), p. 21 f.

Systematization feature	Types of business performance measurement systems				
After the combination of the elements	Computing Systems (quantifiable elements and quantified elements relationships)		Classification systems (quantifiable element and not quantified elements relations)		
	causal connection		no causal connection		
	deterministic connection		heuristic connection		
After the position in occupational social system	Performance measurement systems as				
	Target systems	Decision systems	Communication systems	Control systems	
By the method of development	Inductively derived performance measurement systems		Deductively derived performance measurement systems		
According to the type of the measured facts	Performance measurement systems for the measurement of structures		Performance measurement systems for the measurement of processes		
After the temporal dimension	Performance measurement system with plan (target) figures (planning systems)		Performance measurement systems with actual figures (control systems)		
	temporary		in the long term		
	discontinuous		steady		
	static		dynamic		
After the membership of a corporate function	Performance measurement systems from the function				
	Purchasing	Warehouse Management	Production	Personnel	Finance
After oriented usage	Performance measurement systems for analysis	Performance measurement systems for documentation	Performance measurement systems to control		
	action-oriented	augmenting knowledge	affective		
After drawing object	universal		situational		
	unidimensional		multidimensional		
	cross-functional		function-specific		
	multi-agency		job specific		
	strategically		operative		
	product-related		customer-related		
	potential-related		instrument-related		
After the seclusion	closed		open		
After the IT support	IT supported		Not IT supported		

Table 3: Design possibilities of performance measurement systems[132]

[132] cf. Hienerth (2010), p. 42.

5.2 Requirements for performance measurement systems

In the past, performance measurement systems have proven themselves with a hierarchical structure. Through a hierarchy manifold demands on key figures and performance measurement systems can be better complied.

These requirements are:

- **Clarity:** If a system is clear and well established, it may have more key figures without being cluttered.
- **Simplicity:** Are they used for supervision a limited number is of advantage.
- **Compression of information:** Due to the hierarchical structure, it is possible to be guided by a few key figures. Measures should be compacted meaningful. Only in exceptional cases or in cases of problems in lower levels should be searched for solutions.
- **Multi-causal analysis:** Hierarchically arranged levels allow a “multi-causal” analysis of key figures. Parent key figures are broken down into the underlying. It can thus identify the dependencies. An example of this is: The measure profitability. Here the profit is “mono-causally“ explained by the use of capital.
- **Objectivity and consistency:** The connection in a system restricts the subjective approach and the ability to interpret statements contradictorily.[133]

5.3 Functions of performance measurement systems

Performance measurement systems should be able to operationalize company-specific target systems. They should be able to be used as a control and coordination tool. It is possible to map and track multiple targets in a performance measurement system. However, it must be ensured that the goals are not in conflict with each other. With performance measurement systems goals are mapped and visualized in a comprehensible way. Besides, they also have a declaration-function. With their help, connections and developments are illustrated in the company.[134] As it can be seen in the definition and construction of performance measurement systems, they can also take the function as an early warning system. For this purpose, a performance measurement system must have metrics with corresponding properties. It should contain so-called early warning indicators. The function, which finally a

[133] cf. Gladen (2003), p. 92.
[134] cf. Reichmann (2001), p. 24.

performance measurement system satisfies, always depends on its structure. The existing data base and especially the respective user play a crucial role.[135]

5.4 Time evolution of performance measurement systems

This chapter describes briefly the historical development of performance measurement systems. After this chapter it will become clear why the term "performance measurement system" is fundamentally used today and how it ever got to that name. In the previous chapter it was established that the use of the term “performance measurement system” for this work is predominantly used. However, this term reflects only the last stage of development of the indicator system. In order to distinguish the different stages, the term “indicator system” is reintroduced shortly.

Indicator systems can basically be divided into three categories. These are the traditional indicator systems, the value-oriented indicator systems and the performance measurement systems.

Before a detailed explanation is given, a broad overview of the indicator system evolution should be given.[136]

Since the early nineties of the last century, we can observe a trend towards increased non-financial metrics. It is tried to make indicator systems more future-oriented and balanced. In this way they are more accessible to a variety of stakeholders.[137]

[135] cf. Schreyer (2007), p. 42.
[136] cf. Berndt (2007), p. 88 ff.
[137] cf. Schreyer (2007), p. 42.

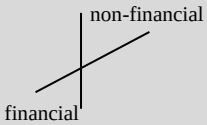
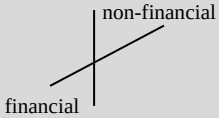
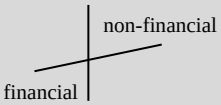
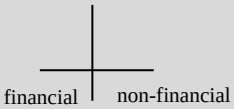
	till 1970	since 170	since 1980	since 1990
New instruments ratios based management and control.	- DuPont key performance measurement system - Tableau de Bord	-ZVEI key performance measurement system - RL key performance measurement system	- Shareholder Value - ABC, ABM, PKR - Total Quality Management	- Balanced Scorecard - Intellectual Capital Management - Risk Management
Categories of financial ratios	- profit (operating profit) - liquidity - yield (ROI)	- profit - liquidity - yield (RONA)	- profit - liquidity - yield - value	- profit - liquidity - yield - value
Categories of non-financial ratios	- quality (waste) -productivity	- quality - productivity - market	-quality - productivity - market - customers - employee - processes	- quality - productivity - market - customers - employee - processes - suppliers - knowledge
Relation of financial and non-financial ratios				

Table 4: Development stages of indicator systems[138]

5.4.1 Phase 1: Traditional financial indicator systems.

In the consideration of the historical development of indicators, one initially thinks of financial ratios. These are mostly cost-effectiveness and liquidity sizes from cost accounting. An example of this would be the return on sales and derived key figures. The classic forerunner of all indicator systems is the DuPont system [see appendix 1], which was developed in 1919. This refers to data from the accounting system. The top figure is the ROI. This is mathematically decomposed into their generating key figures. These are indicators such as corporate profitability, turnover of assets, total assets, current assets or fixed assets. From today's perspective, the inflexibility of the system and the imbalance of the key figures are problematic. They only allow a description at the highest corporate line with financial variables. In addition, often the ROI does not correspond to the company's objectives. The financial indicator

[138] cf. Schreyer (2007), p. 43.

systems also includes the RL system and ZVEI system [s. appendix 2], which was developed in 1969.[139]

5.4.2 Phase 2: Value-based indicator systems

Financial ratios have limited explanatory power about the state of a company. They are not unique due to different assessment options. In addition, the value of the invested capital is not considered. This is problematic, because the correct value of the company is not played back. For this reason, the company may be exposed to a constant threat of takeover. This is the reason why in addition to financial data flows (cash-flow ratios) and discounting have prevailed. They also offer the possibility for the introduction of "shareholder" perspective. Derived key, as the DCF (Discounted Cash Flow) is called value-oriented indicators.[140] In contrast to financial indicators value-oriented indicators are not only focused on the past but also include forward-looking expectations.[141] Therefore appropriate indicator systems are based on a purely mathematical combination of figures and are unlikely to be able to reproduce the complexity of actual corporate structures. In particular, operational levels are not considered. The dynamics of corporate and product developments can only be mapped insufficient.[142]

While traditional indicator systems typically use profit-based key figures as head-key indicators, which are mathematically broken down into further financial measures, value-oriented head-key indicators are characteristic for value-based indicator systems. Value-based key performance indicators usually describe an excess profit (e.g. EVA - Economic Value Added, appreciation value of a company in a period) or a derived key figure from a payment size (e.g. CVA - Cash Value Added, DCF - Discounted Cash Flow).[143] The detailed representation of individual systems is omitted here, because they are primarily in use in listed companies and present themselves as very complex.[144]

Known value-oriented indicators and indicator systems:

- Return on Capital Employed (ROCE) and Return on Average Capital Employed (ROACE) as profitability ratios. These are related to the return on total capital.
- Economic Value Added (EVA) as value size. These are the capital proceeds less cost of capital.

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[139] cf. Berndt (2007), p. 88 f.
[140] cf. Berndt (2007), p. 89.
[141] cf. http://www.wirtschaftslexikon24.com/d/wertorientierte-kennzahlen/wertorientierte-kennzahlen.htm, [read on: 15.09.2014]
[142] cf. Berndt (2007), p. 89.
[143] cf. Weber (2005), p. 390
[144] cf. Resch (2004), p. 92 f.

- Cash flow return on investment (CFROI) as a measure of profitability. A real cash flow is used as a financial size instead of a profit variable. Cash Value Added (CVA) as added value, which is calculated over a predetermined interest rate.
- Shareholder Value (SHV) is a modern value and variant of an enterprise value determination. Objective is to assess the company based on discounted, future cash flows minus the market value of borrowed capital.

In the financial indicator systems, the claims of equity investors and business risk are not considered. By focusing on the business value they are involved. Thus, in addition to the efficiency the profitable growth of the company's value can be measured. Value indicators have the advantage that they take into account the risk to the actual cash money.[145] But a real future orientation cannot be attributed to them also. Therefore, it is very questionable whether a successful corporate control can be achieved with only value indicators. Seems sensible to use some value-based indicators as part of another indicator system or as an additional information gain besides a self-contained measurement system. A further development of value-based indicator systems towards a multidimensional and integrative perspective is represented by the concept RAVE (Real Asset Value Enhancer) by the Boston Consulting Group. It maps the relevant success factors of a company. Furthermore, there are considered besides the capital-related value contributions also customer and employee specific, so called immaterial, value contributions. Through analyzes all value drivers for each success factors are being identified. Then they are deposited with conventional metrics.[146]

5.4.3 Phase 3: Selective indicators and "performance measurement" systems

"Performance Measurement" systems demand balance of performance indicators and a high degree of flexibility. They are therefore largely freed from a rigid indicators concept. Instead, the establishment of appropriate indicators requires a certain methodology that requires the participation of company employees to indicators development and implementation. To ensure a better picture of actual business processes, so-called "performance measurement systems" were introduced, based on selective indicators. It should take place to assess the effectiveness and efficiency of the power and potential of different objects in the enterprise. The key performance indicators and performance measurement systems should be systematically aligned to strategic objectives and success factors of a company. A corresponding indicator system should close the gap between value orientation, strategy and operational performance. Therefore, it plays a central role in the control and strategy process.

[145] cf Lelke (2005), p. 27 f.
[146] cf. Berndt (2007), p. 90.

They should also meet the strategic goal-directions and allow an implementation and evaluation of policies at all operational levels. The structuring of such indicators depends on their settlement in the corporate hierarchy, the access rights and the functional- and time-specific weighting. An example would be: At the beginning of a product life cycle, the increase in market share is more important than the profit, which is gained with the product. This relationship is reversed later.

The best-known performance measurement systems in this group are the EFQM (European Foundation of Quality Management System) model [s. appendix 3] and the Balanced Scorecard (BSC) [s. appendix 4].[147] The EFQM model was introduced in 1991 as a framework directive for the self-assessment of organizations and as a basis for a three-level award program by the European Foundation for Quality Management.[148] The Balanced Scorecard was developed in the early nineties by Robert S. Kaplan and David Norton E.[149] In this phase of performance measurement systems, the requirement for targeting of key figures reveals. It also tries to point out the balance of the late and early indicators and the different internal and external perspectives with their short and long-term goals.[150]

[147] cf. Berndt (2007), p. 91.
[148] cf. http://wirtschaftslexikon.gabler.de/Definition/qualitaet-efqm-ktq-qep.html#head2, [read on: 10.09.2014]
[149] cf. http://www.wirtschaftslexikon24.com/d/balanced-scorecard-bsc/balanced-scorecard-bsc.htm, [read on: 10.09.2014]
[150] cf. Berndt (2007), p. 91.

6 Criteria catalog for the implementation of the characterization

In this chapter, no new knowledge is brought. It should only serve as a summary and overview, what criteria are selected to characterize chosen indicators in chapter nine. So, a criteria catalog is introduced, which is created from the insights of chapters four and five. This criteria catalog is mainly composed of the tables one, two and three from the chapters four and five. In addition, the hierarchy levels and the relationship between key figures were registered.

Criteria catalog for key figures:

Systematization feature	**Types of business figures**					
Business function	purchasing	warehouse management	production	sales	HR	finance
Hierarchy level	Strategic management		Division		Shop floor	
Statistically methodological aspects	absolute numbers			ratios		
	single numbers	sums	differences	average values	relationship numbers	outline numbers	index numbers
Quantitative Structure	aggregates			portion sizes		
Temporal structure	point of time sizes			period sizes		
Content structure	value sizes			volume sizes		
Cognitive value	**key figures with**					
	autonomous value			dependent value		
Sources in Accounting	**key figures of the**					
	balance sheet	accounting		expenses, results of operations and cost accounting		statistics
Elements of the economic principle	input		result		standards of relations between input and result	
Territory of the statement	total operating metrics			part operation metrics		
Planning considerations	target indicators (forward-looking)			actual indicators (backward-looking)		
Number of participating companies	single operating metrics	enterprise metrics		industrial sector metrics		total operating metrics
The range of determination	standard metrics			business specific metrics		
Power of the company	cost-effectiveness metrics			key figures about financial security		

Table 5: Possibilities for the systematization of operating indicators[151]

[151] cf. Hienerth (2010), p. 38.

Criteria catalog for performance measurement systems (Relationship between indicators has been extended to this catalog)**:**

Systematization feature	**Types of business performance measurement systems**					
After the combination of the elements	Computing Systems (quantifiable elements and quantified elements relationships)				Classification systems (quantifiable element and not quantified elements relations)	
	causal connection				no causal connection	
	deterministic connection				heuristic connection	
Relationship between key figures	Logically		Empirically		Hierarchic	
	Definitional	Mathematical	Deterministic	Stochastic	Objectively-hierarchically	Subjective-judgmental
After the position in occupational social system	Performance measurement systems as					
	Target systems	Decision systems	Communication systems	Control systems		
By the method of development	Inductively derived performance measurement systems				Deductively derived performance measurement systems	
According to the type of the measured facts	Performance measurement systems for the measurement of structures				Performance measurement systems for the measurement of processes	
After the temporal dimension	Performance measurement system with plan (target) figures (planning systems)				Performance measurement systems with actual figures (control systems)	
	temporary				in the long term	
	discontinuous				steady	
	static				dynamic	
After the membership of a corporate function	Performance measurement systems from the function					
	Purchasing	Warehouse Management	Production	Personnel	Finance	
After oriented usage	Performance measurement systems for analysis		Performance measurement systems for documentation		Performance measurement systems to control	
	action-oriented		augmenting knowledge		affective	
After drawing object	universal				situational	
	unidimensional				multidimensional	
	cross-functional				function-specific	
	multi-agency				job specific	
	strategically				operative	
	product-related				customer-related	
	potential-related				instrument-related	
After the seclusion	closed				open	
After the IT support	IT supported				Not IT supported	

Table 6: Design possibilities of performance measurement systems[152]

[152] cf. Hienerth (2010), p. 42.

7 Performance measurement systems for individual functional areas

In the same extent as for the company itself, performance measurement systems can be generated for individual functional areas. This chapter will first briefly discuss the formation of performance measurement systems. Furthermore, especially the area of production is examined more closely.[153]

7.1 Creation of performance measurement systems for individual divisions and selection of key figures

KÜPPER mentions a number of development systems. These are:

- Logical derivation of performance measurement systems
- Empirical-theoretical foundation of performance measurement systems
- Empirical-inductive recovery of performance measurement systems
- Model-based derivation of performance measurement systems
- Combination of the individual methods

In the following it will be not discussed every development. It is only a short overview of the different development systems.

About empirical-theoretical foundation for performance measurement systems is spoken, when one uses theoretical statements and hypotheses for the development of performance measurement systems. The Business Administration has the limited extent of empirical hypotheses that can be considered confirmed.[154] In the production area such empirical cause-and-effect relationships seem to be possible. However, even here, these relationships are very complex. Furthermore, this area is subject to a permanent rapid environmental change. If there is little hope in a stable environment, then the empirical-inductive recovery of performance measurement systems can be used as a way out.[155] In this method, key figures are important predictors or indicators whose influence is justified neither logical nor about cause-effect relationships. Inductive recovery means that indicators are developed from empirical knowledge. On the one hand experts from the individual departments can be consulted. On the other hand empirical data can be evaluated by the help of statistical methods. Although this knowledge can be regarded as inaccurate and

[153] cf. Gladen (2011), p. 243.
[154] cf. Küpper (1995), p. 326 ff.
[155] cf. Gladen (2011), p. 244.

incomplete, it is considered probable in this context. And because of this, it is classified as “plausible”.[156]

Through the formal structures of performance measurement systems, approaches have been presented for the formation of performance measurement systems. The relief of information for the management is not always provided in practical implementation. The selection of key figures is often not based on objective criteria. Key figures emerge commonly through trial and error. Key figures are often designed according to the information, which is procurable. If such key figures are taken for the control as a basis, there is a risk that they do not serve the highest, long-term corporate objectives. This is the case in a fast and rapid changing corporate environment. It often results in a juxtaposition of many key figures, because many key figures have only an indicator function.[157] In many cases you look for salvation in a multitude of key figures. Because of the complex interactions several sizes side by side viewed as determinative for the same key figures. However, this is also based on incomplete knowledge and the non-testable theoretical contexts in empirical inductive recovery.[158] In the past, measures have been completed in barely manageable wide. This meant not always a solution of the problem.

To obtain a discharge in information, a reasonable selection of key figures is to be made. In addition, "graveyards of numbers" will be avoided.

Key figures can be generated, in principle, from two directions. This is on the one hand the "top-down" principle, on the other hand, the "bottom-up" principle.[159]

7.1.1 Top-down

In the top-down principle the main goal is estimated. Thereof corresponding sub-goals are derived for the various areas of responsibility. All areas have hereby the task of achieving the sub-goals in their area of responsibility.[160] In this derivation a significantly importance is on the strategic and operational objectives. These are formulated in the planning system. It starts with the strategic success factors of the company in its markets. Then it leads to the formation of function-specific indicators. These support the current leadership. It can also be a collection of critical success factors by the executives.[161]

[156] cf. Küpper (1995), p. 332.
[157] cf. Gladen (2011), p. 245.
[158] cf. Küpper (1995), p. 333.
[159] cf. Gladen (2011), p. 245.
[160] cf. Posluschny (2007), p. 20.
[161] cf. Gladen (2011), p. 245.

7.1.2 Bottom-up

In the bottom-up principle the situation is the other way around. First, sub-goals are determined by the person in charge. The main objective is then calculated or derived from the sub-goals of the individual areas of responsibility.[162] It should selected those feature elements and reproduced in key figures, which expression is relevant and critical for the success.[163]

7.1.3 Relationship between the key figures

The "top-down" and "bottom-up" derivatives are brought together. It is about the question of whether and how to develop a closed system of key figures that is consistent in itself. A known reunification is the system of WEBER / KUMMER. Their starting point is a classification system that allows many different key figures relationships.

7.1.3.1 Key figures identity

Case 1: Identity of the key figures indicates that the objective is adapted to the problem areas in the processes of services. The bottom-up analysis of the influence factors in which the complexity and dynamics were measured, is in line with the top down analysis in which a strategic audit was conducted.

Case 2: The key figures are not identical and depict the same subject in different sizes, the relationship can be empirically-appropriate logical or mathematical functional.

A continuous, closed performance management system can be derived from the case 1 and 2. In case 2, the key figures derived from the strategies are less detailed.[164]

7.1.3.2 No relationship

Between top-down and bottom-up, no relationships can be produced when certain characteristics in the strategic objectives were not mapped or considered. The bottom-up parameters are included in this case only in the selective key figures selection, if they are needed for control functions.[165]

[162] cf. Posluschny (2007), p. 20.
[163] cf. Gladen (2011), p. 245.
[164] cf. Gladen (2011), p. 246 f.
[165] cf. Gladen (2011), p. 246 f.

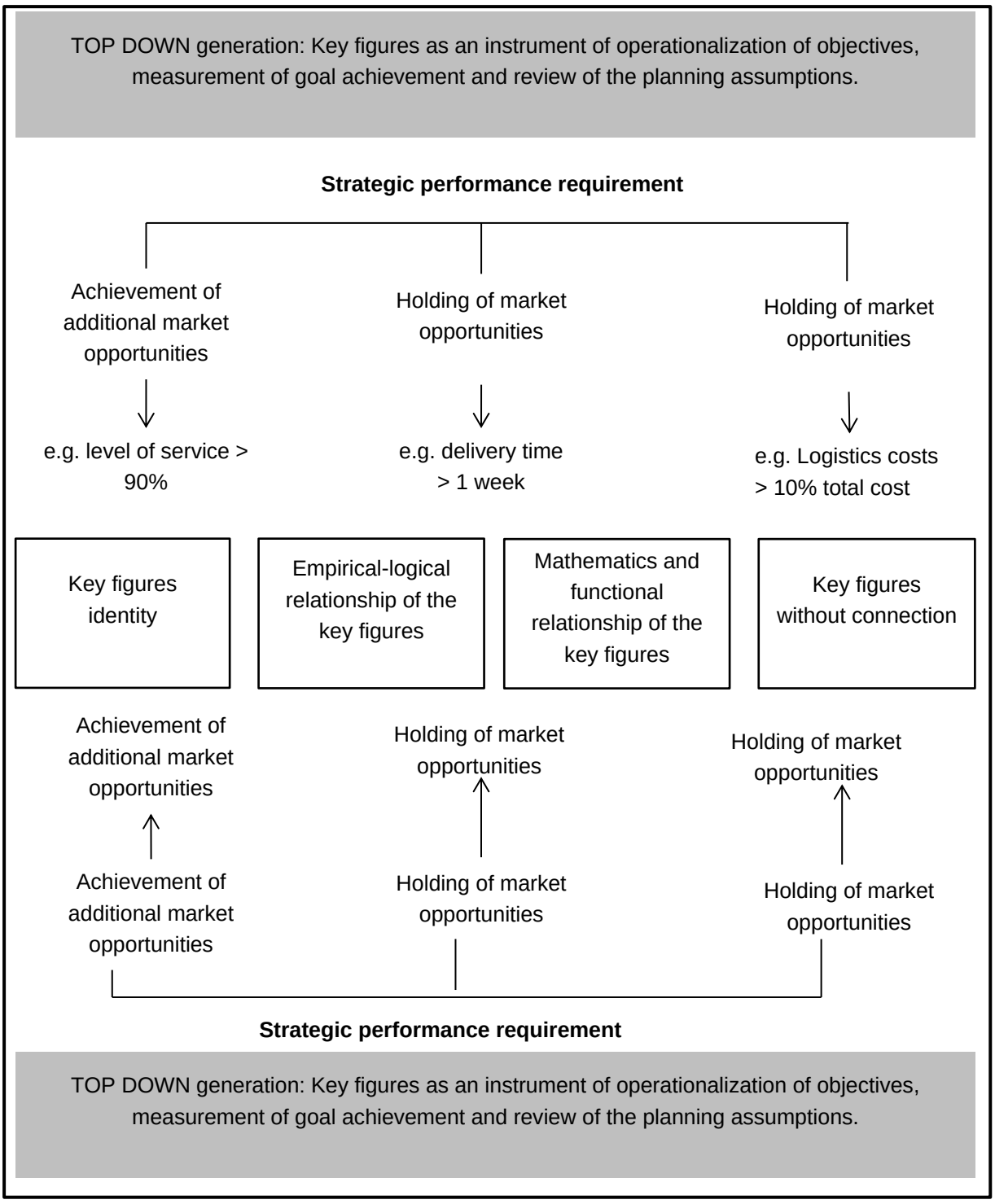


Image 17: Generation of selective indicators[166]

[166] cf. Gladen (2011), p. 246.

7.2 Attempt of classification of key figures to different hierarchy levels

As mentioned earlier [see chapter 7.1] the respective departments are responsible for themselves to look out the most meaningful indicators for their divisions. This can be either determined top-down or bottom-up.[167] However, since then it has been trying to provide the most important key figures in relationship to get some sort of structure in performance measurement systems according to hierarchy levels. This is a difficult task, because not automatically a special indicator can be assigned to exactly one hierarchy level. This in turn is different from company to company. The size of the company plays a certain role as well.[168]

In the next section, the main tools are briefly introduced. Here, no detailed explanation of each model takes place. This is not part of this thesis. Rather, it is an extract which various performance measurement systems developed over time. In fact, different approaches are shown that are undertaken to categorize indicators more closely:

- **Balanced Scorcard** [see Appendix 4]: The balanced scorecard represents the theoretical and practical best-known instrument of performance measurement. The balanced scorecard takes into account monetary and non-monetary metrics, measure performance of an organizational unit from external (Shareholder and costumer) and internal (Processes, innovations) perspective, services of an organizational unit from a strategic and operational point of view and consideration of trailing results (lag indicators) and leading targets (lead indicators). Therefore, the traditional financial metrics experience in the frame of the balanced scorecard concept a supplement in form of a customer perspective, internal process perspective and a learning and growth perspective. These areas should firstly identify trends as early indicators and reflect on the other hand the success of the past. The indicators used should be derived from the respective company's strategy, so that the operationalization of the corporate strategy is guaranteed. The use of a balanced scorecard should prevent optimizations in one of these areas are at the expense of another area, because a balanced consideration of the factors of success is to be guaranteed by the different perspectives.[169]

- **Tableau de Bord** [see Appendix 12]: The aim is the optimization of production processes, which should be achieved through a better understanding of cause-effect relationships between actions and process results. It is a

[167] cf. Gladen (2003), p. 67.
[168] cf. Giese (2011), p. 38ff.
[169] cf. Giese (2011), p. 47ff.

performance measurement system that tracks the most important success factors of a certain area. However, this system is only slightly structured and highly tailored to individual needs of the user. There is still no universal, unified approached Tableau de Bord till now, so that it can be flexibly configured and used. The goal of a Tableau de Bord is to describe the performance of each business unit in a concise manner. Since each division pursues different objectives and has various responsibilities, a single tableau de board is not enough for the entire company. Instead, each business unit needs its own Tableau de Bord, which is aimed specifically for the unit. The individual Tableaux de Bord are thereby connected to each other that the main objectives of a company are broken down into their constituents that the downstream business units, in accordance with its responsibilities, formulate objective, which are used to achieve the overall objectives. Thus, each division creates a sectorial Tableau de Bord for an overview of its performance and runs this result to the parent company level. This makes it possible to assess the contribution in the individual corporate divisions to the overall strategy of the company.[170]

- **Skandia Navigator** [see. Appendix 13]: The Skandia Navigator is one of the first performance measurement instruments, which measures the asset components which are non-deductible in the balance sheet. These include in particular the knowledge of the employees, the organizational knowledge of the company, for example, patents and technologies, as well as the brand name and customer base. The Skandia Navigator consists of five perspectives. The financial perspective looks at the past of the company based on backward-looking, financial ratios and thus shows the financial asset. The four other prospects reflect the intellectual assets of the company. This includes the employee, customer and process perspective and the renewal and development perspective.[171]

- **Performance Pyramid** [see Appendix 11]: This is a performance measurement tool which derives strategic objectives from the corporate vision and breaks down into three different performance levels of the company. The performance levels are hierarchical and are divided into business units, core business processes and departments / workgroups. Here, to each level indicators in specific categories are assigned. By splitting into four levels, it will be ensured that the objectives are derived top-down from the parent levels and the compression of the ratios is bottom-up.[172]

[170] cf. Giese (2011), p. 50f.
[171] cf. Kinne (2009), p. 106f. and Giese (2011), p. 52f.
[172] cf. Pleier (2008), p. 20f. and Giese (2001), p. 54f.

- **Quantum Performance Measurement** [see Appendix 14]: The Quantum Performance Measurement concept has been developed to optimize the company's performance. The degree of achievement, in which the power and the service of a company for the user is optimized, is called as Quantum Performance. In the concept, key figures, called Vital Signs, are used. These provide information on the achievement of certain steps within a process and the degree of achievement of the output of a process. The Vital Signs fulfill a special function by showing employees their contribution in the company and show them how this contribution is rated. The selection of indicators is guided by the corporate strategy and various stakeholders. Vital Signs are determined in the performance dimensions of quality, time and costs that are closely related to each other. The ratio of quality and cost represents for the customer a value relation and the relationship between quality and time a service relationship. The simultaneous optimization of performance dimensions ultimately leads to the Quantum Performance. In order to operationalize and control the simultaneous optimization of performance dimensions more easily, there is a splitting of organization, process and employee performance levels.[173]

After these examples it can be seen in how many ways the approach is to set up a performance measurement system. A classification strictly by hierarchical levels is difficult. Key figures cannot always be accurately allocate in certain levels of the hierarchy.

7.3 Key figures of the production sector

The core of the production activities are tasks that are involved in the value formation of the product for the buyer. These are, for example, machine parts processing or assembly. In the narrower sense it is meant by the production a qualitative transformation of inputs into a final product form. Spatial and temporal transformation of goods and control of material flow are counted among the tasks of logistics. The support functions of primary activities include the operation of the equipment, maintenance of equipment and production management. Quality assurance activities such as testing and inspection are included as well as the monitoring of key indicators of fluctuation, absenteeism, conflict and participation rate. In the service age a whole bundle of services belongs to the content. The comprehensive aim in the production area includes a whole range of services. This includes in the service age, in addition to the industrial core performance, a bundle of services, like the production of a good in its fixed feature which has a variable extent of services. These are, for example, logistic services.

[173] cf. Giese (2011), p. 57f.

The "production function" (or cost function), which is valid in the production area, is determined by long-term strategic preliminary decisions about the "production system". It also depends on the type of goods produced (mass production, contract manufacturing). A decision on the production system cannot be made without consideration of the logistic system, which includes customer and supplier. For example, a decision on the level of vertical integration is to be taken. The following basic characteristics determine the production system in the core:

- **Central versus decentralized production control:** Order of job processing is performed centrally by production control or decentralized by the staff.
- **Storage of semi-finished products versus storage of finished products:** Reduced storage costs with cheaper products vs. high level of service and short delivery times
- **Rigid versus flexible manufacturing system:** Inexpensive mass-produced with lower machine costs vs. flexible to meet individual customer needs with high machine costs
- **Sudden versus continuous product innovation:** Low production costs and high one-time conversion costs vs. high variety costs and low conversion costs

In the following two tables [s. image 20, 21] important performance indicators categories and their associated key figures are listed, which should be considered in the area of production.[174]

Categories of indicators	Determination / indicators
• **process result**	"Production volumes (absolute, relative)"
• **process control** cycle time punctuality quality	"Material value manufacturing inventory", "material used per day (subsequent period)"
	"Punctuality"
	"Production volumes 1st and 2nd choice"
	"Committee (quantity, quote)"
	"Quote of the rework"
• **production logistics** Degree of readiness for delivery Coverage of orders (per product, per module)	"Number of delivered parts", "number of ordered parts"
	"actual stock", "consumption per day"

Table 7: Key figures for the objectives in the production[175]

[174] cf. Gladen (2011), p. 279 ff.
[175] cf. Gladen (2011), p. 280.

Categories of indicators	Determination / indicators
• **Target / actual deviation**	"Single and overheads deviation"
	"Cost center deviation"
	"Special deviations (lot size, product mix, process)"
• **process control** quality GK reduction of preventable "Non-Value-Added Activities" organizational structure	"First-pass yields" / "Committee" / "Return costs"
	"Rework costs" / "guarantee costs" / "maintenance costs" / "disposal costs"
	"Batches" / "set-up costs"
• **productivity**	"Output", "machine hours and hours of work or energy use"
	"Value", "inventory costs depending on capital employed"
• **Materials / purchased parts**	"Consumption", "availability", "quality", "waste", "waste"
• **Capacity utilization of the machines**	Processing time", "down time", "set-up times," capacity "," availability "
• **capital investment**	"Turnover Inventories", "fixed assets", "plant utilization rate", "payback"

Table 8: Key figures for the success objectives in the production[176]

Important and most common key figures for companies are briefly mentioned in the next section, which are more technical in nature. This often can be found in the literature for the production division.

Such a key figure is, for example, the capacity utilization. It is the ratio of production hours and machine hours. With this key figure it is expressed in which extent companies succeed to exploit their capacities by order situation and working time models.

$$capacity\ utilization = \frac{actual\ production\ hours}{machine\ hours} * 100\%$$

Formula 1: Capacity utilization[177]

Another measure is the productivity. It is the ratio of output quantity and input quantity of a particular factor.

$$productivity = \frac{output}{input}$$

Formula 2: Productivity[178]

If this ratio weighted by the respective prices, the result is the economy.

[176] cf. Gladen (2011), p. 281.
[177] Brecht (2012), p. 214.
[178] Brecht (2012), p. 214.

$$productivity = \frac{output * sales\ price}{input * cost\ price}$$

Formula 3: Productivity (weighted by the respective prices)[179]

Another important variable for a company is the stock. Capital is tied up by storage.

By the average inventory capital commitment is expressed in the warehouse.

$$average\ inventory = \frac{initial\ inventory + endign\ inventory}{2}$$

Formula 4: Average inventory[180]

Another important indicator is the duration of storage. This shows the average length of stay of goods in the warehouse.

$$average\ duration\ of\ storage = \frac{average\ stock}{material\ consumption\ of\ a\ period} * 365\ days^{181}$$

Formula 5: Average duration of storage[182]

This was now only a small selection of indicators. But they play a relatively important role in any business, because in them it is quickly recognizable, where savings can be conceded. A closer hierarchical overview of the most important indicators in the production is given in the appendix of this work [s. appendix 5].[183]

7.4 Danger of an oversized key figures registration

The idea of controlling is, everything with key figures is tempting. Instead of subjective assessment only objective results count. Discussions about performance of departments and resources are no longer guided by faith approaches, but of analytically derived requirements. This idea would be ideal for a corporate management. In this view, however, there is often a problem. It is often decided by managers how key figures are defined, how they are fixed and how they are measured. Here, all subjective assessments and personal motives play a role. One problem is that the performance of managers is measured by whether they achieve the highest possible value. Whether a value is however considered to be high or low, is first of all a question of scale and definition.[184]

[179] Brecht (2012), p. 214.
[180] Brecht (2012), p. 215.
[181] Brecht (2012), p. 215.
[182] Brecht (2012), p. 215.
[183] Vgl. http://www.awf-arbeitsgemeinschaft.de/download/Kennzahlen-in-der-Produktion-awf.pdf, p. 8ff.
[184] cf. Paul (2014), p. 235.

An example of this would be the indicator of "customer satisfaction". A review by polls can be very different. It is quite possible that a situation depending on the wording of the questions is subject to large fluctuations, although this was performed by the same person. From an economic perspective, however, tremendous efforts and substantial investments are needed to increase customer satisfaction. To improve the result of using "friendly" formulated questions, however, is a far less time-consuming and tedious project.[185]

Another example would be the quality. Who exactly sets the checklists in this case? Again, the performance of an area improves much faster, because definitions are adjusted accordingly, as something to improve in the "real world". Clearly, a manager will direct his attention very strongly on the determination of the definitions.[186]

Key figures threaten to degenerate into uselessness. They hurt in this case, rather the company. A performance measurement system never forms a company completely. The focus should therefore not be fully placed on the achievement of key performance indicators. If the focus is, for example, only to "readiness to deliver", then there will be no time spent for a special request of a customer. So it would happen to new products. An engineer would not risk a delay to incorporate a feature, if the key figure is only based on the completion of new products. Key figures can never represent an entire company. Rather, these firms are successful, which are not strictly focusing on compliance with the key figures. Companies must be aware of what key figures can achieve and what they cannot. The framework conditions also play an important role. Companies should be aware of the benefits of working with ratios. The disadvantage, which can arise in the blind trust on key figures, should not be suppressed.[187]

[185] cf. Paul (2014), p. 236.
[186] cf. Paul (2014), p. 236.
[187] cf. Paul (2014), p. 235 ff.

8 Visualization

An important step in order to achieve the objectives pursued in a company is the visualization. Only in this way a permanent control of the company's goals is ensured. The uptake value when viewing is up to 30%. By the visualization, often a very complex relationship is shown. So to speak, a statement is brought to the point. Instead of long instructions, a single image is often enough, which signals a certain message. This happens through symbols as well. Moreover, the attention of the viewer can be focused on the essential. This can be implemented for example by striking colors. Furthermore, correlations can be seen by visualization, which would be difficult to mediate. Are visualizations standardized, they run throughout the entire company, and a quick comprehension is guaranteed.[188]

8.1 Basics of visualization regarding dashboards

In the visualization the often used instrument panels or dashboards represent an attempt to present complex information to a user vividly and clearly. These are rules which should be followed so that there are no ambiguities. The real use of instrument panels took place with the help of the ever-growing use of the internet in business end of the 90s. Some of them showed the ongoing business process, while others represented the fulfillment of the business strategy. In a published article by Mark Leon "dashboards Democracy" in Computerworld, June 16, 2003 135 companies were surveyed. Here, more than half already use dashboards. Nowadays instrument panels are inevitable. In each level of the hierarchy of a company you will meet them. However, a problem is identified. Often they will not be read or interpreted correctly. It is important not to introduce many shrill and different colors. Rather, instrument panels are a kind of communication. The main goal is the presentation of the needed information without any distraction on a single screen in a clear and easy way. Sometimes it is difficult because a lot of information must be shown in a compact manner. Often one tends to overload the presentation. There are a few points which should be kept. Instrument panels are no detailed reports. Often they are simply not appropriate for a particular type of information. They should therefore not be used under duress. Sometimes it requires more than one dashboard to be able to represent information suitable.[189]

For the user, they should have the following characteristics:

- Benefit for the viewer
- Such as the instrument panel is to be used

[188] cf. Bingel (2012), p. 7 f.
[189] cf. Kerzner (2011), p. 197 f.

- The measurements were carried out
- The interval at which measurements are made
- How is the index updated
- Similar surveys should be standardized within the company[190]

Depending on hierarchy level these dashboards need to be updated monthly, weekly or in real-time. Typical dashboards are usually standardized and are as follows.[191]

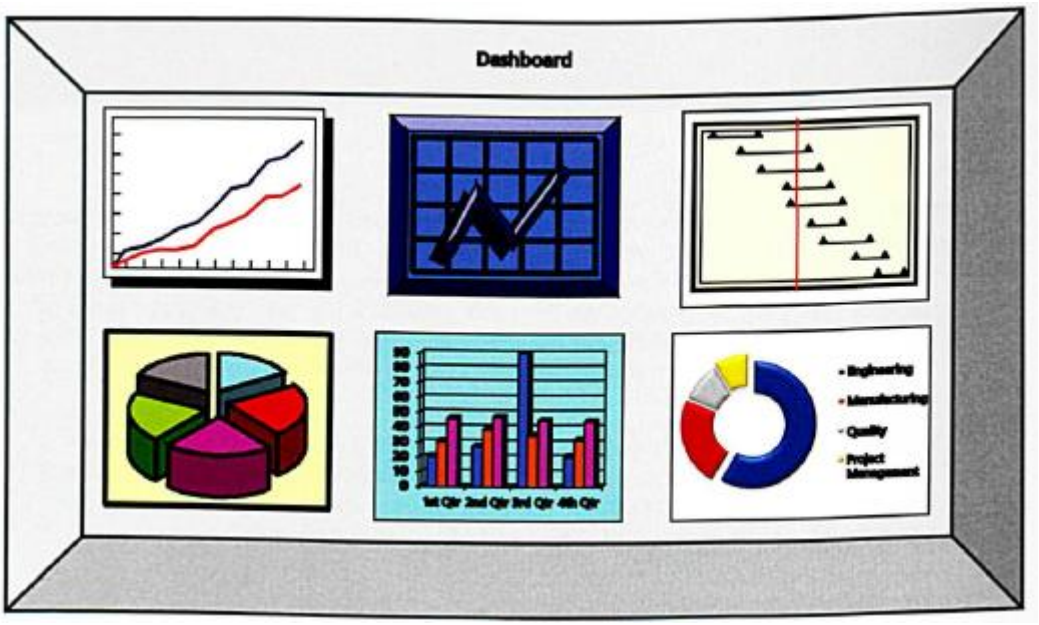


Image 18: Examples of dashboards[192]

Probably the best known and most widely used representation is the traffic light with its colors red, yellow and green. These colors are indicators for different states.[193] While the green light means that everything goes as planned and it needs no help, does the red mean that any problem has occurred. This can be caused in a change of quality of processing time, of the scope or via costs. It takes a quick intervention by a person responsible for this condition to resolve. The yellow light indicates a problem could occur in the near future and it should therefore be monitored more closely. However, an active action is not required by a person in charge at this time. Usually the traffic light with its three colors is the most common one. But there are companies that rely on multiple colors. In such a system the colors itself have a certain statement. Often, a particular problem is already characterized by the corresponding color.[194]

[190] cf. Kerzner (2011), p. 199.
[191] cf. Kerzner (2011), p. 200.
[192] Kerzner (2011), p. 198.
[193] cf.Pollmann / Rühm (2007), p. 215.
[194] cf. Kerzner (2014), p. 33 f.

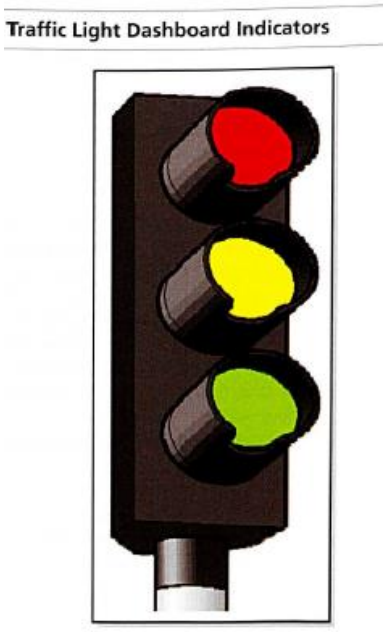


Image 19: Traffic Light Dashboard Indicators[195]

This is just one example of the use of dashboards. Dashboards are a kind of help to analyze and examine key indicators more closely.[196]

They are part of a management cockpit system, in which the company's performance can be derived. Using this system, decisions can be made in the strategic levels of a company. In addition to the dashboards, so-called scorecards [Explanation paragraph below] are in use as well. These are also components of the parent management cockpits. Often dashboards and scorecards are mixed in reality and not distinguished enough. However, there is a difference between dashboards and scorecards [s. table 6 & 7].[197]

Dashboards are central monitoring stations, which provide at a glance the most important business metrics to the decision makers. In most representations are used for visualization, which are familiar from the field of daily life: tables, graphs, pointer or scale. Key figures usually visualized in the form of traffic lights, speedometer or thermometer. [198] So dashboards describe more the operating indicators [s. image 18].

[195] Kerzner (2011), p. 200.

[196] http://www.tecchannel.de/server/sql/1758102/berichtssysteme_teil_2_kennzahlen_dashboards_und_scorecards/index3.html, [read on: 28.10.2014]

[197] http://www.tecchannel.de/server/sql/1758102/berichtssysteme_teil_2_kennzahlen_dashboards_und_scorecards/index3.html, [read on: 28.10.2014]

[198] cf. http://www.tecchannel.de/server/sql/1758102/berichtssysteme_teil_2_kennzahlen_dashboards_und_scorecards/index3.html, [read on: 28.10.2014]

It is different with the scorecards. They describe more the strategic view in the corporate environment. [199] With them, especially the key performance indicators are visualized. KPIs are known as key economic indicators that represent the achievement of strategic business objectives. With them the entrepreneurial performance is controlled and measured. They can also be visualized by traffic lights, speedometer, etc. However, their view is on an extended strategic planning period. Often KPIs consist of smaller key figures bundles, which influence each other. For this reason one cannot easily influence scorecards as it is possible for example to dashboards. Often they give only an overview of single information which is needed for the company or the current division [s. image 19].[200]

Image 20: Example of a scorecard

[199] cf. Kerzner (2011), p. 201.

[200] cf. http://www.tecchannel.de/server/sql/1758102/berichtssysteme_teil_2_kennzahlen_dashboards_und_scorecards/index4.html, [read on: 28.10.2014]

TABLE 6-1 Comparing Features

FEATURE	DASHBOARD	SCORECARD
Purpose	Measures performance	Charts progress
Users	Supervisors, specialists	Executives, managers, and staff
Updates	Right-time feeds	Periodic snapshots
Data	Events	Summaries
Display	Visual graphs, raw data	Visual graphs, comments

Table 9: Comparing Features[201]

TABLE 6-2 Comparison of Dashboards and Scorecards

FACTOR	DASHBOARDS	SCORECARDS
Performance	Operational issues	Strategic issues
WBS level for measurement	Work package level	Summary level
Frequency of update	Real time data	Periodic data
Target audience	Working levels	Executive levels

Table 10: Comparison of Dashboards and Scorecard[202]

Finally, it is in practice no matter which term is used. It must be clear to all parties where the focus is. In both kinds, information is displayed on a single screen, so that the viewer sees it at a glance. However, dashboards are preferably used for operational matters. They give more information on individual indicators.[203] *Eckerson* describes three types of dashboards. He distinguishes between operational, tactical and strategic dashboards.[204]

[201] Kerzner (2011), p. 202.
[202] Kerzner (2011), p. 203.
[203] cf. Kerzner (2011), p. 203.
[204] cf. Eckerson (2011), p. 101.

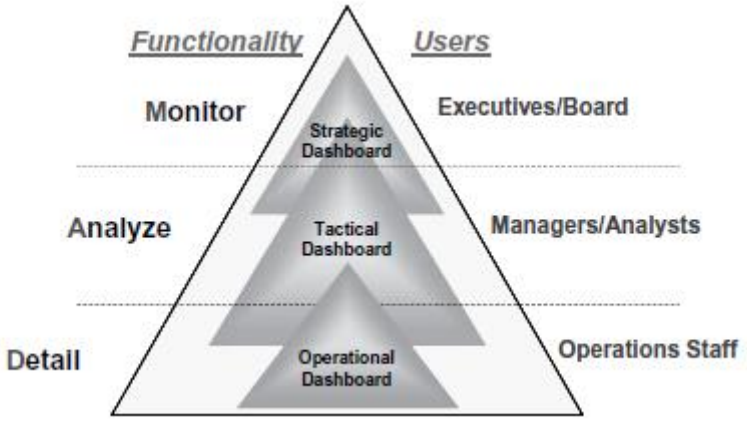


Image 21: Mapping Users to Dashboards[205]

- **Operational Dashboard:** These are used for operating activities. You control those activities. They also ensure that productivity, quality and efficiency remain in the predetermined frame. These dashboards are mainly used by front-line staff. They monitor the main components of the production every minute, hour or day. This data is transmitted and displayed directly from the core processes. So the correspondent is known at all times. The focus of operational dashboards is to display what is happening at the moment and what is going on. As previously mentioned, front-line workers mainly use the operating dashboards. However, this does not necessarily mean that top executives do not even watch these dashboards. Often they are just as interested in daily events as the front-line staff. Often make these types of dashboards use of alerts to draw attention to deviations. This is very quickly apparent, because the focus is only on certain individual figures. Not infrequently, an automatic pre-set answer is given to certain discrepancies. This is often the case in complex systems where fast manual intervention does not appear quite useful. The main focus of the operational dashboards is the representation of individual indicators such as output of shop floor machines, web or network traffic or sales transactions. Most of these metrics have only operational significance. Therefore, operational dashboards display detailed or light aggregated data. They rarely display a summary of data.[206]

- **Tactical Dashboards:** Tactical dashboards are the most commonly used of the three types. They are mainly used for the optimization of business processes in the individual departments. Examples are finance, sales,

[205] Eckerson (2011), p. 103.
[206] cf. Eckerson (2011), p. 107 ff.

marketing or human resources. Sometimes these dashboards also specify a company-wide overview. In general, they are used for monitoring the performance in respect of certain pre-determined, goals. For this, the tactical dashboards use a combination of detailed and summarized data.[207] Through this data summary they are of interest only for a particular organization or group of persons within the company.[208] Tactical dashboards show about a dozen KPIs. They also make connections to other tactical dashboards. Often, they look like a portal or a wild collection of key performance figures. The focus on tactical dashboards is in contrast to operational dashboards in the past. They show what already happened and help the persons in charge to take appropriate countermeasures to improve or prevent relevant events in the future.[209] So, tactical dashboards display key indicators, which are positioned between the operational and strategic dashboards. These figures are mostly departmental goals or objectives.[210]

- **Strategic Dashboards:** Strategic dashboards display and monitor the company's goals. This is the responsibility of the business executive. For this reason, those dashboards are located there.[211] Strategic dashboards can also be referred to as scorecards. As previously stated scorecards used almost exclusively in the strategic level. Therefore, strategic dashboards are referred to as scorecards. The executive of a company use strategic dashboards to check the achievement of strategic targets. For this purpose there are held monthly or quarterly meetings with business units and departmental managers. The data, which is displayed on the strategic dashboards is strongly summarized and updated in a monthly or quarterly period. Therefore, the focus of strategic dashboards is in the future. More precisely, how can pre-set goals are achieved or certain situations are avoided in the future.[212]

[207] cf. Eckerson (2011), p. 111.
[208] cf. Kerzner (2011), . 204.
[209] cf. Eckerson (2011), p. 111.
[210] cf. Eckerson (2011), p. 115.
[211] cf. Kerzner (2011), p. 204.
[212] cf. Eckerson (2011), p. 115.

	Operational	Tactical	Strategic
Purpose	Control operations	Optimize processes	Manage strategy
Scope	Operational	Departmental	Enterprise
Users	Staff+	Managers+	Executives+
Primary activity	Act	Analyze	Review
Focus	Current	Past	Future
Data refresh	Daily/Intraday	Daily/Weekly	Monthly/Quarterly
Information	Detailed	Detailed/Summary	Summary
Architecture	Core systems	Data warehouse	Excel or data mart
Metrics	Drivers	Drivers/Outcomes	Outcomes
"Looks like a…"	Dashboard	Metrics Portal	Scorecard

Image 22: Main Characteristics of Performance Dashboards[213]

8.1.1 The benefits of dashboards

Through digital dashboards users get insight into how certain projects perform. In addition, specific data are mediated by them. Further advantages are:

- visual representation of performance indicators
- Identification of negative trends
- Possibility of improvement of negative trends
- Efficiency and inefficiency is shown
- Detailed trends with all necessary data are shown
- Possibility of better decisions through based on facts knowledge
- Immediate knowledge of deviation of strategies and overall objectives of the original strategy
- Possibility of visualization of the overall system

In order to continuously improve a project or a process according to *Kerzner* four steps are necessary.

1. Measurement of performance. Converting this into data
2. Data must be converted into knowledge
3. This knowledge must be applied. Knowledge must turn into action.
4. The applied knowledge leading to improvements[214]

[213] Eckerson (2011), p. 105.
[214] cf. Kerzner (2011), p. 205.

8.1.2 Guidelines for dashboards

It is a major effort for a company, regardless which size, to establish a dashboard system. The following questions should be answered first.

- **What is the purpose a dashboard should fulfill?** A dashboard can be aimed at the needs of mid-level manager, as well as hourly or daily monitoring processes for shop floor employees.
- **Who is the target audience to be addressed by a dashboard?** Each dashboard is customized for the respective target group. This can be: CEOs, department heads, foremen or shop floor employees.
- **Is an alignment of the same information to different target groups needed?** For example, marketing departments do not need any information about personnel departments. But in contrast, a CEO wants to have nearly all information at a glance.
- **What is measured?** Processes must be clearly defined. Processes must also be transparent to see the necessary responsibilities.
- **What actions should be withdrawn from the individual reports?** Should an alarm introduced, if processes exceed their predetermined limits?
- **Who is responsible for monitoring, events or processes?** Which deviations lead to which measures by which persons in charge?
- **Is each report supplemented with comparative and historical data?** Comparative data is important to find out how you stand in competition with other companies. In addition, processes in the past can be compared with current processes based on historical data.
- **Are the measures clearly identified?** Predetermined KSI's or KPI's can be used as measured variables.
- **What views should the dashboard feature?** The dashboard can have analytical, strategic, monitoring or consolidation views.
- **Which technology should be used?** There are various technologies a dashboard can be operated. Also the maintenance effort plays an important role. Examples include: ASP.Net, Java or reporting service.
- **Should process data sequence also be reverberated in report KPI viewing sequence?** A unusual viewing sequence could cause confusion to persons who are familiar with a certain flow of data in a process-chain.
- **Reflects the dashboard the complete picture?** Are critical business information left aside, the reader often does not understand relevant contexts.
- **What is the important information that should be taken by the reader?** Each report must have a clear and memorable summary.
- **Was the correct display of the information used?** Incorrect use of charts can lead to confusion. Correct information is misinterpreted.

- **Are all reports of the entire company be standardized?** Same or similar reports, which are used in different departments with contrary colors or different images, provide confusion for the user.[215]

There are also some rules for dashboards, which should be considered to allow an easy comprehension. There are "five golden rules" for creating a dashboard.

1. **Diagrams are the main component of the dashboard:** By specifying numbers, no deeper understanding can be achieved. The content of a dashboard should be understood at a glance. For this reason, complex tables and long texts should be avoided. Diagrams are therefore the best solution. They show the contents quickly and efficiently. The viewer quickly recognized the important information. Depending on the number of data to be visualized, the type of the chart is selected.
2. **A dashboard has a high information density:** A dashboard should always fill the entire screen. Then there is enough space available for the most important data. Images should not occur in dashboards. They only distract from the essential. Bar charts are preferable to pie charts. Pie charts are not easier to read than bar charts contrary to the general opinion. They also need a lot more space.
3. **Simple presentation of content:** 3D charts should be avoided, because they are often difficult to read. If design elements have no statement, they should be disclaimed. There are no animations on a dashboard. Graphs are best read when they are displayed in different shades of gray. Bright colors should be avoided, because they emphasize data and distort the interpretation result. Also the arrangement and presentation of the data has a significant influence. Therefore, time units should always be recorded from left to right. For example, on the X-axis. Structures such as products belong to the Y-axis.
4. **Collect and represent data for comparison:** Diagrams are there to show comparisons. Diagrams that contain a lot of comparisons are more understandable and more meaningful than those that represent a few comparisons. If there is a need to read the corresponding report first, the diagram is designed in a false way.
5. **A dashboard has a uniform design:** Dashboards should have a uniform appearance. These include, represent all elements as standardized as possible. Same targets should be denoted by the same symbol. Nothing is more confusing than represent the same content with different charts. Also on dimensions should be regarded. It should not be exceeded six dimensions.[216]

[215] cf. http://www.dashboardinsight.com/articles/digital-dashboards/fundamentals/15-key-questions-you-should-ask-yourself-before-building-a-dashboard.aspx, [read on: 05.11.2014]
[216] cf. http://www.haufe.de/marketing-vertrieb/online-marketing/fuenf-goldene-regeln-fuer-dashboards_132_269482.html, [read on: 05.11.2014]

These were five detailed rules for dashboards. *Kerzner* mentions more generally rules for creating dashboards.

- The design of a dashboard starts with the understanding what the user needs
- Simple displays suffice for dashboards
- Simple tools are sufficient for Dashboard Design
- Represent as few indicators as possible at once
- Selection of indicators, which remain the users in mind
- Control the health and user friendliness of the dashboard
- Limit indicators on a single screen[217]

8.1.3 Design of effective dashboards

To design good and clear displays for dashboards is very important. Only dashboards, which are easy to understand, will bring an additional value for the users. In particular, the visual design is important. Dashboards will be only accepted, if the give you time advantage. If users need too much time to understand them, they will be rejected. To know what should be shown on the displays, it has to be clear what the critical success factors are. These factors are usually the KPIs. The higher the hierarchical level within the company, the more increases the summary of information for the dashboards. For example, a CFO will not to struggle with simple metrics.[218]

It is important that the first impression is correct. Is this confusing, employees are turn away from it and do not use this dashboard. The basic guiding principle for the design of a dashboard is: less is more. No artistic masterpiece needs to be made for this purpose. Dealing with visual design should be sparse. Each element or figure has to fulfill its purpose on the display. There are general guidelines to design a dashboard. They overlap partially with those in chapter 7.1.2. They can be seen as a supplement.[219]

8.1.3.1 Information must be presented on a single screen

This is not always easy. A dashboard designer often has a lot of information that must be displayed on a single screen. Users should not have to scroll to see important information. This would only lead to unnecessary confusion. All relevant must be visible at a glance. Nor should users have to click on the radio buttons to see more information or to compare them. Data which are not visible are not used by employees. Of course, this does not mean that dashboards consist of only a single display. If information is requested specifically, it requires more subordinate screens. But they must present the information required in turn to a single screen. The various

[217] cf. Kerzner (2011), p. 205.
[218] cf Kerzner (2011), p. 209 f.
[219] cf. Eckerson (2011), p. 229f.

screens are hierarchically constructed. The information, which are summarized most, appear as top-level displays. Displays with more detailed information will follow behind.[220]

8.1.3.2 Balance between sparseness and compactness

Experts are also divided on this issue. Some say that three to four indicators are sufficient to preserve the overview. Others argue that more ratios are possible, if they show the whole picture. So what is the right number? The answer can be found only among users. There must be found a balance between sparsity and density. Between these two positions there will always be a tradeoff. If one site increases or decreases, the other site will change in the opposite way. In this matter, the audience must be included. Shop floor employees prefer more detailed and dense illustrations of metrics and their development. Managers, however, prefer a sparse metrics-staffed display. They need to monitor and check more than one dashboard. Due to this fact a too densely packed display would cause confusion in addition.[221]

In the same way it behaves in a different circumstance. Are employees trained in the handling of dashboards, they are able to absorb more information at once. In this case, employees will get frustrated, if they have to click through diverse screens for the needed information. This can be applied one to one on the other side. Employees, who are not familiar with the use of dashboards, quickly get confused. For those, experts have to develop sparely filled dashboards.[222]

8.1.3.3 Abandonment of decoration

Is a variety of Information packed on a single screen, information is usually abbreviated or summarized. To summarize information as much as possible, metrics are frequently used. They are often expressed in the form of graphic elements. By graphics much information on a small space can be shown. However it happens again and again, that dashboard designers are carried away with graphical elements. In this case often graphics are designed, which are striking. However, they fail to provide information on states. The designers should ask themselves: "Do the graphics show the most important and most significant data on the smallest space?”. For example, radial gauges need too much space due to their circular shape. Even graphical traffic lights or thermometers are not always the best solution, because they also need a lot of space. Often it is enough to visualize one of the three traffic light colors next to the indicator. Some design experts have the opinion that you have not to show visualizations, if the performance is acceptable.[223]

[220] cf. Eckerson (2011), p. 230f.
[221] cf. Eckerson (2011), p. 231.
[222] cf. Eckerson (2011), p. 231.
[223] cf. Eckerson (2011), p. 231.

8.1.3.4 The layout should be intuitive

In rare cases, the layout will fit from the start. There are no defined rules at which position certain things have to be. A start may be that the Dashboard is built as a website template. With this form, almost every employee is familiar. But there are already critics who dissuade the website template. According to their opinion, this layout would only pretend familiarity and provide confusion in reality. A common website template is shown in image 29.

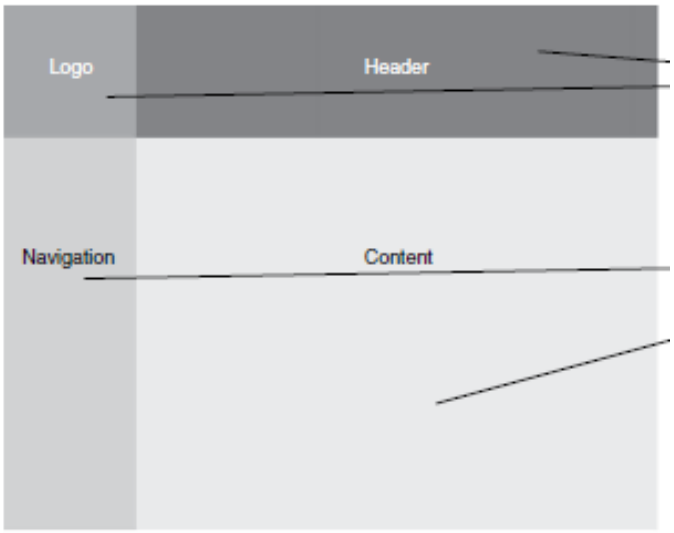


Image 23: Common website template[224]

The position of the objects on dashboards is important.[225] In this case, experts do not quite agree in the positioning of elements on the dashboard. But in most cases they almost match and deviate only slightly from each other.

So *ECKERSON* describes the importance of the position of various elements on a web template as follows: In his view dashboards describe a kind of story that explain the importance of the depicted and make it understandable. Therefore, the most important quadrant is the top left. This is considered first. Hence objects with the greatest importance should be in this section. This quadrant is followed by the top right one. The next position is bottom left. The bottom right quadrant gets the least attention and is considered last. For this reason, the most important information is positioned in the top left. Less significant data follows according to their importance in the other squares. Sometimes arrows or numbers are used to show how the course of the dashboard is to read. The center of dashboards can also be used as a focal point. Sometimes a graphic is set in the center. The other graphics around describe the composing of the inner one.[226]

[224] Eckerson (2011), p. 233.
[225] cf. Eckerson (2011), p. 229 ff.
[226] cf. Eckerson (2011), p. 234.

Contrary to *ECKERSON*, *KERZNER* describes the positions a bit different. However, it is based on the assumption that all information has the same importance. In this case, the quadrant with the highest attention is the top right. It is followed by the upper left. The next quadrant is the bottom right. And finally the bottom left (s. image 30). From that it can be seen that sometimes the arrangements differ. However, experts agree on top and bottom. It only changes the side selection.

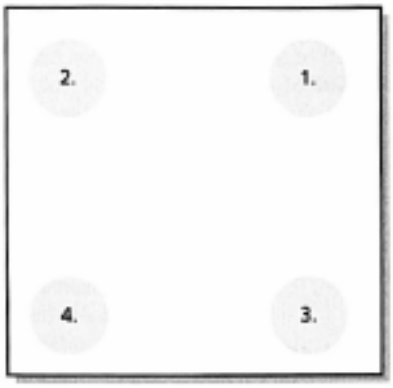


Image 24: Preferred fields of view[227]

The selection of a template purport, how data must be positioned. Users who are used to certain templates will read them in a “rehearsed” manner. The position of data is also important in a different way. Should information be considered by individual users as related, they have to be positioned next to each other or in a group. Color matches also help that information is considered coherently. In this way human perception understands a fast connection. This is especially important for graphics and their appending KPIs. If they are too far apart or even agitatedly on a dashboard display, the audience will has difficulties to see or understand a context.[228]

8.1.3.5 Reasonable arrangement of the components

A dashboard contains besides traditional charts and panes other components. Those must also be optimally embedded. Examples include, tabs, filters or help menus.

- **Tabs:** Folder tabs at the top of the dashboard are very useful to switch between views for certain users. This makes it easier to switch rapidly back and forth from different views. It does not have to be clicked through an endless hierarchical structure or to be scrolled in an inconvenient way. New views are available by clicking on the folder tab. This also means that a dashboard has to be developed only once. This saves a lot of time and money in contrast to a new development each time a user or group needs a different screen. No matter how the dashboard is designed. Dashboards are intended only to show the user what he wants to see. This means that a dashboard is

[227] Kerzner (2011), p. 217.
[228] cf. Kerzner (2011), p. 216f.

only intended to indicate what falls within the area of responsibility. Poorly designed displays are recognized by the fact that many different components are displayed. Individual users have to pick and choose, which ones are most useful to them. This means loss of time. Good dashboards show only ads from the beginning, which fall within the remit of the respective user.[229]

- **Filters:** Filters allow the user to single out data or refine views. Filters are the base form of interaction with dashboards. They allow in a certain way to split hierarchies and display more details about the data. The other way around, it is also possible through them to summarize data and to look at the big picture. It is equally possible to go in the horizontal direction. This means to drill across the data and to show different dimensions. If a filter is used, then a graph changes to the filtered data. In the application of filters a common mistake is that the filters are often ambiguous. This means that no one can tell what filter belongs to which graph. This causes a problem because filters can be applied to any chart, to a select group of charts or on individual charts. Therefore, this filter option should be placed so that each user can immediately see the togetherness. Filters for individual charts are often designed directly above.[230]

  Often filters have dozens of options to change the graph in every possible way. This can quickly lead to confusion. For this reason, every user should be able to activate or deactivate them with a single click. The best way to visualize a variety of filter is a navigation-band. This is usually located to the left or right as a column on the dashboard display. Filters can be activated in different ways. Some examples of this are: Radio buttons, check boxes or drop-down lists. Radio buttons are only used of you can use one filter at a time. In contrast to radio buttons, check boxes or drop-down lists are always used if more than one filter has to run at the same time.[231]

- **Text:** A text can be an important addition for a dashboard. Sometimes the text is the only way specific information can be displayed. Sometimes it should be shown the ten best customers or the ten best or worst products. In this case the text is the best way to do it. Short text extracts explain difficult-to-understand metrics, future predictions or certain actions. Often dashboard designers feel compelled to add help texts. However, they take up unnecessary space. Once a certain measure is understood, no one will read

[229] cf. Eckerson (2011), p. 234f.
[230] cf. Eckerson (2011), p. 235.
[231] cf. Eckerson (2011), p. 235.

the text again. Here, help buttons are a better solution. Users can click on them, if help is needed.[232]

- **Fonts:** The choice of fonts is very important. There are fonts that can be easily read. These do not require a lot of squiggle. Of these fonts, one should be chosen. Examples of these fonts are Times New Roman, Arial, Tahoma or Helvetica.[233] Another advantage of using these fonts is that it can be assumed in HTML-based software that these fonts are installed by the user. Nevertheless, it is recommended that in the HTML script one to two alternative fonts are given. They will be shown automatically when a font cannot be displayed.[234] In general, for tabs and section heading larger font sizes are used. Smaller ones are more likely in use for auxiliary texts, such as legends or footnotes. Graph or chart headings have the same font size as the text. They are only shown in bold. Just as the graph or chart heading, axis, rows or columns titles are also shown in bold. If desired, a complementary font can be used for headings. On the whole texts should be used as little as possible.[235]

  If texts are unavoidable, it will be mainly distinguished between the two fonts Antiqua and Grotesque. The font Antiqua uses serifs. These fonts have tick-like extensions at the end of the letters, which usually improve the readability. The serif font is preferably for print media. Another feature of the serif fonts are their differences in line widths within a letter. As a result, very decorative font designs are possible, which sometimes can be perceived as an ornate way, however.

Image 25: Antiqua fonts[236]

In contrast to the Antiqua fonts, the Grotesque fonts do not have serifs. They have very little or no differences in the line thicknesses.[237]

[232] cf. Eckerson (2011), p. 236.
[233] cf. Eckerson (2011), p .236.
[234] cf. Stapelkamp (2007), p. 94.
[235] cf. Eckerson (2011), p. 236.
[236] Stapelkamp (2007), p. 92.
[237] cf. Stapelkamp (2007), p. 92.

Image 26: Grotesque fonts[238]

In order to choose the appropriate font, the ergonomic aspects of the presentation medium have to be considered. Also, the use habits of the particular target group have to be included. In printing media, high resolution can be produced. This is why many details can be shown. At the screen and interface design possibilities for typographical presentation are severely limited. The design possibilities are influenced by the screen resolution. Serif fonts are particularly unsuitable if they can be shown only in a relatively low resolution and the display media is a self-luminous or backlit media. The low resolution can lead to tearing out fine line widths. In addition, self-luminous media can lead to overexposure of thin line widths. Especially the brightness and colorful contrast between the print and background is not balanced. This circumstance may lead to an excessive burden on the eyes of the beholder. Depending on the display technology, even a flicker can come along due to repetition frequencies of the image structure, e.g. in CRT displays. For presentation on screens specially designed screen fonts or pixel fonts are suitable. Their line width is evenly matched to the distances and angles of the grid view and individually designed for the appropriate font size.[239]

Colors and contrasts are in general much more intense in self-luminous media as in printed media, at which the light is only reflected. An important point is that the text and background is mapped to each other with a suitable contrast. So, the perception of impressions and content is not a burden. Brightness and colored contrast between text and background should always be brought in line and complementary colors should be avoided. They would cause a flicker when someone read the text. In printed media, black text on a white background is very well to read. In self-luminous media however, it should be noted that a white background shines brighter than a printed document. This is in the long run not only exhausting for the eyes, but also the text is outshone in certain circumstances. In particular, if the font type is formed of very thin line widths.[240]

Different typefaces are often displayed in different sizes. Even so they have the identical font size. Therefore, only an approximate value can be specified

[238] Stapelkamp (2007), p. 93.
[239] cf. Stapelkamp (2007), p. 93f.
[240] cf. Stapelkamp (2007), p. 96.

as recommended font size for the display of self-luminous media. It can be done, no exact size specification. The size shown depends on several factors. The necessary or usual viewing distance is also taken into account. Furthermore, it has to be considered which resolution and color depth the display medium has. On this account different recommendations for font types and font sizes can be advised. In the design should be considered for the purpose of accessibility that it is advisable to make arrangements, which allow adjusting the font sizes, contrasts and color reproduction. From a design perspective, a change of the aforementioned parameters can cause a catastrophic dissection of the well-considered layout.[241]

- *Proportionality in fonts:* Moreover fonts are distinguished in proportional and non-proportional fonts. Non-proportional fonts are called monospace font. In this case, each character has the same width. This kind of typefaces are called monospaced font because the characters, regardless of their actual width, always have the same space available. The "*Courier*" is such a font. For non-proportional fonts, the characters have the exact horizontal extent that they need. For example, an "I" gets less space than an "o". A known font is the OPTIMA Roma.[242]

Image 27: Proportional Courier-font[243]

Image 28: Non-proportional Optima-font[244]

- *The characters' antialiasing:* In fonts antialiasing is used to give the impression that the edges of letters are smooth. However, this cannot be due to the raster display of the screens. The gradation is optically attenuated by a course of font color, which merges into the background color. Therefore, antialiasing is not applicable to every font sizes, background colors and line widths. The smaller the font is, the less antialiasing should be used. The writing is getting too out

[241] cf. Stapelkamp (2007), p. 97.
[242] cf. Stapelkamp (2007), p. 121.
[243] Stapelkamp (2007), p. 121.
[244] Stapelkamp (2007), p. 121.

of focus. It acts then exaggerated softened and blurred. Antialiasing should only be applied to serif fonts if the line thickness is large enough. In most productions, which are displayed in a self-luminous media, the designer can determine whether and at what font size a font is smoothed.[245]

Image 29: Examples of antialiasing[246]

- *Line spacing:* The distance of the rows to each other should be relatively larger or smaller depending on the length of the rows. This primarily affects the readability of a text. If the line spacing is very low, so the lines seem to touch or overlap. Is it too far, so the lines are not perceived as coherent. The ideal line spacing is 100% to 150% of the x-height of the font of each type. The line spacing is of great significance for the reading speed. A study by a psychologist at the University of Toronto has been studied reading texts on television CRT displays. This study found out that the number of characters per line, the number of lines themselves and their distance to each other have a greater impact on the reading speed, as the contrast and the distance from the screen.[247]

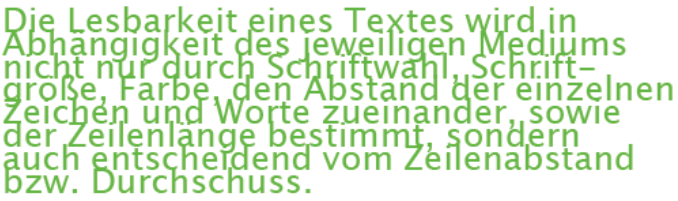


Image 30: Example of line spacing (narrow)[248]

[245] cf. Stapelkamp (2007), p. 122.
[246] Stapelkamp (2007), p. 122.
[247] cf. Stapelkamp (2007), p. 123.
[248] Stapelkamp (2007), p. 123.

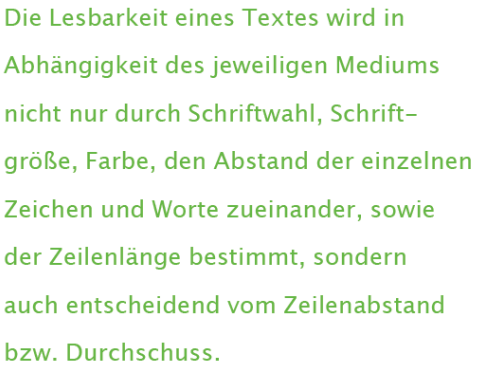


Image 31: Example of line spacing (wide)[249]

- *Column width:* Depending on which media he text is shown, which font and what font size is selected, the result is the appropriate level for the column width. Basically, seven to ten words per line produce a readable column. Through a long line, the exchange to the next one can be affected. Through a too short line, the text is hard to read as well. In addition, then the typeface looks very restless.[250]

- *The amount of the text:* For various reasons, it is not useful to display large amounts of text on a screen or other self-luminous media. On the one hand it is very tiring to read a text on a luminous medium that also flickers sometimes because of refresh rates, and on the other hand it is often not expected by the users of this media to be offered long texts. Using a scroll function, with which one can move contents vertically or horizontally within a visible region of the respective digital media, it would be possible even with self-luminous media to accommodate large amounts of text and make it accessible. However, it should be noted that in the visible region can be shown only the beginning of the information. This is why the essential information should be located there. This is hardly possible, because the visible range is often just too small. A brief summary of the main contents and a list of content areas with a respective link to the appropriate section in the text could help to support the user in the use of a scroll function. However, studies have shown that the user is only conditionally willing to use scroll functions. It is better to avoid scrolling functions, or at least to organize relevant content in a way that the essentials can be captured quickly.[251]

8.1.3.6 Reduction of design elements

An error which is repeatedly made by designers is that they focus on complex visualizations while leaving the important data behind. The visualization possibilities are almost unlimited. The range reaches form frames to backgrounds to shades. But

[249] Stapelkamp (2007), p. 123.
[250] cf. Stapelkamp (2007), p. 124.
[251] cf. Stapelkamp (2007), p. 125.

just because there are these possibilities, it does not mean that they all are to be used. The problem is that complex animations often compete with the really important data and so they lose attention.[252]

An example of a poorly designed dashboard is shown below (s. image 33). This dashboard has three background colors. It has one for the dashboard itself, another for the tabs and still another for the graphs. The purpose with the different shadings was that the different areas should be indicated from each other. Though, this is unnecessary, because too many shades or colors only affect the attention and make it more difficult to understand the overall picture.[253]

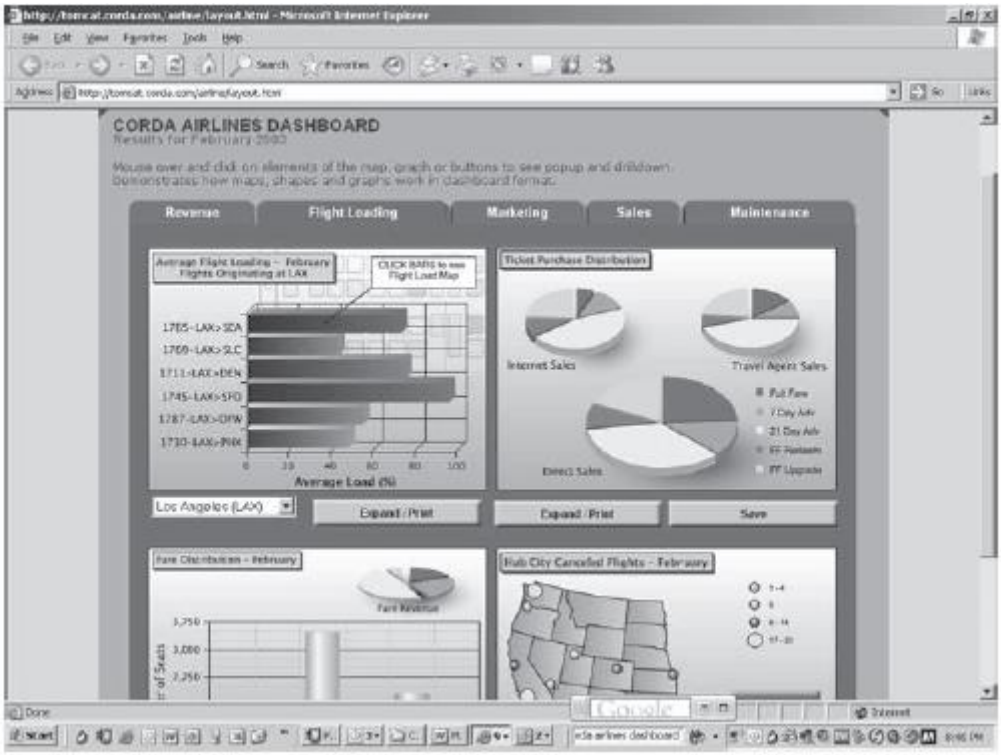


Image 32: Example of an iniquitous designed dashboard[254]

White space and gestalt: The "white space" is a design principle, which deals with the proper allocation of printed area to white space. In contrast to image 38, a properly-designed dashboard uses little background color. Actually, it should not use any background colors or shades. This brings only unnecessary distraction into consideration. It will do just fine if you just separate information by white space. Subconsciously, every viewer sorts the right information and recognizes their togetherness. As a result, the users do not get confused by unnecessary colors.

[252] cf. Eckerson (2011), p. 236.
[253] cf. Eckerson (2011), p. 236f.
[254] Eckerson (2011), p. 237.

There are about two dozen gestalt principles. These describe visualizations, which the users try to organize subconsciously.[255]

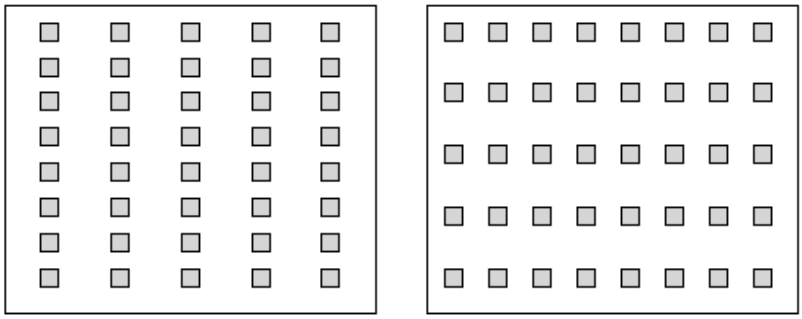


Image 33: Different perception by making use of whitespace[256]

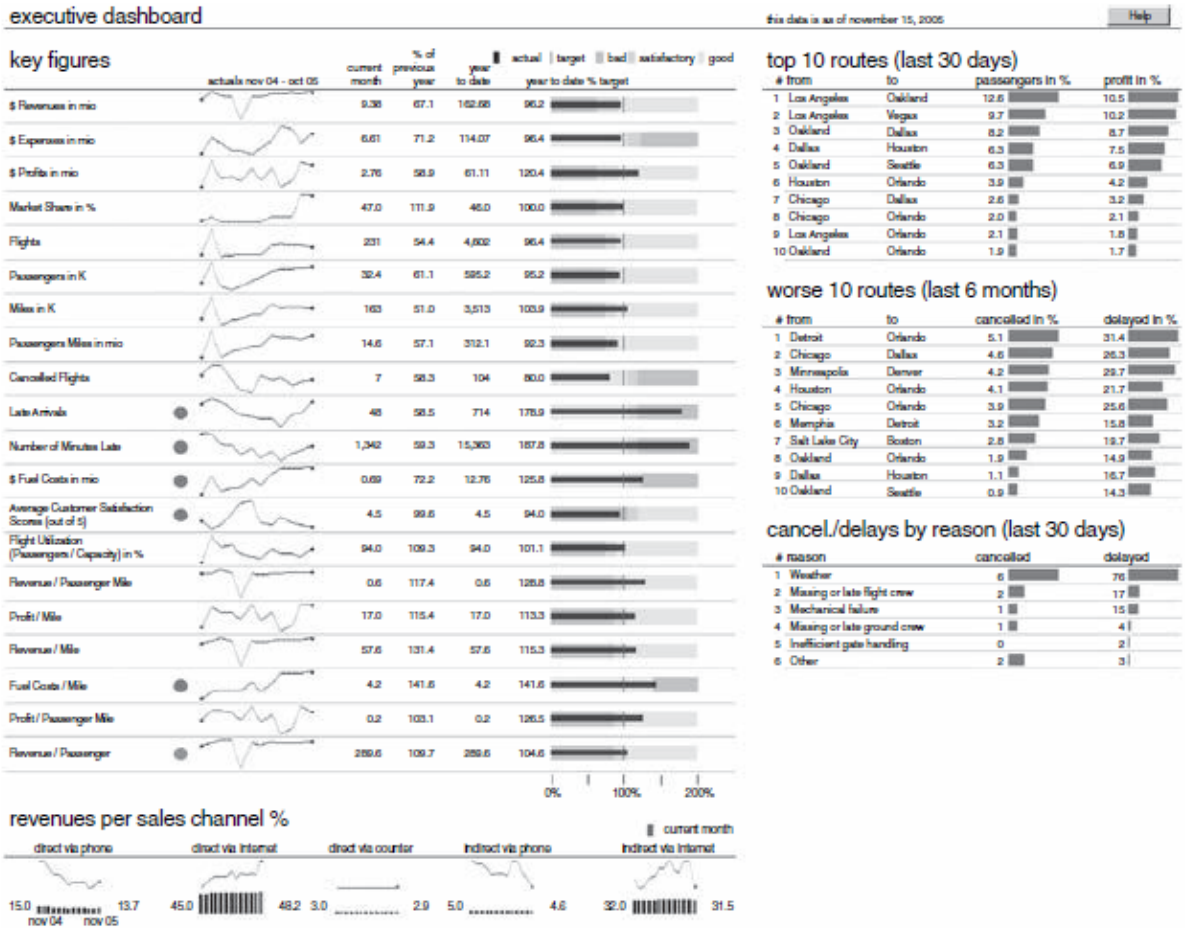


Image 34: Example of white space and gestalt[257]

They are based on psychological studies which have been made in Germany in the early 1900's.[258] This study can be summarized under the term “perceptual psychology” (in German: “Wahrnehmungspsychologie”). The human brain needs to

[255] cf. Eckerson (2011), p. 237f.
[256] Eckerson (2011), p. 239.
[257] Eckerson (2011), p. 238.
[258] cf. Eckerson (2011), p. 237.

have the ability to organize stimuli, which arrive on the retina, and to combine them that the environment is not only perceived as a plurality of color patches. These principles according to which the perception is organized are summarized under the term design concepts.[259]

Some of the most important principles are:

- *Principle of proximity:* This law describes the togetherness of information. Sees the viewer data that were placed close to each other, he recognizes their togetherness. E.g., two logos shown next to each other, they are recognized as two, because the “white space” between them separates the two emblems. It also specifies the grouping of the different logos.[260]

Image 35: Proximity

Closely spaced elements are perceived as a single group.[261]

- *Principle of similarity:* This law states that it depends on the form itself. Data or information is considered as belonging together, when they occur in the same shape. The color itself or the used background color plays also an important role.[262]

[259] cf. http://www.intramundia.net/demo/kommunikation/wahrnehmungspsychologie.html, [read on: 29.11.2014]
[260] cf. Stapelkamp (2007), p. 24
[261] Stapelkamp (2007), p. 24.
[262] cf. Stapelkamp (2007), p. 29.

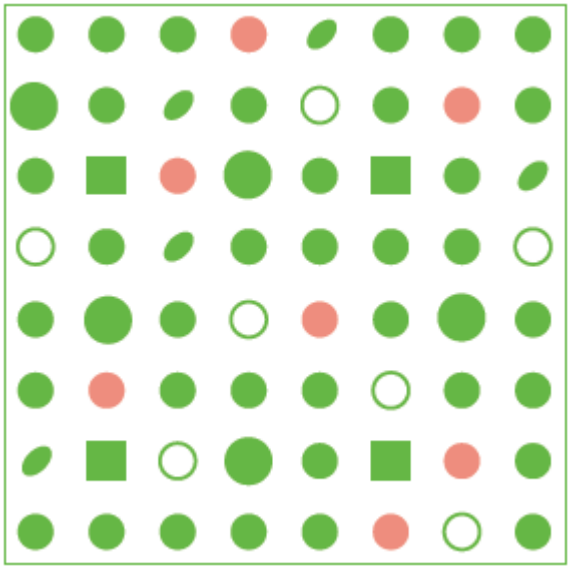


Image 36: Similarity

Similar elements are considered as belonging together.[263]

- *Principle of "prägnanz":* This law is also called figure-ground phenomenon. It describes e.g. how in an image some visual elements take the prominent role (the figure) and others the minor role in the background (the ground). The visual field is accordingly divided into these two forms. An important point about this phenomenon is that the viewer can only focus on one mold. Either the figure or the ground. The most famous example of this figure-ground representation is the "Rubin Face / Vase illusion" of Egar Rubin.[264]

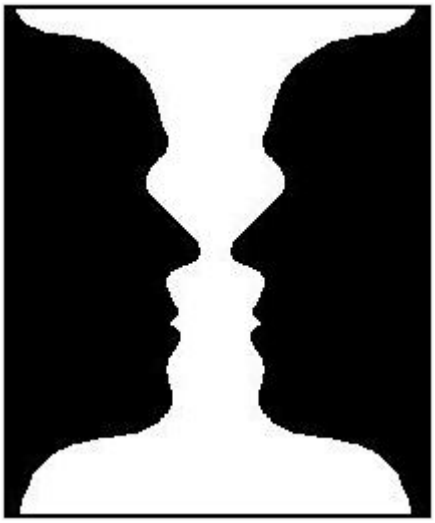


Image 37: Rubin Face/Vase Illusion[265]

[263] Stapelkamp (2007), p. 29.
[264] cf. https://www.interaction-design.org/encyclopedia/gestalt_principles_of_form_perception.html, [read on: 26.11.2014]
[265] http://artandperception.com/2008/07/light-dark-figure-ground.html, [read on: 26.11.2014]

- *Principle of symmetry:* This law describes that viewers want to add symmetrical shapes to many illustrations. Many objects can be divided in two or less symmetrical halves by the viewer. The more similar the objects are, the more likely they are grouped or recognized as belonging together. A good example of this phenomenon is brackets in a written text. Readers tend not to see individual brackets. They look always at pairs that belong together. They are not seen as individual brackets.[266]

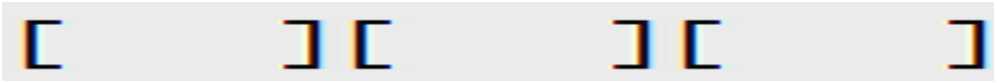


Image 38: Symmetry

The phenomenon of brackets[267]

- *Principle of closure:* This law describes the so to speak "auto completion" in the human brain. The perception attempts to fill the missing pars of an image or in a text that a sense is recognizable in it.[268]

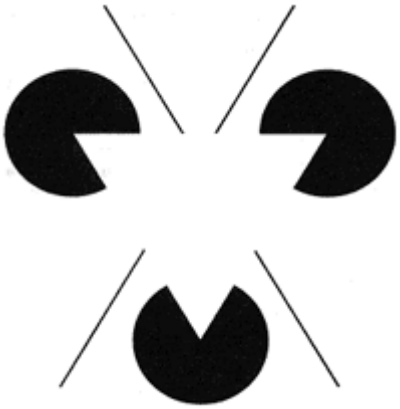


Image 39: Closure

Tendency to consider incomplete as complete[269]

Stifled lines: As it can be seen in image 35, it is possible to display almost 50 metrics all at once and in a concise manner. Despite that they are also displayed on a single page, these indicators are very readable. A responsible person can quickly

[266] cf. https://www.interaction-design.org/encyclopedia/gestalt_principles_of_form_perception.html, [read on: 26.11.2014]
[267] https://www.interaction-design.org/encyclopedia/gestalt_principles_of_form_perception.html, [read on: 2611.2014]
[268] cf. https://www.interaction-design.org/encyclopedia/gestalt_principles_of_form_perception.html, [read on: 26.11.2014]
[269] http://www.intramundia.net/demo/kommunikation/wahrnehmungspsychologie.html, [read on: 26.11.2014]

read through the indicators without getting distracted or slipping into other lines. This condition is provided by the muted lines. Muted lines manage a balance between clear separation and togetherness. When using bold, dashed or solid lines, the designers often create only more confusion. Steamed lines also work within graphs or charts. Often a distinction is made clear only through them that might otherwise lead to false interpretations. Muted lines do not attract too much attention or catch the users' eyes. They are much more subtly in the background and separate the individual information of each other.[270]

8.1.3.7 Colors

Colors trigger emotions and, depending on the cultural background, interpreted differently. It is therefore relatively difficult to define common rules for the use of colors. Some aspects concerning the importance of color, contrast sensitivity, visual defect and use of color, however, can be defined and used to guide the user to warn or inform.[271] The principle of "less is more" should not be disregarded. Bright colors should only be taken for identification of very meaningful objects. It is often recommended to use only muted colors. You should only change the brightness or color intensity according to the importance of the information. This is already sufficient to highlight important data from the remaining ones. Following a few important points about using color are shown.[272]

Colors and their representation in different media: Media are classified between two categories, respective to the color appearance and mixing:

- *not self-luminous media*
- *self-luminous media*

Printed matter, color powder or colored objects are not self-luminous objects. CRT displays, LCD monitors, plasma monitors are self-luminous media. These three types of self-luminous media can greatly differ in the reproduction of colors. CRT monitors represent color at the best, LCD monitors display images at the sharpest and plasma monitors provide a brighter and higher contrast. In addition to the display technology it is also to consider the ambient light and the resulting reflections as well as in computer application the used operating system. Depending on which media representation and which operating systems are used by the respective target group, factors related to color accuracy, brightness and contrast have to be considered. They can often predict only very limited. Therefore it is recommended to identify the target group as much as possible and to produce specifically for the user's behavior.[273]

[270] cf. Eckerson (2011), p. 238.
[271] cf. Stapelkamp (2007), p. 32.
[272] cf. Eckerson (2011), p. 238f.
[273] cf. Stapelkamp (2007), p. 41.

Color depth: The color depth describes how many colors or shades of gray a system can simultaneously illustrate. The color depth is specified in bit (binary digit). The number of bits corresponds to an exponent of the number 2. With a color depth of 4 bit 2^4 = 16 colors can be displayed. 8 bits are 2^8 = 256 colors, 16 bit are 2^{16} = 65.536 colors and 24 bit are 2^{24} = 16.777.216 colors. With 24 bit all recognizable colors by humans can be displayed. Depending on the monitor sometimes only a limited amount of colors can be mapped. This must be considered first, where representations are to be displayed.[274]

Resolution: Most self-luminous media have different resolutions. This must be considered especially by the designers. If imagines like graphs or charts are shown in great detail, it can cause problems with low-resolution screens.[275]

The phenomenon of afterimages: Afterimages arise from the tendency of the human eye to enhance contrast. Looking at a red area about 25-40 seconds and exchanges these against a white one, it appears on that white surface the complementary color turquoise. Yellow afterimage appears in purple and magenta green. Conversely appears the other color of the color pairs. This knowledge is important for the choice of the appropriate color circle and design considerations that affect the choice of colors depending on color schemes, color expectations and the meaning of the respective colors or their associations and interpretations.[276]

Simultaneous contrast: Color is generally perceived differently in its one and its brightness. It depends on the ambient color. Information on the simultaneous contrast can be used to direct, to strain and to stimulate the perception of the viewer by increasing the contrast. On the other side, the perception can be spared by a targeted reduction of the contrast. For areas that draw and require a lot of attention to themselves, such as tests, signs or panels, should be ensured that the viewers' eyes are not overexerted. In particular, in displays, monitors and control panels, which are exposed to different light and lightning conditions, the use of contrast is required.[277]

[274] cf. Stapelkamp (2007), p. 52.
[275] cf. Stapelkamp (2007), p. 55.
[276] cf. Stapelkamp (2007), p. 35.
[277] cf. Stapelkamp (2007), p. 58.

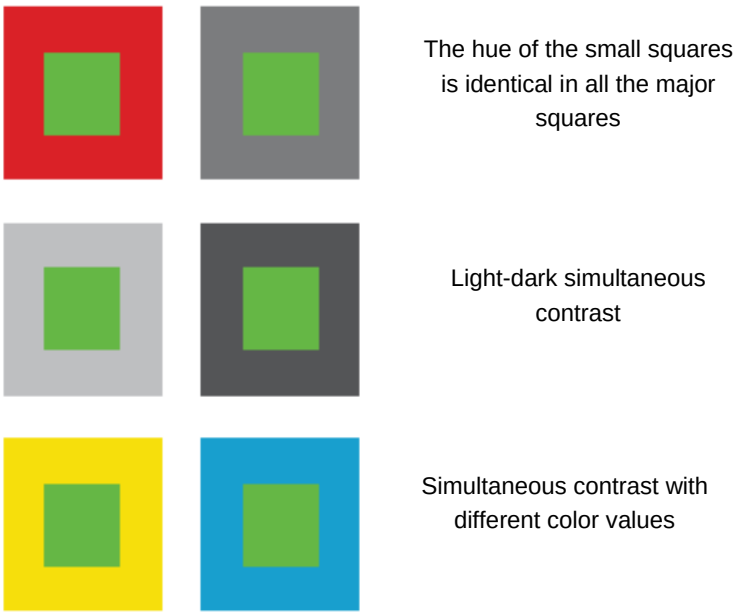


Image 40: Simultaneous contrast[278]

Complementary contrast: With complementary contrast those colors are meant facing each other in the color circle. Because different circles of color depending on the color model and thereby different color pairs arise, which could be described as complementary colors, a definition or the designation of specific complementary colors is not possible. Due to the phenomenon of afterimages the color circle by *Harald Küpper* can be recommended as suitable. Yet the phenomenon of afterimages is not fully understood when it comes to science, but it occurs in the same way to every human being. This means, that the expectations of this phenomenon are predictable. The complementary contrasts of the color circle by *Harald Küpper* are particularly suited for design considerations, both for aesthetic and ergonomically criteria.[279]

Image 41: Complementary contrast[280]

[278] Stapelkamp (2007), p. 58.
[279] cf. Stapelkamp (2007), p. 60.
[280] Stapelkamp (2007), p. 60.

Color-in-itself contrast: The name of this contrast may sound a bit headstrong. But it describes where the quality of this contrast lies. By combining several color tones, a contrast effect is obtained, which can stand for liveliness and also for versatility.[281] Primary and secondary colors have in the color-in-itself contrast the strongest contrast effect. Color-in-itself contrasts appear colorful, loud and powerful in general. The variations of the color-in-itself contrast occupy a wide bandwidth and thus allow a very wide range of effects. If you separate the areas of color with black or white lines, the color properties and the variegation increase, because the individual colors can be perceived in a better way and the mutual irradiation is broken. Each color retrieve their own original effect.[282] This contrast is often used when children should be addressed as a target group with a diversity of colors. This contrast is also used if creativity should be expressed.[283]

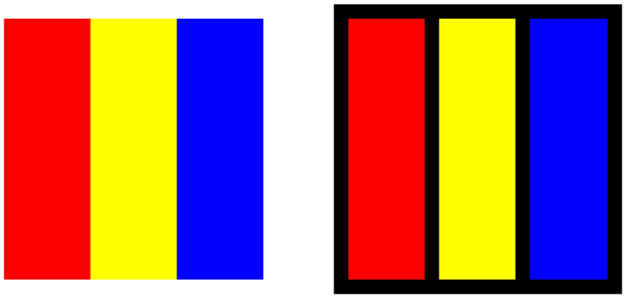


Image 42: Color-in-itself contrast[284]

Quantity contrast: If the contrast is expressed by an imbalance of color amount distribution, it is called quantity contrast. Is there a uniform distribution of colors in volume and intensity the design can appear balanced. But also there is a thin line to seem tedious. The quantity as well as the colorful-achromatic contrast is excellent for the design of information and control software and in general for any kind of hardware or software control panels. Contents as well as functional aspects can be represented in a good differentiated way with these contrasts.[285]

Image 43: Quantity contrast[286]

[281] cf. Stapelkamp (2007), p. 58ff.
[282] cf. http://lehrerfortbildung-bw.de/kompetenzen/gestaltung/farbe/kontrast/farb-kon/, [read on: 30.11.2014]
[283] cf. Stapelkamp (2007), p. 62.
[284] http://lehrerfortbildung-bw.de/kompetenzen/gestaltung/farbe/kontrast/farb-kon/, [read on: 30.11.2014]
[285] cf. Stapelkamp (2007), p. 64.
[286] Stapelkamp (2007), p. 64.

Colorful-achromatic contrast: As the name suggests, this contrast is formed by the combination of rich, colorful with discolored, achromatic colors, whereupon the bleached shades are formed by colored shades of gray. The Colorful-achromatic and quantity contrast are very suitable color contrasts for the design of screen and interface design. They can also be excellently combined with each other. The reduced use of color, the muted gray color gradations and large areas offer not only creative freedom, they also provide the opportunity to harmonize ergonomic with formal aspects.[287]

Image 44: Colorful-achromatic contrast[288]

Light-dark contrast: This contrast is probably one of the most famous ones. This contrast catches the eye especially when it was not considered. It makes a significant contribution to make details recognizable at all. This contrast helps to display the text from the background in a differentiated and sufficient noticeable way. The light-dark contrast is an ergonomic factor and not just relevant for those, who have a vision or color amblyopia. An excessive light-dark contrast may affect very tiring on the eyes.

Image 45: Light-dark contrast[289]

Cold-warm contrast: In the color circle are colors, which are perceived rather cold, as well as colors, which are perceived rather warm. In addition, gray shades seem cold adverse to color shades. Within the range of grey shades, the brownish shades are perceived as warm towards the bluish shades. Even within a color family colder and warmer tones are detected. These emotional qualities are compared with the cold-warm contrast to produce stress fields as an example. However, such differences in quality can also be used to simulate space because cold colors seem more distant and warm close. This is known by the natural light perspective, also called color perspective. The more distant something in nature is, the more bluish, cool and pale colors appear and the closer it is, the warmer and stronger are the colors. The visual system has adapted during evolution to this perception, so that the color perspective can always be used as a variant of the cold-warm contrast, if a spatial perception or a differentiation between highlighting and taking back should be

[287] cf. Stapelkamp (2007), p. 66.
[288] Stapelkamp (2007), p. 66.
[289] Stapelkamp (2007), p. 68.

caused with a few color media. The characteristics of that spatial effect, which arise from the cold-warm contrast, can be used by the screen and interface design to form structures and to define significance sizes. Features or contents can be moved in the fore or background only by change from a warm to a cold coloring depending on the strategy and need.[290]

Image 46: Cold-warm contrast[291]

Quality contrast: If a pure hue is surrounded by its own light and dark tonal levels, it affects more intense. As a result, its importance is increased compared to the graded tone. This effect is called quality contrast. With such a tone-on-tone design areas can be accrued by tonal gradation in sectors and assigned to specific content and functions. The total area experiences a clear structure. However, there is also the risk of causing monotony by the use of slight color.[292]

Image 47: Quality contrast[293]

Synesthesia: Synesthesia is the term for the combination of colors with sensations. The term describes the relationship of color perception with sensations of smell, taste, touch, hearing, or of the muscular sense. Visually perceived colors can trigger feelings, which directly address one of the sense organs. Many industries make the advantage of the synesthetic. A perfume that promises activity and freshness is rather green, turquoise or blue packaged as a dark red. And also the shape and color of the bottle are designed in close interaction with the scent.[294]

Color	Taste	Odor	Sense of touch	Hearing	Muscular sense
Yellow	sour	sour	smooth	shrill, high	light
Red	sweet	strong	fixed	loud	moderate
Green	fruity	fresh	smooth	babbling	medium light
Blue	aqueous	odorless	smooth	remote	relatively light
Violet	bitter	narcotic	velvety	sad, deep	heavy

[290] cf. Stapelkamp (2007), p. 70.
[291] Stapelkamp (2007), p. 70.
[292] cf. Stapelkamp (2007), p. 64 ff.
[293] Stapelkamp (2007), p. 72.
[294] cf. Hammer (2008), p. 186 f.

White	salty	odorless	dry	still	very light
Black	inky	musty	hard	deep	very heavy

Table 11: Synesthesia[295]

Color meaning: Depending on the cultural background colors are interpreted differently. This is especially to be considered when products are sold internationally, such as the service of a website. But even if the product is only regional sold, consideration should be given to avoid cultural misunderstandings. But it's not only about avoiding misunderstandings, but also to ensure compliance with significant conditions. In moderate climate, the color green is an everyday color. In climatically hotter regions, it is rare or even an existential symbol of prosperity and fertility. However, this also shows that a color can be seen even within a country or within the same cultural area different in meaning, unless there different climates occur. Also, regardless of the cultural and climatic differences, the importance of color is not always the same. The green of an immature peach is finally interpreted differently than the green of a park in summer light. It is not just to consider the color itself, but also the context in which it is used or perceived. Colors trigger emotions and are also used to symbolize emotions, whether as a color in an image or a word in a sentence. The Appendix 6 contains a table, which represents associations of color with different countries.[296]

Color, text and background: Texts have according to their own color and the color of the background on which they stand different color effects. The interaction of the two color elements is also the reason for a good or bad readability. In this context, the previously described color contrasts act. In addition, the effect of a text may crucially depend on the colors used. So, a red text on a white background is perceived more as advertising and not as relevant information. Black text on a white background is still assumed most serious and is both close and distant legible. For display on a self-luminous medium, such as a computer monitor, a bright shining, white background should be avoided in favor of a bright, muted hue. Decreases the brightness contrast, the font is illegible, however. Here it is important to choose the color and contrast sensitivity. An example of the different colors, text and backgrounds is shown in Appendix 7.[297]

Defective color vision: In the design of products, in particular interfaces, it should be noted that there are users who have visual impairments and therefore require rich in contrast displays, or even certain color markings. Thus, for example, 8% of men

[295] Hammer (2008), p. 186.
[296] cf. Stapelkamp (2007), p. 83.
[297] cf. Stapelkamp (2007), p. 85.

and 0.4% of the female population have defective color vision. The proportion of women, who have defective color vision, is so vanishingly small that a sophisticated statistical approach is worth only for the male population.

Male population with red-green color amblyopia:

- North America 8%
- Europe 8,76%
- Eastern Europe 9,31%
- Asia 6%
- Africa 4%

Color-vision deficiency is innate and usually inherited. Treatment is not possible. Worldwide, approximately 250 million people are dichromatic. However, the term ametropia is in this context not appropriated. People with red-green visual impairment see e.g. up to 15 brown shades that people without visual impairment can hardly differentiate. Defective color vision means that some colors cannot or can only weakly recognized or distinguished from each other by affected persons. The red-green color amblyopia, which is also often called incorrectly as color blindness is the most common color-vision deficiency. It results from a mutation of the X chromosome. Males have only one X chromosome, so color-vision deficiency among men is much more often than among women, who have two X chromosomes. In 50% of these color vision defects occurs a green weakness of the color green, 25% have a green blindness, 15% have a red blindness and 10% suffer on weakness of the color red. Disturbances in the blue range are very rare as well as a total color blindness. The total color blindness called achromatopsia is due to a genetic defect. In a variant of this vision, the atypical achromatopsia, a residue of blue remains visible to the person concerned.[298]

With so-called Ishihara plates which were developed in 1917 in Japan, can be determined whether or which color-vision deficiency is present. In the left panel of the “not affected persons” detect an eight. The red-green color blind sees a three 3 or no number at all. In the central panel a seven can be read. The color defectives do not recognize a number. The right panel shows a 35. Green-blinds recognize a three, Red-blind a five. People who have a weak ametropia recognize both numbers, but they see the numbers cloudy. In Appendix 9 there is a summary of the percentage occurrence of color-vision deficiency.[299]

[298] cf. Stapelkamp (2007), p. 86.
[299] cf. Stapelkamp (2007), p. 86.

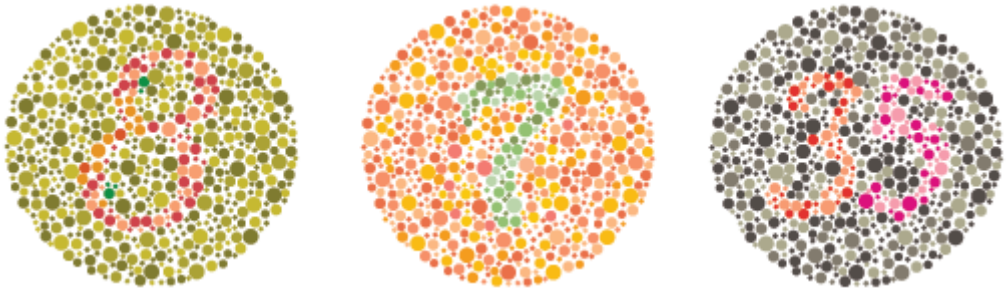


Image 48: Ishihara plates[300]

Visualization of color-vision deficiency: There is software that can simulate for non-color-vision deficiency persons, how color-vision deficiency persons see the designed pages. On the www.vischeck.com page, this can also recognize this. This site illustrates how ametropic persons perceive certain pages or images. This assistance should be used by all designers all to design all forms of interfaces or displays accordingly. In this way, you can determine which colors and contrasts that work well in the sense of barrier-free or better should be changed. At the achromatopsia, a total color-blindness, colors are seen only in shades of gray. The colors are specified with hexadecimal code.[301]

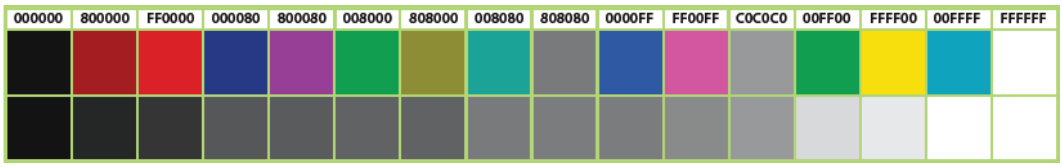


Image 49: Examples of colors with their hexadecimal code[302]

Short summary of rules for dealing with color: Since color contributes a considerable part of a success or failure of a display, the most important rules should be summarized.

- Colors should be used prudently and if possible sparingly. Chroma could make the choice of color seem arbitrary. The color scheme of two primary colors can represent product or service characteristics and orientation within an interactive system in a sufficient way. The colors should be coordinated and it should not be used more than 4 colors.
- A contrasting use of colors ensures a sharp-contoured impression and a good legibility.

[300] Stapelkamp (2007), p. 87.
[301] cf. Stapelkamp (2007), p. 83 ff.
[302] Stapelkamp (2007), p. 88.

- The foreground color should be sufficiently withdrawn from the background color.
- Decreases the brightness contrast, the font becomes illegible.
- A light-dark contrast in particular allows for visually impaired legibility of text, image and function.
- The more colorful a text, the more illegible it is.
- Text should not be represented with blue. Blue is a relatively short-wavelength light. Light is seen blurred, the shorter the wavelength becomes. Because of that, blue is blurrier than other colors.
- In order to avoid the 'flicker' of colors, primary colors should not be used together, for example, in the text or in background combinations. Their wavelengths are very close to each other. Therefore, they will be perceived as a flicker by the human eye.
- Red and green should not be used in parallel, because depending on the region, four to nine percent of the population has a red-green blindness.
- Yellow gradations should not be used simultaneously or side by side when the differentiability of these gradations must be absolutely guaranteed. The same goes for blue tonal gradations. With the age the lens of an eye yellows. This is why yellow and blue gradations can be hardly differentiated.
- For information, which is viewed on a computer monitor or electronic display, the colors should always be strong and full of contrasts. Especially when used outdoors, for example, in traffic control systems or in displays of public transport. It can never be excluded that annoying ambient light affects the contrast level.
- Depending on the display medium and the intension of usage, it should be considered that the colors should be optimized for a black and white printing.
- Color standards, culturally or geographically related definitions and different meaning interpretations of certain colors should be followed and respected.[303]

In Appendix 9 there is a summary of the most common contrasts.

8.1.4 Designing charts in a proper way

Of course, the principles that have been mentioned in the previous chapter also apply to the design of individual charts. The key is that you focus on the data and not on the charts themselves. The graph communicates the required information. One can say that graphs and charts “wrap” numbers in a concise form.[304]

[303] cf. Stapelkamp (2007), p. 90.
[304] cf. Eckerson (2011), p. 240.

8.1.4.1 Doing more with less

As already mentioned a few times before, you can apply the same rule with charts. “Less is more”. There is the danger that graphs disguise information by too much embellishment. It must always be the actual statement or purpose remain visible. Unnecessary graphical elements are to be cut out. Also, it is not recommended the use of three-dimensional charts or graphs. They look professionally, but they often distract too much. Colorful, with great detail designed images are indeed often beautiful to look at, but disguise and distract from the actual information, which should be transmitted.[305]

8.1.4.2 The usage of charts to compare

With charts it becomes easier to compare information. It is easy to compare, for example, sales or the generated profit in different regions. Instead of numbers it can be seen successes or failures at a glance. People recognize relationships to each other faster if they were visualized graphically. The designers need to know what information or data is the most interesting one to the viewer. With such knowledge axes and dimensions of the charts, depending on the use, can be exactly matched. An example of this is shown in image 57. This image displays how different dimensions change the whole understanding. The two charts are based on the same initial data. In the first sales by region are divided. This is, for example, useful for managers in different regions. On the second chart the products sold in the various regions are compared. This in turn is interesting for a product manager, who wants to know what the best products are.[306]

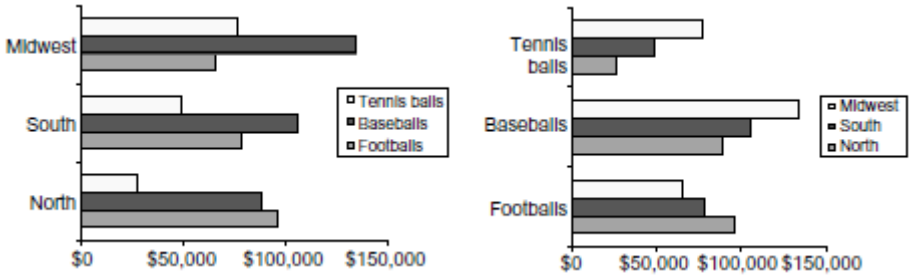


Image 50: Example of graphs to compare[307]

From this example you can see why the later viewers should be known. Here, very much time can be saved. To illustrate comparisons quickly and clearly, the elements being compared should be close, side by side. It is not useful if these are far from each other and possibly needs to be scrolled or scroll back to compare numbers or other things together. Charts should have so little eye movement as possible. Only in this case they can be viewed quickly. Just as important as the right axis labels are the axis proportions. Ratios must be found which represent all at once. They shall not

[305] cf. Eckerson (2011), p. 240.
[306] cf. Eckerson (2011), p. 241.
[307] Eckerson (2011), p. 242.

be too small, otherwise "upward outliers" cannot be displayed correctly. It is also recommended that the axis label always starts at zero. Otherwise, differences would appear too large, which in reality are low.[308]

8.1.4.3 Preattentive perception of visual information

The human vision has the ability to perceive certain visual characteristics preattentivley. The viewer recognizes them immediately without directing his attention specifically on it. Features like color, size and shape, are among these characteristics. This preattentive perception can be meaningfully used to highlight important visual information for an interface. But caution is necessary: it is always limited to a single characteristic. A combination of different preattentive noticeable features is no longer preattentively perceptible. In Figure 57 the main forms of preattentive perception are presented.[309]

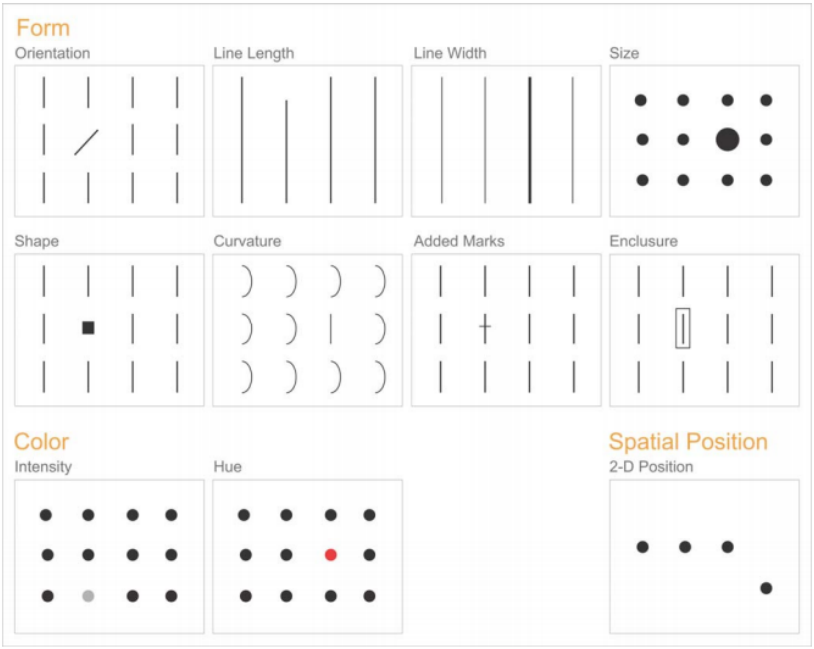


Image 51: Preattentive attributes of visual perception most applicable to data presentation[310]

8.1.4.4 Using paths to the more detailed or wider representation

To capture the entire situation with a chart, the charts should allow to zoom in or out to additional levels of detail. It should also be possible that the viewer can switch between different views. If the viewers are able to activate various functions, it will be an advantage. For example, to sort, calculate, annotate, or export. However, there is a danger that too many functions confuse. Therefore, designers should be very carefully with functions, which can be activated. A good solution to “immerse” further

[308] cf. Eckerson (2011), p. 241f.
[309] cf. Alexander (2013), p. 238.
[310] http://www.perceptualedge.com/articles/ie/visual_perception.pdf, S. 5., [read on: 06.12.2014]

in certain charts is a click. For example viewer can use a left click on a key figure, icon or bar to go a level down. With a right click they can go back or go to higher level of hierarchy.[311]

8.1.4.5 Types of graphs

Choosing the right chart type plays an essential role for information to communicate properly. At the beginning it must be clear what data you want to visualize. Also, the following questions should be clarified in advance. Which type of chart conveys the message or the information best? A circuit diagram usually looks good, but is it right for this issue? Does the time play an important role for the presentation of the information? Should (market-) shares, contrasts between target and actual values, relationships between data or accumulated data displayed? Is the change of the data over a given period important for the display or is merely a comparison of the data at a certain time significant?[312] A distinction is made between the visualization of key performance indicators and individual indicators or key figures. Key Performance Indicators represent a small summary of various individual values. Because of this, they are visualized in a different way.

Visualization of key performance indicators: There are five common solutions when it comes to the visualization of KPI's.

- **Alert or alarm icon:** Probably the best known and simplest alarm symbol is a geometric shape that occurs in different colors. Most of these come in the colors red, yellow and green. As a symbol, a circle appears most in the appropriate color. The color indicates the condition of the KPIs. This type of visualization is used when other information should be supported. Also by a large density of KPI's which are to be seen at a glance, this color symbols are used. This type of visualization is also used when statements to be made on a system state. For example, if machines or applications are ready. It must be considered that a certain percentage of the workforce having color deficits.[313]

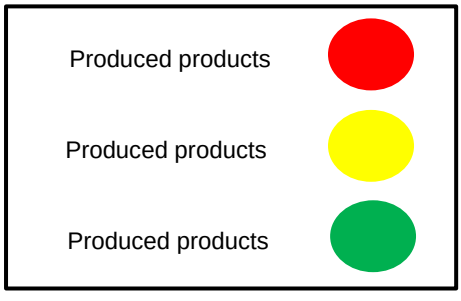


Image 52: Alert Icons

[311] cf. Eckerson (2011), p. 244.
[312] cf. Pollmann (2007), p. 104.
[313] cf. Kerzner (2007), p. 211.

- **Traffic lights icon:** This symbol is very common. It has a small advantage over the normal alarm icon. This advantage is that the importance of traffic lights almost everyone knows and because of that the display is read correctly. This symbol is especially often used when the image becomes irregular considered by a large crowd. They can assign the meaning of traffic lights just away.[314]

Image 53: Traffic lights[315]

- **Trend icon:** These are icons that indicate the behavior of key performance indicators. This can appear in three states. Movement towards the goal of moving away from the target and a static behavior. To this end, a lot of different symbols can be used. These can also be combined with state colors to achieve even greater significance. These symbols are mainly used to express whether KPI's change to the positive or negative over the time.[316]

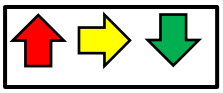


Image 54: Trend Icons

- **Progress bar:** This bar expresses more than just one dimension of information about a KPI. Usually these are described on the scale, color and limit. In the simplest version a progress bar describes the progress of KPI's in one dimension. In combination with colors and warning levels a possible attainment or an exceedance of a limit can be expressed. Progress bars are mainly used to show progress against a certain positive goal. Disadvantageously their use is when the elements to be measured can assume negative values. Progress bars are also suited to show comparisons between KPI's or other indicators. The prerequisite for this is that they are measured in the same dimension.[317]

[314] cf. Kerzner (2007), p. 211f.
[315] http://cdn.designrfix.com/wp-content/uploads/2011/07/free-psd-files-2011-2july-46.jpg, [read on 05.12.2014]
[316] cf. Kerzner (2007), p. 212.
[317] cf. Kerzner (2007), p. 212.

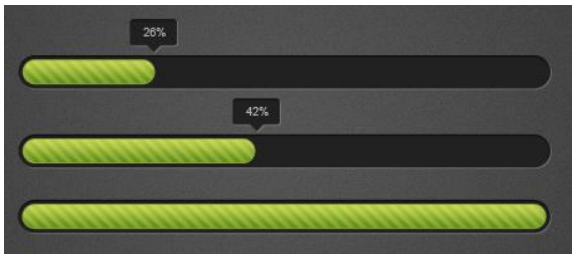


Image 55: Progress bars[318]

- **Different gauges:** Gauges are perfect for a quick illustration of positive and negative values. They can be seen as dynamic displays. Combined with different alarm levels conditions of KPI's can be immediately read, which draw certain actions. However, gauges should be reserved only to the highest key performance indicators. Those, which hold the highest level of the hierarchy. This change is e.g. during the day on a regular basis and not by leaps and bounds. For this reason, a representation with Gauges is better. Very important is their size. If they are visualized too small, there is a risk not being able to read necessary information in a proper way. In addition, gauges usually consist of a variety of elements. This leads to confusion in a small visualization. Too large visualizations waste valuable space unnecessarily on the dashboard. The visualization should be chosen wisely, because they get innately a lot of attention by the viewer from the start.[319]

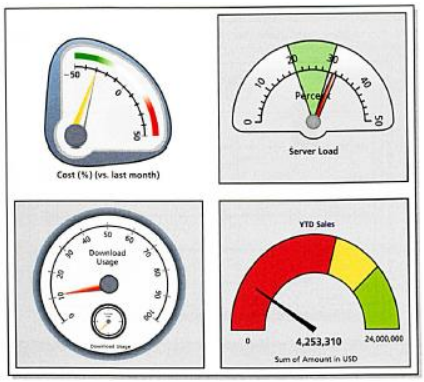


Image 56: Different examples of gauges[320]

Visualization of supporting key figures: Especially in the European-influenced culture is read from left to right. The subconscious mind perceives elements which are arranged from left to right, as a movement or development. For displaying the time, a time series graph is needed, in which the x-axis occurs as a time axis. For this

[318] http://www.psdfolder.com/wp-content/uploads/2012/05/Progress-Bar.jpg, [read on: 05.12.2014]
[319] cf. Kerzner (2007), p. 212f.
[320] Kerzner (2007), p. 225.

reason, you can divide chart types in time-dependent and time-independent charts. In the time-dependent diagrams, time plays an essential role and is crucial for the understanding. In the time-independent one, the exact moment does not care so much. The intention is to show how the situation was assessed at a given time.[321] Now some diagrams of the two types are described below.[322]

- **Pie charts:** Pie charts are primarily used to visualize relationships to the whole. Through them, for example, a contribution to the total contribution or a share of the total share is shown. However with pie charts there are quick lots of problems. If the entire construct exists of too many items, it quickly comes to confusion. Often the items are colored with different colors. Distinguish clearly between the colors is all the more difficult. An exact differentiation between the colors becomes more difficult. Likewise with labels. Are too many areas labeled, it leads to confusion of the viewer. In addition, it should be taken into account that the chart size decreases with increasing subareas and no clear distinction of different sizes can be perceived. For this reason, pie charts should only be used for the visualization of small overviews, consisting of only a few areas. They are preferably to be used in coarser overviews and should not be shown in detailed aspects.[323] In a more detailed representation bar charts are more preferable.[324]

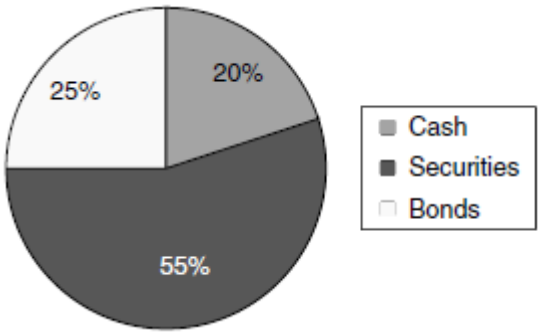


Image 57: Pie chart[325]

- **Bar charts:** Bar charts are column charts which has been rotated by 90 °. Bar charts compare different categories with each other. With them, a comparison is shown very clearly and easily understandable. The advantage with this type of diagrams is that the various categories can be measured in the same dimension. Because of that, one axis shows the different categories and on

[321] cf. Pollmann (2007), p. 107., 110.
[322] cf. Kerzner (2007), p. 213.
[323] cf. Kerzner (2007), p. 213.
[324] cf. Eckerson (2011), p. 246.
[325] Eckerson (2011), p. 246.

the other axis there is the value, in which the different categories should be measured. For this reason, charts are often used for comparisons between different categories bar. In contrast to pie charts a lot of categories do not lead to confusion of the reader.[326] Bar graphs represent actually more a distance and less a size. This type of chart is very useful to illustrate rankings. These data should be sorted in descending order so that statements are not lost.[327]

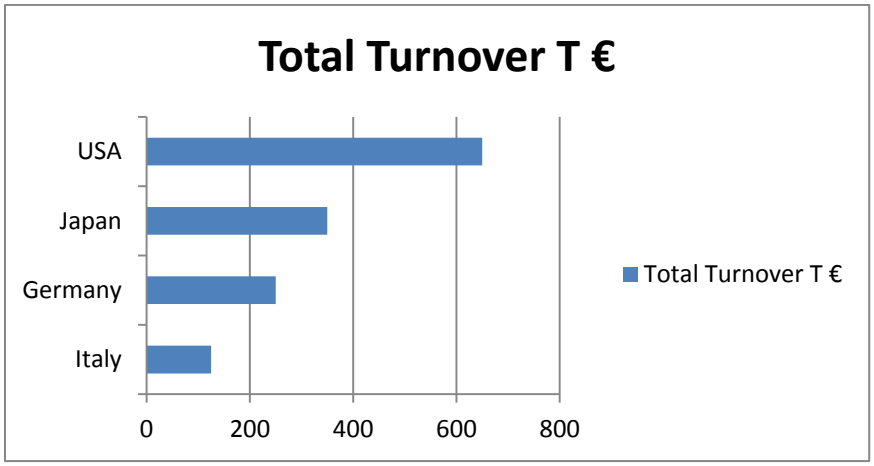


Image 58: Bar chart[328]

- **Column charts:** The column chart is a type of the bar charts. It is caused by the "filling" of the area under a value to the x axis with a standing rectangular area. Therefore it acts as a body. Depending on the brightness of the used color, and depending on the width of the columns, the chart appears lighter or more massive. Also the amount and spacing of the columns to each other is important. The more columns are visible on the x-axis, the more it appears as an area chart. In such cases, a line graph is advisable.[329]

[326] cf. Kerzner (2007), p. 213 f.
[327] cf. Pollmann (2007), p. 112.
[328] cf. http://www.controllingportal.de/Fachinfo/Excel-Tipps/Excel-Diagramme/einfaches-Balken-Diagramm.html, [read on: 10.12.2014]
[329] cf. Pollmann (2007), p. 104 f.

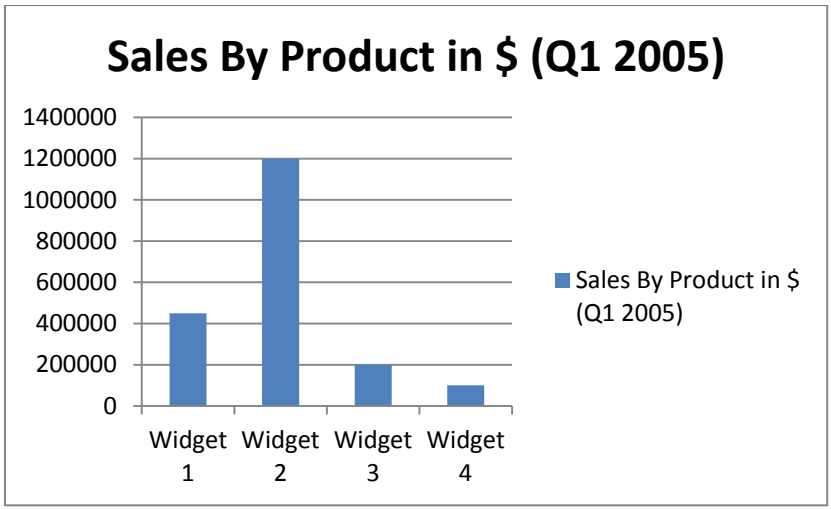


Image 59: Column Chart[330]

- **Line charts:** Line charts are in some cases the best way to show, how a business or a concern evolves or how much progress it takes. These charts can represent different data values over a certain period of time. So, trends can be very well recognized.[331] For this reason, these charts are used for detailed comparisons of data points. The time axis is the x-axis in most cases. On the Y-axis data values are displayed that were measured.[332]

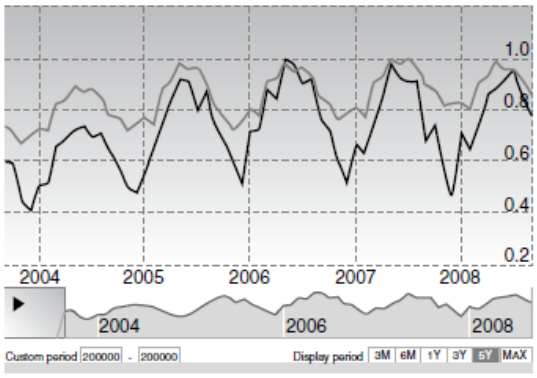


Image 60: Line chart[333]

- **Area charts:** If in a line chart, the area between the line and the x-axis is filled out, it becomes an area chart. Area charts are very suitable for displaying totals. However, they are less suitable for reproducing changes.[334] Area charts are also well suitable for simple comparisons with multiple data series. If the

[330] cf. Kerzner (2007), p. 214.
[331] cf. Eckerson (2011), p. 246.
[332] cf. Kerzner (2007), p. 215.
[333] Eckerson (2007), p. 215.
[334] cf. Pollmann (2007), p. 109.

various data series dyed in different colors or contrasts, the data series can be well compared to each other.[335]

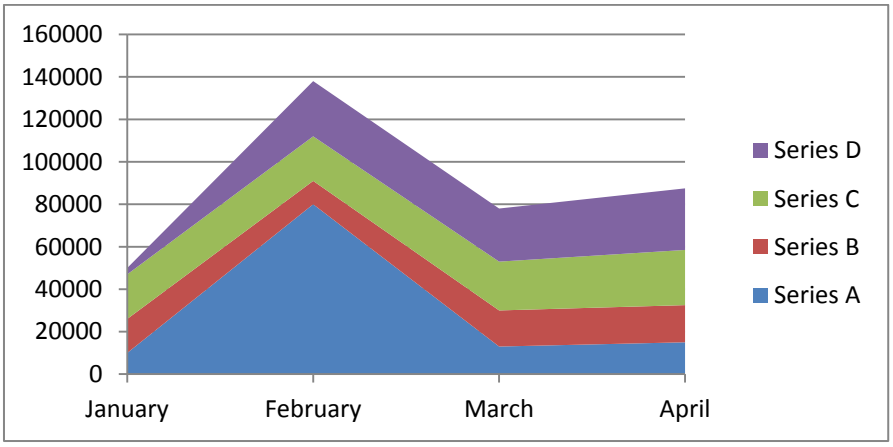


Image 61: Area chart[336]

- **Tables and lists:** In dashboards often texts or lists are used to represent details sufficient. Texts are used to specify numeric values. These are, for example, budget data. Texts are also often used for lists, in which hidden values should be exposed.[337] Therefore, tables or lists are used when a more detailed representation is required, which cannot be represented by graphs. These graphs would often confuse too much, because they require a lot of lines.[338]

	2006 Actual	2006 Plan	2006 Forecast	2005 Actual
Magazines	246,953	243,225	228,372	248,003
Reports	684,313	635,324	659,493	617,271
Web	84,023	84,280	87,313	83,335
Events	24,235	23,255	23,950	21,656
Membership	2,227	2,333	2,283	2,222

Image 62: Table chart[339]

Now this was a selection of the most important types of graphs. From them a variety of other types can be derived. Does a situation require so new graphs can be invented. The most important is that the presented image is understood and

[335] cf. Kerzner (2007), p. 215.
[336] cf. Kerzner (2007), p. 220.
[337] cf. Eckerson (2007), p. 245.
[338] cf. Kerzner (2007), p. 215.
[339] Eckerson (2007), p. 245.

interpreted correctly. In Annex 11 other types of graphs can still be found which are not in use so often. Nevertheless, they belong to the usual types of graphs.

8.2 Visualization options on the shop floor

Many companies are reorganized with the aim of creating decentralized, process-oriented and partially autonomous areas of responsibility. Business processes should be carried out as completely as possible and without interfaces to other areas. The local organization of the company brings a significant increase of flexibility and speed of execution of business processes. Small and medium-sized companies have introduced team organization and installed continuous improvement processes successfully. The staff of the operating level will be confronted with new tasks by the introduction of decentralized organizational structures. In addition to the right performance of the direct productive tasks, they have to take care on the one hand to the planning and coordination and on the other hand ensure the continuous development and improvement of their own work processes.[340] In order to improve business sectors systematically the installation of continuous improvement processes (CIP) is advisable. CIP is a method to apply the teams to autonomously optimize their own workflow. The goal of continuous improvement is to identify and eliminate non-value added activities, reduce cycle times in the process, efface waste and improve working conditions for all employees. CIP is based on a systematic and continuous detection and evaluation of the weak points in the process. The many small errors, deviations, differences, problems and shortcomings of the work processes are to be permanently eliminated by the staff at shop floor level. Requirement of an effective continuous improvement process is the standardization of work processes. The operations per cycle, the applicable working methods, their order and nature of the provision of material and equipment and their spatial arrangement are accurate to describe and followed during the execution. Comprehensive standardization with as few degrees of freedom in the execution as possible facilitates the identification of inefficient working methods and organizational deficits. Only when each work cycle is always executed in the same way, deviations, errors and areas for improvement are identified. Then, they can be replaced by more efficient solutions and transferred to other bents. The experience shows, that without standards improvements cannot be permanently established and pass slowly out of mind. Already overcome believed errors and problems creep in again. Standardization and especially the documentation of standards ensure that the achieved progress is permanent.[341]

Standardization is not contrary to flexibility. First, the team members are always part of the continuous improvement and should scrutinize and optimize standards permanently. So, standards can be changed at any time. To the other, standards

[340] cf. Kaluza / Blecker (2005), p. 368.
[341] cf. Kaluza / Blecker (2005), p. 371.

make processes of a corporation transparent and enable the company to take any necessary changes in the processes.[342]

For this implementation, the visualization plays an important role. Visualization, which helps support decisions, is the clear visualization of all standards, objectives and conditions so that employees can see and understand the differences at a glance. Thereby panels, displays, intranets, markings and labels are used. Information and facts are communicated in a simple, easy understandable and quick way. Besides, workplace, environment and premises will be functional emphasized. Table 9 gives an overview of the visualization objectives and the common forms of visualization in the production.

Types	Visualization at the workplace	Visualization of goals
Goals	• Identify procedure clearly • Establish and explain standards • Give hints • Support process-safe behavior • Documentation of activities	• Communication of objectives, status, problems and successes • CIP support • Promotion of internal communication
Forms	• Marks (land, labor areas, shelves) • Standard worksheets • Notes (critical operations, hazardous materials, quality) • Cleaning, maintenance schedules	• Key Figures Table, Team walls • Flip charts in meeting areas • Quality check points • Displays, Andon boards

Table 12: Overview of visualization forms and their goals to reach[343]

Often so called “key figures boards” are used in the production. Standardized key figures panels are used for visualization of the performance targets and as a tool for self-control of the team. For each team the achievement is documented via indicators. The team members are involved in the preparation and prosecution of the data. The breakdown of the figures panel is standardized, e.g. safety, quality, productivity, delivery reliability, sick leave, proposal rate, etc. The panel results are discussed regularly in the teams.[344]

[342] cf. Kaluza / Blecker (2005), p. 372.
[343] cf. Kaluza / Blecker (2005), p. 372.
[344] cf. Kaluza / Blecker (2005), p. 372f.

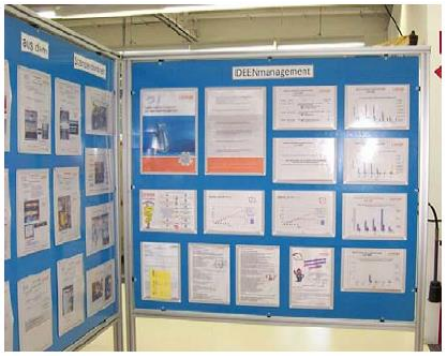


Image 63: Key figures boards[345]

To detect differences in individual factors of production, quality tools are often used in this field. In the literature, they are called the "elementary tools of quality assurance" or called "Q7". They include the cause-and-effect diagram, the check sheet, the control chart, the histogram, the pareto chart, the scatter diagram and the stratification. They were originally created from the Japanese Ishikawa for the use of quality circles. He had also developed the Ishikawa diagram. The Q7 are visual tools to identify, understand and solve problems. The tools are largely based on mathematical and statistical foundations that have been prepared specifically for use in the workshop area. However, it will be not further dealt with the various charts, because they are not the subject of this work. They should indicate only possible methods in practice.[346]

[345] http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 8., [read on: 20.12.2014]
[346] cf. Koch (2011), p. 136 f.

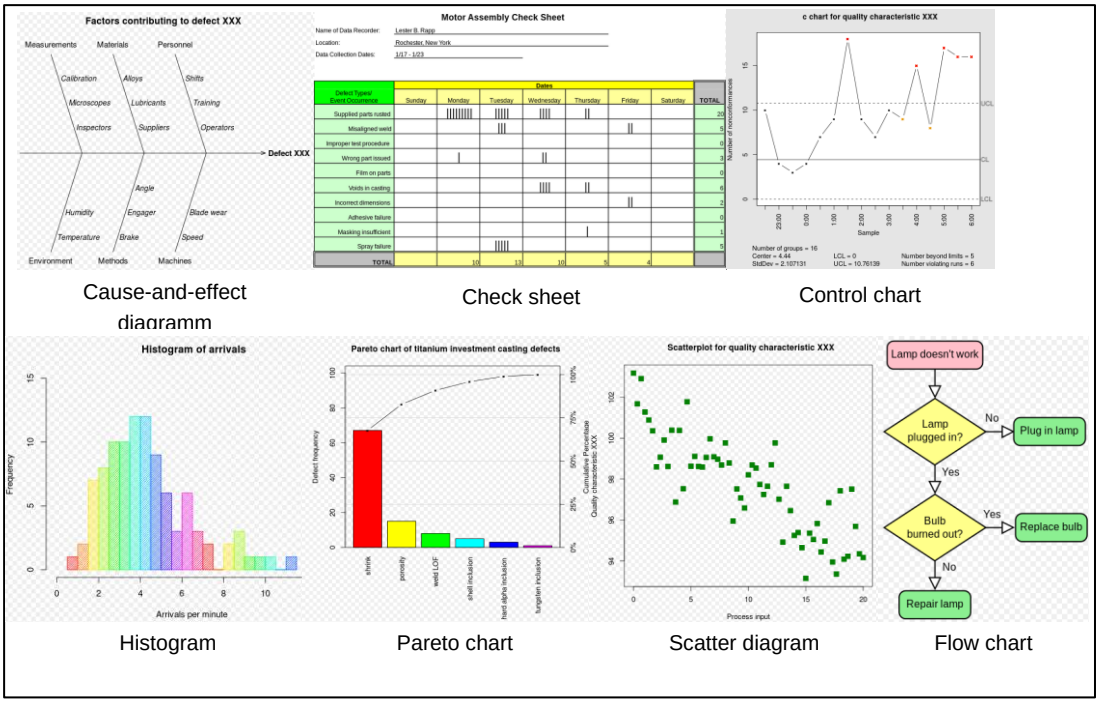


Image 64: Q7[347]

Starting point for an early decision support is the knowledge of the current state of the work system and running processes. Typical of visualizations in production today are manual, paper-based forms of representation, for example, Key figures boards. The structure and content of the visualizations is always the same. That means, they always show the same parameters. For continuous information this concept is suitable in any case. New IT-based visualization tools allow the realization of more comfortable and more extensive forms of visualization by:

- simple, specific workplace evaluations
- Traffic lights, flags
- targeted display of "problem" key figures
- Identification of "problem drivers"
- Retracing of incorporated raw data[348]

8.2.1 Specific examples of the shop floor

Target in each production is a high productivity obtained by stable processes with minimal work in progress. That means, whenever an error in this value flow occurs, the process must be stopped in order to find the error or problem as quickly as possible to resolve. It is important that the clock and cycle time is displayed on top of the line all the time. All employees and managers should be advised that it is the responsibility of the individual processing station, not only to produce in cycle time,

[347] http://en.wikipedia.org/wiki/Seven_Basic_Tools_of_Quality, [read on: 20.12.2014]
[348] cf. Kaluza / Blecker (2005), p. 376 f.

but to approach the cycle time to the cycle time by removing obstacles. The difference between the cycle time and the clock time must be made visible. A visual support for clocking is the Andon board. Andon is a system for monitoring processes by the real-time transmission of information on production or logistics conditions such as:

- Production status: Number of items, which should be produced (set), number of parts produced (actual), differences / production trend (trend), etc.
- Stock: remaining stock on hand, the amount of reorder, time period until shortage
- Cycle times
- Performance indicators
- Distress calls from the production line
- Error messages
- Information messages
- et cetera[349]

Simple and complex systems based on electronics are used. Simple systems consist of one or more displays / displays and work independently. Such systems are focused exclusively on the transmission of information.[350]

Probably the most widely used display form in the production is the Andon board. Andon boards are designed to customer specifications. Each Andon board is controlled by a separate unit of account. Special software allows you to change the parameter (e.g. production calendar) by the direct connection (Ethernet) between a laptop and the processing unit. It requires no special client infrastructure. Each Andon board is powered up. The numerical input is connected to a source number (e.g. sensor). Because of this, a transparency of different types of time-wasting is achieved.[351]

[349] cf. http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 26f., [read on: 20.12.2014]
[350] cf. http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 27., [read on: 20.12.2014]
[351] cf. http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 28., [read on: 20.12.2014]

Image 65: Simple Andon boards[352]

Also known as distress calls from the production line are displayed on Andon boards. These systems allow the employee to forward the respective problems quickly and easily. If needed, any job position activates an integrated radio transmitter to trigger a call for help. Each call for help goes directly to the digital display system (Andon board) and is displayed. So, the executive or the employee in charge can react to the problem. In addition, this cry for help can also be enhanced by acoustic signals. After the respective issues are resolved, the cries for help are acknowledged by the radio transmitter. A computer takes over the management of these distress calls.[353]

Visual indicators on big screens find more and more fields of application and help to point out deficiencies visually, to trigger fast reactions or to inform, how the situation soon evolves to react accordingly. In the maintenance a board shows all machinery and equipment (e.g. green = everything is OK, yellow = needs to be serviced soon, red = machine downtime). An action is immediately set in motion at red display. A Heijunka board visualizes the employees how the current order transaction occurs and how to develop the next few days, so that the line team can decide how they can use their capacities to the displayed utilization.[354]

[352] http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 28., [read on: 20.12.2014]
[353] cf. http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 28., [read on: 20.12.2014]
[354] cf. http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 29., [read on: 20.12.2014]

Image 66: Visualization of different machine conditions[355]

Image 67: Heijunka boards[356]

The status of the planned daily output can be electronically displayed. The visualization of the actual balance is performed on a traffic lights system on a monitor in each group or power unit. As long as the lights are red, the group / power unit is not on the same-day basis. That means that it must be decided in time, how the same-day basis can be secured (move overtime, personnel, etc.). If the traffic lights green, the group reached the same-day basis and the staff migrates to other jobs or in the group where the traffic lights are still red or they help to finish the layer. Behind all these electronic possibilities there must be a corresponding improvement management, which documents why the deviation is created and must ensure that the cause is found and eliminated. That means that these electronic helpers are meters of proficiency levels and pulse generators at the same time. Unilateral use leads to false leadership. This would only claim open achievements without an investigation of the actual impediments. Another aspect results from the fast decision. Instead of going through the different hierarchy levels, the authorized person makes

355 http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 29., [read on: 20.12.2014]
356 http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 29., [read on: 20.12.2014]

quickly decisions to prevent possible conflicts. A lean enterprise is not generated, if lean processes only reduced to shop floor processes.[357]

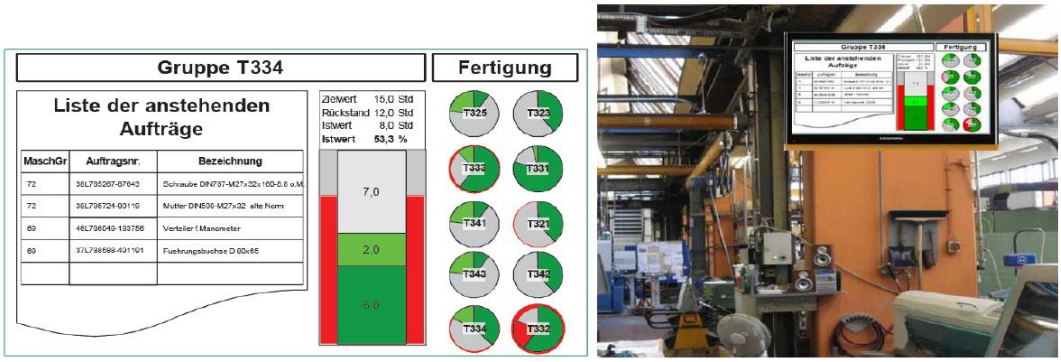


Image 68: Visualization of the same-day basis[358]

As part of the Lean management, all successful work and activities are standardized within the company so that they can always be carried out in the same manner and quality regardless of the person and time in the future. The standardization of operation is documented on standard worksheets and is visible to all employees. A Standardized Work Combination Sheet for example, determines the order of the production steps within a scope of work and the planned time requirements of each work step. However, a standard worksheet (Standardized Work Chart) depicts the layout of a workstation and the production steps in numerical order and progress. The standard worksheets are constantly updated to cope with the continuous improvement of operations. They also serve as a basis for training of employees and as work instructions of new staff.[359]

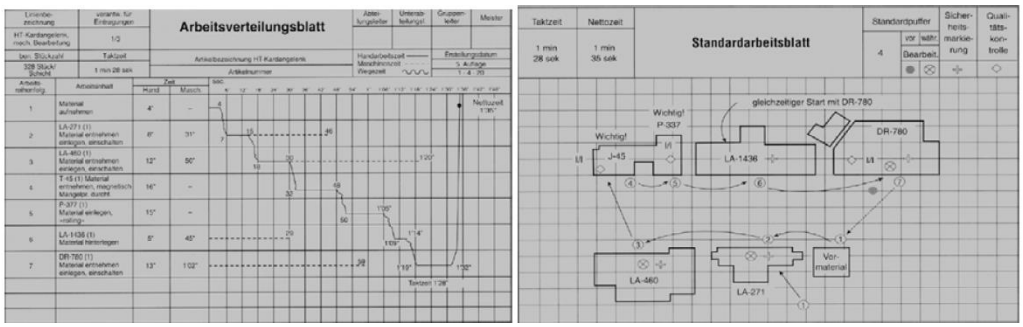


Image 69: Distribution of work sheet and standard worksheet[360]

[357] cf. http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 29., [read on: 20.12.2014]
[358] http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 30., [read on: 20.12.2014]
[359] cf. http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 29f., [read on: 20.12.2014]
[360] http://www.awf-arbeitsgemeinschaft.de/download/Visuelles%20Management-Engroff.pdf, p. 30., [read on: 20.12.2014]

8.3 Visualization in the operational management level

In contrast to the shop floor, the operational management is a hierarchical level above. At this stage, not only single metrics are evaluated. The focus is more related to the interaction of the individual indicators on each other. Here, especially the MES plays an important role. With this system, the three areas of production, human resources and quality are brought together and reviewed in real time.[361]

8.3.1 Manufacturing Execution System (MES)

The Manufacturing Execution System is a software solution that bridges the information gap between the Enterprise Resource and Planning System and the Production Floor. Generally speaking, it combines the planning level with the operational production areas. Due to the increased transparency and real-time data, weaknesses in the value creation process can systematically be identified and countermeasures can be performed faster.[362] Vertical integration is of utmost importance. The MES-system represents a point of control between the temporal extremes. The within seconds acting automation in manufacturing on the one hand and the ERP world on the other hand, which operates in the medium and long-term range.[363]

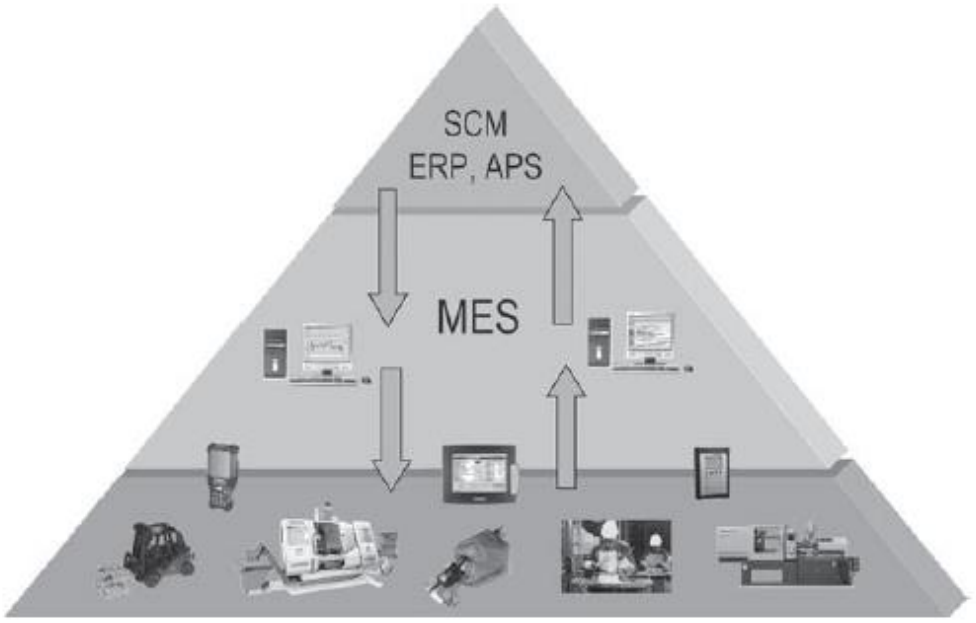


Image 70: The vertical integration of enterprise levels by MES[364]

[361] cf. Gerberich (2011), p.37 ff.
[362] cf. Gerbericht (2011). p. 37.
[363] cf. Kletti (2007), p. 57.
[364] Kletti (2007), p.57

The exchange of information between the operational level and the MES is done in real time and is based on the technology of the machinery and equipment. An MES represent online the use of materials, equipment, appliances and other capabilities at all times. Moreover, it allows the dispatchers as planner, foreman or plant manager in case of problems immediate alternative decisions. Data from the ERP are applied and processed with production requirements. Then they are sent to the production. During the confirmation it is often necessary to compress data from production, so they can be used by an ERP system. At the same time, however, the production management must be informed about all the necessary details. Especially within the feedback in complex production lines the accumulation of data is very high. This could be process data, working acts of machines, machine downtime or work process-related feedback. For these data, an ERP system has no use. Here, a MES ensures that the data is processed and transferred in an ERP suited way. The MES exchanges irregularly with the ERP system. With the production, however, there is a permanent nominal / actual comparison important. This is the only way to react adequately to differences between planned and actual situation.[365]

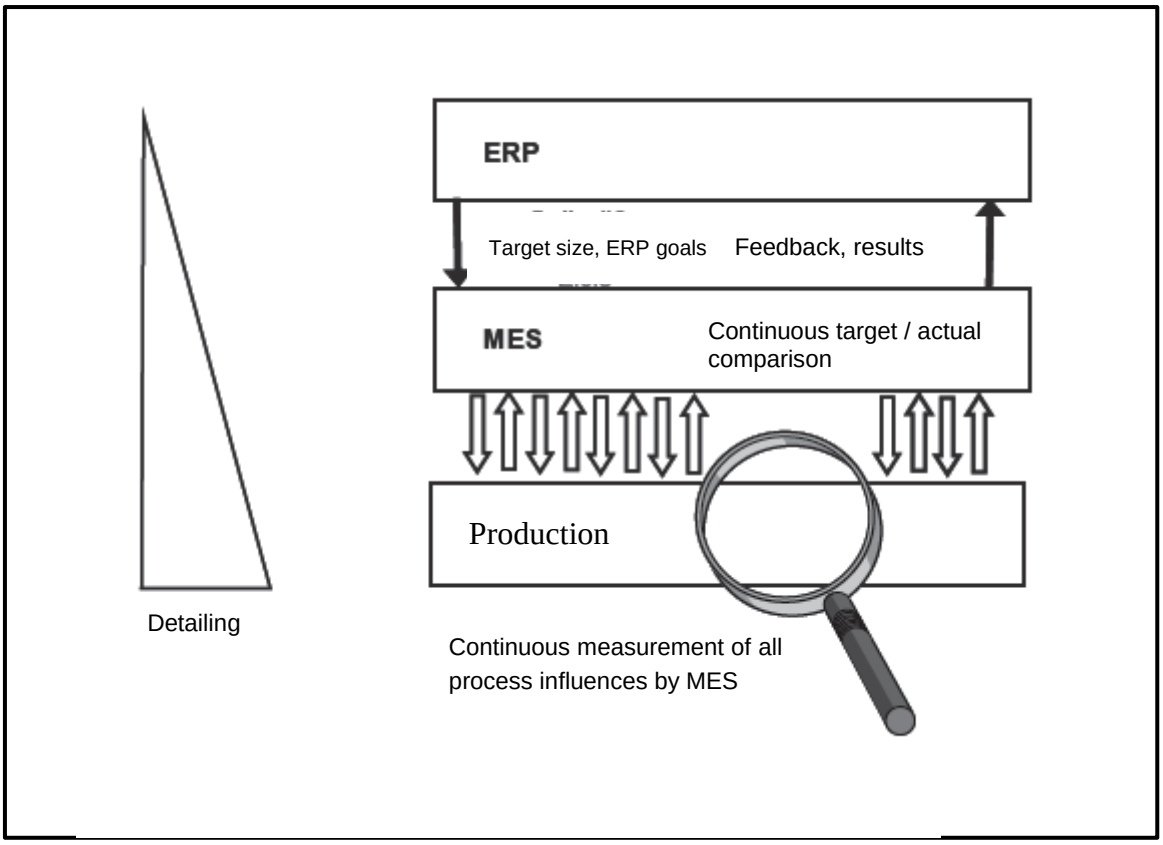


Image 71: MES in the enterprise hierarchy[366]

[365] cf. Kletti (2007), p. 57 f.
[366] Kletti (2007), p. 58.

In defining the term Manufacturing Execution Systems is still often designed differently, because the angle of observation is different. Two definitions should be briefly introduced.[367]

- MES is defined as a technology that has developed in Europe from very different disciplines such as business data collection, time and attendance, quality assurance and production planning. The homogenized and condensed version of these technologies can be combined with the concept of MES.[368]
- Manufacturing Execution Systems (MES) provide in the production control level the vertical and horizontal integration. They are an important link between the machine control and the systems of corporate management level.[369]

8.3.2 MES models

A number of institutions have already taken up the issue MES. They attempt to preserve the term MES with the help of definitions and norms. There are various forms visible. Only the most important will be briefly introduced.

MESA

The Manufacturing Execution System Association was the first organization that has addressed this issue. It is one of the most experienced, which report on this topic. The MESA commits here a very pragmatic approach and described eleven functional groups. These are necessary for an effective support of the production management [370]. This was the prior model. It was called the original “MESA-11”. It was developed in 1997. The current model was created in 2008. [371]

Those functional groups are:

- **Product Tracking and Genealogy:** Documentation of all processes in the development of a product. Detecting the materials used and the ambient conditions.
- **Resource Allocation & Status:** Management and monitoring of resources (machines, tools, personnel).
- **Performance Analysis:** Comparison and evaluation of measured and recorded actual values (plants or areas of operation requirements, customer requirements, etc.).

[367] cf. Gerbericht (2011), p. 40
[368] cf. Kletti (2006), p. 11.
[369] cf. Gerbericht (2011), p. 42., quoted after VDI-Kompetenzfeld Informationstechnik 30.10.2003, p. 1.
[370] cf. Thiel / Meyer / Fuchs (2008), p. 41f., Kletti (2006), p. 25 f.,
[371] cf. http://www.mesa.org/en/modelstrategicinitiatives/MESAModel.asp [read on: 16.10.2014]

- **Process Management:** Monitoring of the actual production process in accordance with the planned and actual loads and specifications.
- **Data Collection / Acquisition:** Automatic or manual recording of all production-relevant operational data. These are connected to the production unit.
- **Quality Management:** Analysis of production-relevant data in real time. Recording, tracking and analysis of the product and the process. Verification with the ideal.
- **Labor Management:** Control and definition of work processes and work distribution to employment and personnel.
- **Dispatching Production Units:** Manage in the production used feedstock and intermediates. Documentation of material consumption.
- **Logistics Focused:** Transport Management System (TMS), Warehouse Management System (WMS).
- **Controls:** Product Life Cycle (PLC), Data Collection System (DCS) [372]

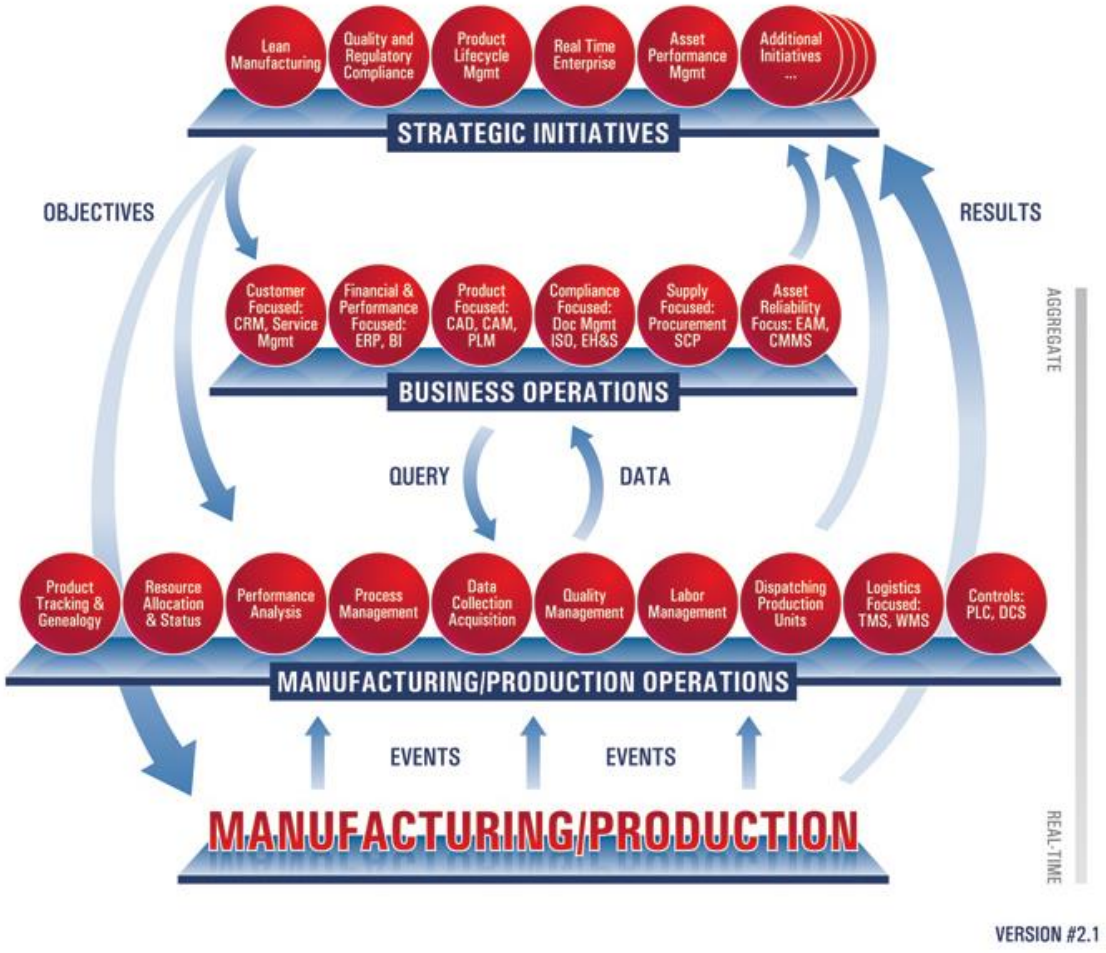


Image 72: MESA model[373]

[372] cf. Thiel / Meyer / Fuchs (2008), p. 41 f., Kletti (2006), p. 25 f.
[373] http://www.mesa.org/en/modelstrategicinitiatives/MESAModel.asp [read on: 14.10.2014]

VDI-guideline 5600

Looking at the previous function-oriented MES model in more detail, it can be seen, that this model cannot be always transposed in the exact equal way to Europe. For this reason, the “Verband Deutscher Ingenieure” altercated with this issue and trimmed the definition to German needs. The 5600 Directive "VDI Guideline 5600" was the result of this expert panel.[374]

The following eight tasks of MES were defined:

- **Detailed Scheduling and Process Control:** Supports the execution of the work queue. Consideration of the production constraints according to a predetermined target orientation of production.
- **Equipment Management:** Ensuring on time and demand availability and technical operability of the equipment. Frequently goal conflict of demand for long-term availability and desired high reliability.
- **Material Management:** supply and disposal of production with material. Management of work in progress.
- **Personnel Management:** Providing staff with suitable qualifications on time for the production process. Consideration of personnel related capacity data. Management of time accounts.
- **Data Acquisition:** Event-controlled recording of data from a process. In addition to the automatic data transfer semi-automatic and manual recording of data are possible. MES task: input processing and pre-compression of the data. Providing of status information.
- **Performance Analysis:** Realization of control loops with different cycle times in the manufacturing environment:
    - Loop with a short cycle time for operative interference of the process due to identified target / actual deviations.
    - Loop with a long cycle time to optimize the process and qualification of the specifications.
- **Quality Management:** Ensuring product quality and capability of the process. Included sub-tasks:
    - Quality planning
    - Quality Testing
    - Management of measuring and test equipment
- **Information Management:** Switching point to integrate other MES tasks and to accomplish all the workflows in executing the pool of orders and the process optimization. [375]

[374] cf. Gerbericht (2011), p. 50.
[375] cf. VDI-Richtlinie 5600 (2007), p. 16 ff.

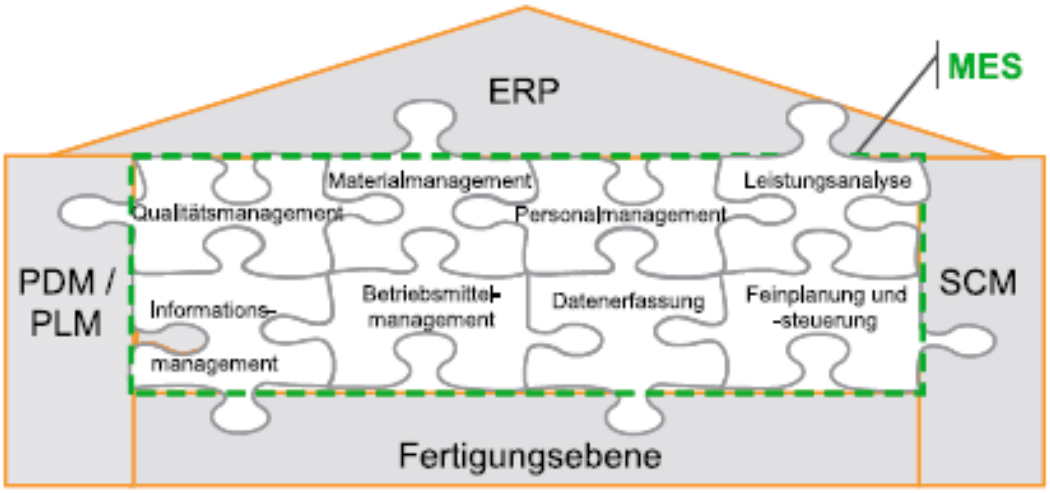


Image 73: MES between the enterprise levels[376]

8.3.3 The MES Reference Model

The statements of this chapter are much related to the literature of “Gerbericht Thorsten“. The modeling is based on the fact that the MES modules are very different from various MES providers. In the following model it should be not mentioned individual solutions from single providers. Here, it is the same as in other industry sectors. A large company delivers often everything itself. Smaller companies are specialized in individual areas. It should be only created an abstract universal MES Reference Model, which still reflects the available MES modules on the market.

The MES modules of the reference model can be characterized:

- Multi-supplier
- Individually implementable
- Representative function range
- Applicability in the automotive industry
- Reliable procurement possible
- No special or niche MES modules
- Standardized SAP interfaces
- Web-based
- Database-oriented platform
- Consideration of ISA S95
- Compliance with the definitions of MESA and VDI

[376] Gerbericht (2011), p. 52.

The definitions of MESA and the VDI faced with individual MES tasks and functions, so-called “real MES modules”[377] can be identified.

As a result of this comparison it can be noted that all the identified real MES modules meet the requirements of the VDI and the MESA completely. Thus, these MES modules can be transferred in a MES reference model with nine modules.

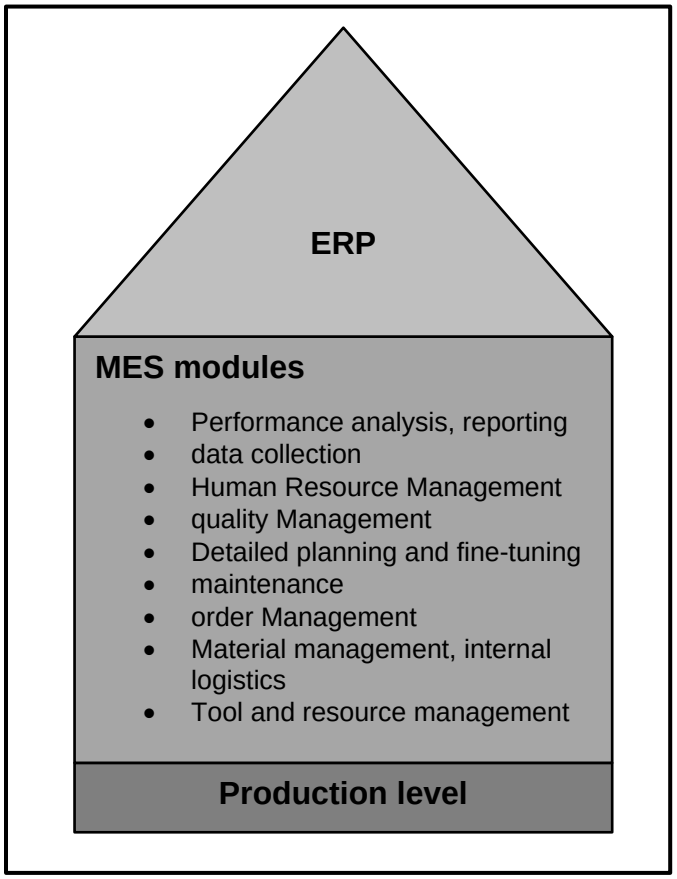


Image 74: MES reference model[378]

The reference model visualizes the main tasks of the nine MES modules. They connect vertically the production level (shop-floor level) with the ERP.

In the following is a brief description of each real MES modules. A more detailed explanation can be found in the appropriate literature. This is however not part of this work.

Performance analysis, reporting: The focus of this first MES module is on the performance analysis and the subsequent reporting of the results obtained, although a visualization for example on an Online Performance Monitor (OPM) is possible. By target-actual comparison, calculating and displaying of indicators the production-controlling is supported. For example, as an important metric the OEE can be

[377] By Gerbericht, real MES modules are understood as MES software solutions that are available on the MES market.
[378] Gerbericht (2011), p. 55.

visualized. This consists of the availability, effectiveness and quality rate and is a measure of the efficiency of a production process, based on a machine or system, production cell with multiple machines or an entire assembly line.[379]

Data collection: The data acquisition module collects order, mechanical and personal times and amounts such as amounts of material, processing times, downtimes, quality, engineering and maintenance data, which are recorded directly at the source. This data can be automatically detected or manually entered into the MES module. The manual input is performed by an operator via MES client with touch screen or keyboard. When entering they are verified and then natively checked for consistency. Also the status of orders, resources and materials is monitored.[380]

Human Resource Management: This module integrates various functions that support the production management. In this module, personnel information such as guided qualifications is managed. Based on this, a qualification matching can be performed and access permissions are given. With the integrated shift models staffing plans can be created and personnel requirements can be determined. For this purpose, the module provides an overview of the active staff, supports for the manual creation of deployment plans and delivers these in an automated way. These plans are based on the stress situation of the department or the company. Finally this MES module supports the wage calculation with data from the manufacturing process.[381]

Quality management: Quality management is considered in Mesa function model and in the VDI guideline as a unit, so the quality management is also included in the MES reference model as a module. However, the available MES quality management modules in the market include the individual functions setup: *control, process locking and tracking*. Due to their different mode of action on different targets and the presence of comparison partner in the Lean philosophy, these three functions are separately analyzed and evaluated in the benefit and interdependency matrix. In the next steps of Lean MES choices these differentiated view is maintained.[382]

Detailed planning and control: For the reference model, the individual functions of production planning and controlling are divided into two MES modules. This partly reflects the structure of manufacturing execution systems available on the market, on the other hand the planned MES concept for the analyzed company. This MES module takes over the detailed planning and management of customer orders, but excludes the directly performed micro-planning on the production lines. It is usually implemented as a control station, the detailed planning and control of production can

[379] cf. Gerbericht (2011), p. 56.
[380] cf. Gerbericht (2011), p. 57f.
[381] cf. Gerbericht (2011), p. 59f.
[382] cf. Gerbericht (2011), p. 60f.

be performed manually or automatically. In this case, the appropriate resources are assigned to each production order. For this purpose, the system visualizes the order situation in manufacturing in real time. It simulates in a breakdown if production orders can be rescheduled and plans the solution, which is founded. If necessary, a module for the order management is needed.[383]

Maintenance management: The maintenance management of resources, integrated in the MES module can constitute the basic maintenance strategies. This is the preventive, operational and condition-based maintenance. The planning and management of appropriate measures in the light of the data life monitoring is performed. The planning and management of adequate measures are implemented. In this process, data of holding times are considered. The planning is carried out based on the integrated maintenance calendar. In addition, the overall behavior of all maintained equipment and facilities is presented in a summary. Functions of cost accounting and controlling can be integrated as a supplement.

Order management: The short-term management of construction contracts directly to a production line is the task of this MES module. The order management module takes over the micro planning under taking into account the current availability of the material and possible disturbances in the production process. These are often not visible in the system of the MES module "Detailed planning and control". The focus of this MES module is primarily the transport of information for the production orders to the production lines.[384]

Material management, internal logistics: This MES module includes the management of production materials and supports the management of internal logistics. According to the VDI guideline 5600, it ensures on schedule-time and on-demand supply and disposal of the production with material. This module is also in charge for the guidance and processing of the rotating stock. That means materials from outside the exactly planned stocks in the warehouse. Furthermore, in the MES material management it is the possibility to realize a batch management.[385]

Tools, equipment management: Means of operation and operating resources such as tools are an eminent part of the work system. For this reason, the systematic management for achieving the production result is essential. This task is performed by the MES module tool and equipment management. It includes the management of the tool inventory and tool data as well as the organization of tool maintenance if they are not integrated into the maintenance module. In addition, the tool assignment is taken over as part of detailed planning.[386]

[383] cf. Gerbericht (2011), p. 63f.
[384] cf. Gerbericht (2011), p. 64f.
[385] cf. Gerbericht (2011), p. 66f.
[386] cf. Gerbericht (2011), p. 67f.

8.3.4 Example of a MES-Cockpit

In a so called „Production-Cockpit“ large amounts of information, which exists in form of indicators or key performance indicators, will be represented in a compact way. The degree of compression can vary, depending on destination and addressee. In practice, representations, such as traffic lights, speedometer or thermometers are often encountered. The technical implementation can be done using a separate information system or as part of a management information system or data warehouse.[387]

In the following chapter a MES-Cockpit is briefly explained. However, each system has a different structure. Regardless, there is still a certain similarity, because all these programs work in the same framework. However MES systems are usually implemented by external companies. Thereby a comparison of various solutions in literature and by third parties turns out to be difficult. These are almost always the in-house expertise and are not communicated in public. Representative will be discussed the concept of the company “MPDV Mikrolab GmbH”.

The MES-Cockpit is a web-based program. Thus, it can be accessed through a web browser without any additional installation. Integration into existing or new set up enterprise portals is possible. Every user can individually compile the cockpit himself, depending on the required data and evaluations, and save for later use. In this juncture it can be accessed imported data from different databases. From these combined data, it is possible to generate meaningful metrics.[388]

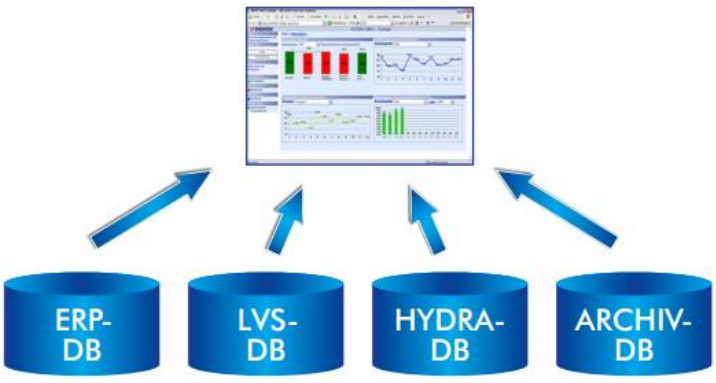


Image 75: Different databases for a MES cockpit[389]

Management-level objectives are defined, which serve as target values. These requirements are implemented in the production line or work preparation in specific metrics and ratios. For example, to increase productivity, there can be adjusted several set screws in the production. The setup time per machine can be used for an

[387] cf. Wickel-Kirsch/Janusch/Knorr (2008), p. 152.
[388] cf. http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 2., [read on: 27.12.2014]
[389] http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 2., [read on: 27.12.2014]

indicator for example. Therefore, the actual periods of the setup time in production will be recorded. The data from the MES are compressed and can be evaluated per machine, shift or day. Though, observed abnormalities are clearly visualized in the MES cockpit to define possible measures. Based on the available data, the formulas of standard codes or own metrics can be stored in the MES cockpit by the user. In order to achieve the company's goals, time-related reference values are defined. Then they are available in the system with their different display possibilities and allow direct target-actual comparisons. By considering the recent history trends in the development can be read. If the planned target values were achieved, a high quality process forms the basis. It this is not the case, the process must be checked and corrected in order to achieve improvements.[390]

The structure of the MES cockpit: When opening the MES cockpit the user gets to the home page, where comprehensive, overarching key information are provided. The user can display detailed information by clicking through the home page. The level of detail increase, the deeper the user enters the plains ("drill-down"). The MES cockpit always visualizes the evaluations by using various graphics.[391]

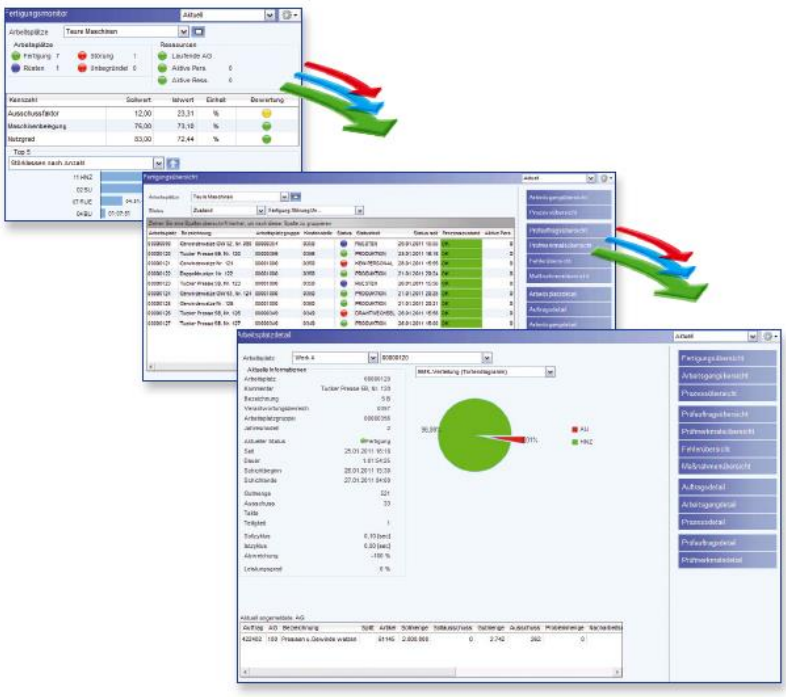


Image 76: Different levels of a MES cockpit[392]

The MES cockpit offers three applications that are adapted to the specific roles and perspectives of users. These three areas of application are the “Status Monitoring”, “Condition Monitoring” and “Performance Analysis”.[393]

[390] cf. http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 2f., [read on: 27.12.2014]
[391] cf. http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 3.., [read on: 27.12.2014]
[392] http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 3., [read on: 27.12.2014]

Status Monitoring: In the “Status Monitoring” the current status in the production or the currently running layer is shown. Here, the compression of the information is aligned to the currently selected display level. On the homepage the Master or production scheduler gets an overview of the user-specific information from the current layer. On the dashboard, the various monitors can be mounted user-specific and because of that, specific information can be displayed. By choosing a monitor, further details can be displayed, for example, individual machines down to the currently running operation on a given machine (drill down). The information is also graphically available. The graphic machinery park indicates the physical location and the set ads and layouts of the user. In addition to the pure status display of machinery, the associated terminal and the buffer material, a display of the current indicators, current article, operation cycle, etc. is shown.[394]

Image 77: Status Monitoring (Home page)[395]

Condition Monitoring: The Condition Monitoring provides the production line, the operations scheduling and quality assurance the ability to visualize the latest figures on a basis of predefined conditions and represent deviations from the defined target values.

[393] cf. http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 3., [read on: 27.12.2014]
[394] cf. http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 4.., [read on: 27.12.2014]
[395] http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 4., [read on: 27.12.2014]

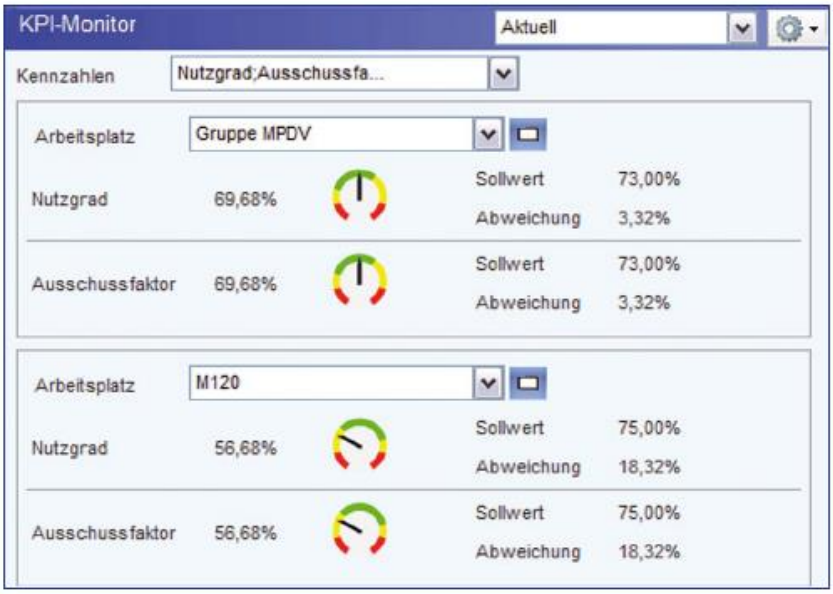


Image 78: KPI-Monitor[396]

For instance, in the KPI monitor selected indicators with the actual value, the defined set point and the resulting deviation can be displayed for specific job groups. With the help of Condition Monitoring based on evaluations, it can be recognized, which values deviate too far from the company's own standards. Has at a particular workplace the rejection rate in the current layer increased enormously, it can be requested on the spot, which causes underlie. For example, if there is a defect at the machine or the newly used raw material is defective, it can be rapidly responded to the set point deviation. In the Condition Monitoring module the manufacturing/production monitor displays a tabular representation of figures with review. This makes it visible at a glance in what direction the actual deviates from the set point.[397]

[396] http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 4., [read on: 27.12.2014]
[397] cf. http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 4f., [read on: 27.12.2014]

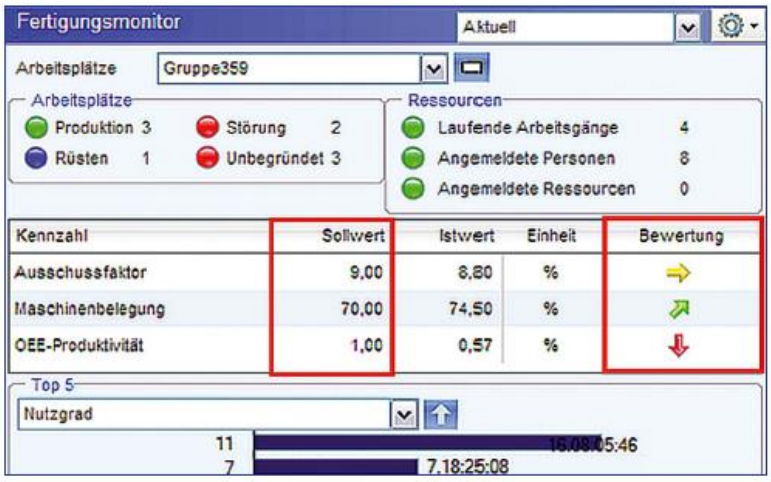


Image 79: Production monitor[398]

Performance Analysis: Using the Performance Analysis, a week-point analysis for the defined metrics can be carried out over a longer period. Time state and object comparisons can be visualized, to get more transparency about the possibly existing deviations from the defined target values. The following are some examples:[399]

Target tracking evaluation: Visualization of an indicator's trend for a given period in relation to the defined set point.

Image 80: Target tracking evaluation[400]

Totals report: Tabular and graphical representation of an indicator that is calculated for selected structures in order to compare jobs, cost centers or areas.

[398] http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 4., [read on: 27.12.2014]
[399] cf. http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 5., [read on: 27.12.2014]
[400] http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 5., [read on: 27.12.2014]

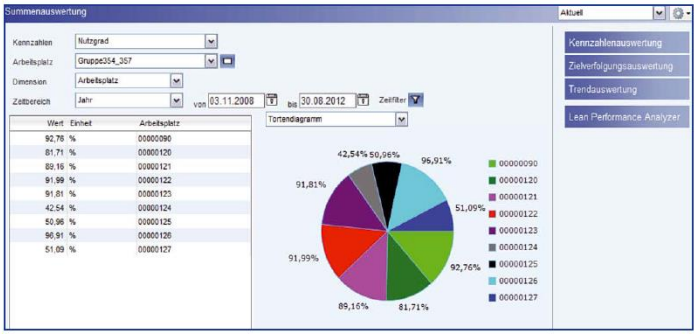


Image 81: Totals report[401]

Evaluation of key figures: Indicator comparisons with a choice of up to four selection groups with up to two time ranges.

Image 82: Evaluation of key figures[402]

Trend analysis: Display of key figures courses with their respective boundaries in direct comparison to the average, maximum and minimum course of a selectable control group.[403]

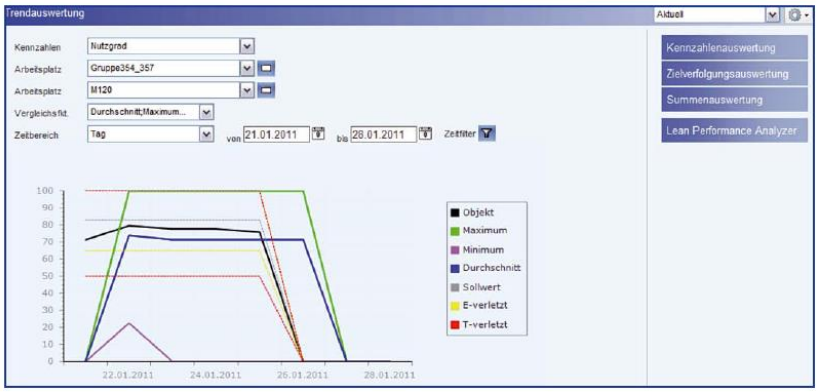


Image 83: Trend analysis[404]

[401] http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 5., [read on: 27.12.2014]
[402] http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 5., [read on: 27.12.2014]
[403] cf. http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 5., [read on: 27.12.2014]
[404] http://www.it-auswahl.de/Content/Documents/MES-Cockpit.pdf, p. 5., [read on: 27.12.2014]

9 Application of certain key figures

In the following section important key figures, according to the findings of this work, are characterized and visualized. Well-known indicators are used, which serve in almost every company. In this process, the following key figures “ROI” (KPI), cycle time” (KPI) and “scrap rate” (PI) are described. These three were taken, because they are applied to different hierarchical levels within a company.

The characterizations, which apply to the key figure, are stored in the catalog with brown color. If several fields are brown, the figure is part of several characterizations.

9.1 Grading of the KPI “Return on Investment (ROI)”

The “Return on Investment” is the key performance indicator in the financial perspective and also in the performance measurement system of the DuPont system.[405] As a key performance indicator the “Return on Investment” represents a specific rate to the fixed capital. This measure is mathematically decomposed into return on sales and asset turnover. Moreover, a further degradation takes place by the help of mathematical operations of these variables until a depth is reached, which allows a systematic analysis of the main factors influencing the return on investment. The structure of the system, which is classified to a computing system, because of the mathematical links between the individual figures, is shown in Appendix 1.[406] The connection between the different indicators, which the key performance indicator “Return on Investment” consists, are based on a logical relation.

The ROI is the most important benchmark for the economic use of capital in the whole company, in investment project, and also in production areas. Operating profit is calculated top-down as "earnings before interest and taxes” (EBIT) and bottom-up from sales minus costs. The ROI is often defined as the minimum size of the company (often in the range between 10 and 20% before tax). For projects that result is derived from cost and revenue changes by the proposed project. With a predetermined minimum ROI, economic capital usage can be supported. Too high thresholds, however, may jeopardize future projects.[407]

[405] cf. Bauer / Hayessen (2009), p. 43.
[406] cf. http://www.wirtschaftslexikon24.com/d/du-pont-kennzahlensystem/du-pont-kennzahlensystem.htm [read on: 17.03.2015]
[407] cf. Bauer / Hayessen (2009), p. 43.

$$ROI = \frac{operating\ income}{capital\ investment} \times 100\%$$

Formula 6: ROI[408]

This measure is mainly used in the management levels of a company, because the profitability target is the most important aim for most companies. In addition, this figure refers to the performance of the whole company. It is therefore less designed to control directly single departments.[409]

From the table two [chapter four], the key figure structure is B 2 b. The numerator represents the operating income where the denominator indicates the total invested capital.

The characterization of the KPI "Return on Investment":

Systematization feature	**Types of business figures**					
Business function	Purchasing	warehouse management	production	sales	HR	finance
Hierarchy level	Strategic management		Division		Shop floor	
Statistically methodological aspects	absolute numbers			ratios		
	single numbers	sums	Differences	average values	relationship numbers	outline numbers	index numbers
Quantitative Structure	Aggregates			portion sizes		
Temporal structure	point of time sizes			period sizes		
Content structure	value sizes			volume sizes		
Cognitive value	**key figures with**					
	autonomous value			dependent value		
Sources in Accounting	**key figures of the**					
	balance sheet	Accounting		expenses, results of operations and cost accounting		statistics
Elements of the economic principle	input		result		standards of relations between input and result	
Territory of the statement	total operating metrics			part operation metrics		
Planning considerations	target indicators (forward-looking)			actual indicators (backward-looking)		
Number of participating companies	single operating metrics	enterprise metrics		industrial sector metrics	total operating metrics	
The range of determination	standard metrics			business specific metrics		

[408] cf. Bauer / Hayessen (2009), p. 43.
[409] cf. Gladen (2003), p. 97.

Power of the company	cost-effectiveness metrics	key figures about financial security

Table 13: Characterization of the KPI "Return on Investment"[410]

Since the ROI is just "head key figure" in the DuPont system, this value alone is not meaningful. Only with the help of the values, which make up the ROI, clear information is provided. The DuPont Performance Measurment System is classified as follows.

The characterization of the DuPont performance measurement system:

Systematization feature	**Types of business performance measurement systems**					
After the combination of the elements	Computing Systems (quantifiable elements and quantified elements relationships)				Classification systems (quantifiable element and not quantified elements relations)	
	causal connection				no causal connection	
	deterministic connection				heuristic connection	
Relationship between key figures	Logically		Empirically		Hierarchic	
	Definitional	Mathematical	Deterministic	Stochastic	Objectively-hierarchically	Subjective-judgmental
After the position in occupational social system	Performance measurement systems as					
	Target systems	Decision systems			Communication systems	Control systems
By the method of development	Inductively derived performance measurement systems				Deductively derived performance measurement systems	
According to the type of the measured facts	Performance measurement systems for the measurement of structures				Performance measurement systems for the measurement of processes	
After the temporal dimension	Performance measurement system with plan (target) figures (planning systems)				Performance measurement systems with actual figures (control systems)	
	Temporary				in the long term	
	Discontinuous				steady	
	Static				dynamic	
After the membership of a corporate function	Performance measurement systems from the function					
	Purchasing	Warehouse Management	Production	Personnel	Finance	
After oriented usage	Performance measurement systems for analysis		Performance measurement systems for documentation		Performance measurement systems to control	
	action-oriented		augmenting knowledge		affective	
After drawing object	Universal				situational	
	Unidimensional				multidimensional	
	cross-functional				function-specific	
	multi-agency				job specific	
	strategically				operative	
	product-related				customer-related	

[410] cf. Hienerth (2010), p. 38.

	potential-related	instrument-related
After the seclusion	Closed	open
After the IT support	IT supported	Not IT supported

Table 14: Characterization of the DuPont performance measurement system[411]

Because the different indicator dependencies can be well demonstrated by the ROI-scheme or ROI-tree, this visualization type [see Appendix 1] is mainly used in practice.[412] With this type of visualization there are no particular matters to which attention must be paid. It should only be displayed in a clear manner [see chapter 8.1.3 and 8.1.4].

Here, all the individual visualization rules need not be complied, because the most common representations are the ones of a tree diagram. The most important requirements are:

The presentation should fit on a single screen [8.1.3.1]. If further values are needed for understanding, the visualization should be designed in the way that it is possible to zoom from a general overview to several oversights in a more detailed way [8.1.4.4]. This does not mean that the other rules can be neglected, if a visualization is done. However, it is usually not introduced an extensive visualization when it comes to the visualization of a DuPont system.

9.2 Grading of the PI "Scrap rate"

This indicator provides the portion which is faulty in production and should be scrapped. Also it shows the proportion of error-related and not further processed production objects. The scrap rate is defined by the following formula:

$$Scrap\ rate = \frac{Scrap\ amount\ (one\ place) in\ a\ period}{Total\ production\ quantity\ (one\ place)\ in\ a\ period} x100$$

Formula 7: Scrap rate[413]

The required values of the numerator and the denominator can be collected and accordingly processed from the (computerized) information systems, production planning, production management and production control, but particularly in the quality control. There, they are, for example, segmented to error types and to the

[411] cf. Hienerth (2010), p. 42.
[412] cf. Schels / Seidel (2010), p.441.
[413] cf. Krause / Arora (2010), p. 214.

assembly sites or stages. Then they are transmitted to the appropriate decision makers.[414]

The scrap rate is an important benchmark for quality management. All scrap elements are major errors that a post-editing is not possible or is not economically worthwhile. Limits are however defined for individual companies. In detail, the ratios differ depending on the product and production process to a considerable degree. Even the term time is an important criterion for selecting an acceptable scrap rate. At the start of production and the subsequent start-up phase, higher values are initially expected. These must be kept low and reduced rapidly to an appropriate level by using appropriate quality techniques from the beginning. The individuality of entrepreneurial production processes makes it difficult in practice to compare the interplant comparability. In other areas, this is quite common. A comparison over time and between organizationally independent sub-areas of a company with standardized terminologies, planned / actual relations and developments can be represented much easier. The indicator "scrap rate" can be seen as a relative figure. More specifically it is an arrangement figure.[415]

When interpreting this indicator, it should be aware that the rejection rate alone does not allow any statement about the success of new machines and/or production methods. At the same time, the level of training of employees (incorporation of the respective machine and in the new production methods) must be included in the analysis. The following additional figures should therefore be included for future strategies: Downtime / machine, repair / machine, absenteeism / employee, training / employee, quality, etc.[416]

This ratio is now characterized in more detail by the help of the criteria catalog.

From the table two [chapter four], the key figure structure is C 1 b. The numerator represents the scrap rate in units where the denominator indicates the total production amount.[417]

The characterization of the PI “scrap rate”

Systematization feature	**Types of business figures**						
Business function	purchasing	warehouse management	production	sales	HR	finance	
Hierarchy level	Strategic management		Division		Shop floor		
Statistically methodological aspects	absolute numbers			ratios			
	single	sums	differences	average	relationship	outline	index

[414] cf. Krause / Arora (2010), p. 214f.
[415] cf. Krause / Arora (2010), p. 215.
[416] cf. Ossola-Haring (2009), p. 318f.
[417] cf. Meyer (2011), p. 100.

	numbers			values	numbers	numbers	numbers
Quantitative Structure	aggregates				portion sizes		
Temporal structure	point of time sizes				period sizes		
Content structure	value sizes				volume sizes		
Cognitive value	**key figures with**						
	autonomous value				dependent value		
Sources in Accounting	**key figures of the**						
	balance sheet		accounting		expenses, results of operations and cost accounting		statistics
Elements of the economic principle	input			result		standards of relations between input and result	
Territory of the statement	total operating metrics				part operation metrics		
Planning considerations	target indicators (forward-looking)				actual indicators (backward-looking)		
Number of participating companies	single operating metrics		enterprise metrics		industrial sector metrics		total operating metrics
The range of determination	standard metrics				business specific metrics		
Power of the company	cost-effectiveness metrics				key figures about financial security		

Table 15: Characterization of the PI "Scrap rate"[418]

Under the concept of the performance pyramid [see appendix 11], which was published by Lynch and Cross in 1991 the measure of the "Scrap rate" is settled in the workplace level. In this key figure, employees on the shop floor can actively intervene. This ratio could also be some hierarchy levels higher. Most often, however, it is a measure in the shop floors.[419]

A possible visualization of this figure could look as follows.

[418] cf. Hienerth (2010), p. 38.
[419] cf. Kobrin (2010), p. 31.

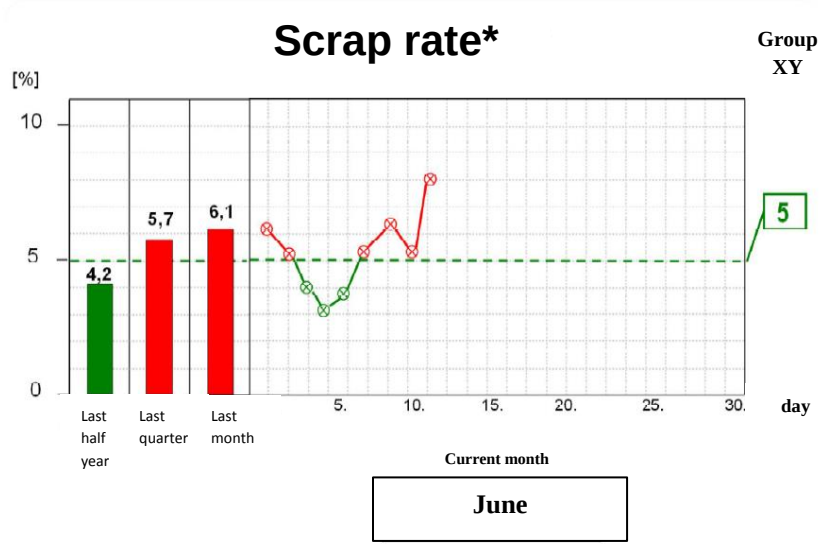


Image 84: Possible visualization of the figure "Scrap rate"[420]

This visualization option leans heavily on the definition of REFA, because they have a lot of expertise in this area. In addition, the visualization covers with those from the theory of chapter 8.

This graphic initially fulfils all the basic requirements that have been defined in section 8.1.2.

Furthermore, the guidelines in section 8.1.3 are achieved. The information is displayed on a single screen. The balance between sparseness and compactness is given. It is also not experimented with lots of color. Rather, the colors of the traffic lights are utilized. Green signals, that everything is right. The red color means, that a specified parameter was exceeded. However, it should be noted that in some regions the red-green blindness vary differently. An intuitive layout is also given. It is immediately recognized that this chart is read from left to right. It is only focused on the essentials and this is the “Scrap rate”. No gimmick around it. Also described in 8.1.4 design proposals for charts are included. Not every rule or proposal can or must be followed for the different key figures. This should be self-explanatory. Especially the way from the clear to the detailed view is visible in this image [see 8.1.4.4]. The first bar refers only to the last year. From left to right it always gets more into detail, until finally each date is represented. For this purpose, it can be said that for an overview of a presentation more columns are used, wherein for a detailed representations more graphs are used.

420 cf. http://www.refa-nordwest.de/fileadmin/user_upload/luedenscheid/PDF/Petzel_REFA_NW_LGS_140625.pdf, p. 24. [read on: 02.04.2015]

9.3 Grading of the KPI “Cycle time”

This key figure describes how much the average (planned or realized) time is, which is needed in creating a product or service from the start of the first working process to the end of the last working process. The definition of this key figure can be interpreted differently. Depending on a broader or narrower interpretation of the term "cycle time", various components can be distinguished. In general, this will be counted at least:

$$Cycle\ time = occupation\ times + transition\ times + wait\ times$$

Formula 8: Cycle time[421]

Under these terms are understood: Occupancy times are e.g. processing times, setup and test times. Under transition times it is understood e.g. transport times. Wait times, for example, are periods of storage as well as sequential, trouble and personnel-related delays. This mentioned (rather narrowly defined) division illustrates an exemplary way. There are in science and practice a variety of differentiation-proposals, which have been developed. If, for example, the entire cycle time needed, further time components are added. In addition, the upstream component (from order entry to the start of production) and downstream (from the end of production to delivery to the customer) are attached. The key figure "cycle time" is specified in the dimension of time, in minutes, hours, days, etc. This is done as required.[422]

Because the cycle time and their associated components vary often, another example is added shortly. After REFA (Verband für Arbeitsgestaltung, Betriebsorganisation und Unternehmensentwicklung) the key figure „cycle time“ is the time, which is required for an entity to pass through a system. The calculation of the cycle time is dependent on the particular system and entity types. After REFA the cycle time is composed of plan time, interval time and extra time. In practice, the cycle time is often defined by the following constituents: setup time, processing time, wait time, piece time and production time. The REFA definitions can be synchronized with those definitions, used in practice. So the plan time accords to the set up time and processing time, the interval time accords to the wait time and the additional time corresponds e.g. to the transport.[423]

In order to determine or derive the cycle time, necessary values for the individual components, in particular from the (computerized) information systems of production planning, production scheduling and production control can be withdrawn. In a further view of this term, the upstream and downstream economic and administrative

[421] cf. Krause / Arora (2010), p. 243.
[422] cf. Krause / Arora (2010), p. 243.
[423] cf. http://www.leonardo-group.com/Public/flipbook_lexikon_2.0/index.html#/57/zoomed, p. 56f. [read on: 21.03.2015]

operations in their temporal extension are raised from the corresponding business information systems. This would be, for example, the order acceptance and purchase the one hand, and the invoicing and sales on the other. As a basis serve in practice now mostly the so called ERP systems.[424]

The key figure "cycle time" is a KPI, because it is not a number of its one. It is comprised by several indicators. It is the head indicator in a hierarchical system. This key performance system is composed mathematically and counts to the computing systems.

The conceptual definition of the cycle time with the definition of the Start and End result arises largely from the company's individual circumstances. Usually, the cycle time is still used in the manufacturing sector in the context of production planning and production control. A general default value is not useful to determine because it depends heavily on product complexity and the production methods used. As a guide to the amount and for comparisons internal opportunities (target / actual relation) and also external opportunities (industry average, best-practice-values) can be used. The focus of the design of the cycle time is usually the question of how they can be reduced. From the perspective of the sales market, customers generally are eager to receive their order as soon as possible. To the company's view not to have to carry a high capital, order-related production is becoming increasingly important with short cycle times.[425]

From the table two [chapter four], the key figure structure is A 1 b.

The characterization of the KPI “Cycle time”

Systematization feature	**Types of business figures**					
Business function	purchasing	warehouse management	production	sales	HR	finance
Hierarchy level	Strategic management		Division		Shop floor	
Statistically methodological aspects	absolute numbers			ratios		
	single numbers	sums	differences	average values	relationship numbers	outline numbers	index numbers
Quantitative Structure	aggregates			portion sizes		
Temporal structure	point of time sizes			period sizes		
Content structure	value sizes			volume sizes		
Cognitive value	**key figures with**					
	autonomous value			dependent value		
Sources in Accounting	**key figures of the**					
	balance sheet	accounting		expenses, results of operations and cost	statistics	

[424] cf. Krause / Arora (2010), p. 243.
[425] cf. Krause / Arora (2010), p. 244.

			accounting	
Elements of the economic principle	input	result	standards of relations between input and result	
Territory of the statement	total operating metrics		part operation metrics	
Planning considerations	target indicators (forward-looking)		actual indicators (backward-looking)	
Number of participating companies	single operating metrics	enterprise metrics	industrial sector metrics	total operating metrics
The range of determination	standard metrics		business specific metrics	
Power of the company	cost-effectiveness metrics		key figures about financial security	

Table 16: Characterization of the KPI "Cycle time"[426]

By the visualization of the lead time it is necessary to distinguish on the hierarchy level it will be visualized. On the shop floor, the trend over a certain period is of less interest. Here, the current lead time is important. The higher the corporate hierarchy increases, the more important is a long-term approach and a detailed information overview, how this result is achieved.

A possible visualization of the cycle time for higher hierachy levels:

The cycle time is a very complex figure. There are many statements in it. Therefore, it is important that attention is paid to the points in chapter 8.1.3. Above all, the point 8.1.3.1 is very important. Is the presentation distributed over several screens, there arises very quickly confusion.

In addition, the points in chapter 8.1.4 must be observed in the design of such charts. Particularly the point 8.1.4.4 is of great importance. Because this indicator is very complex, it is almost impossible to place the causes and actual values on a single screen. For this reason, use is made by MES cockpits [see chapter 8] for this measure.

[426] cf. Hienerth (2010), p. 38.

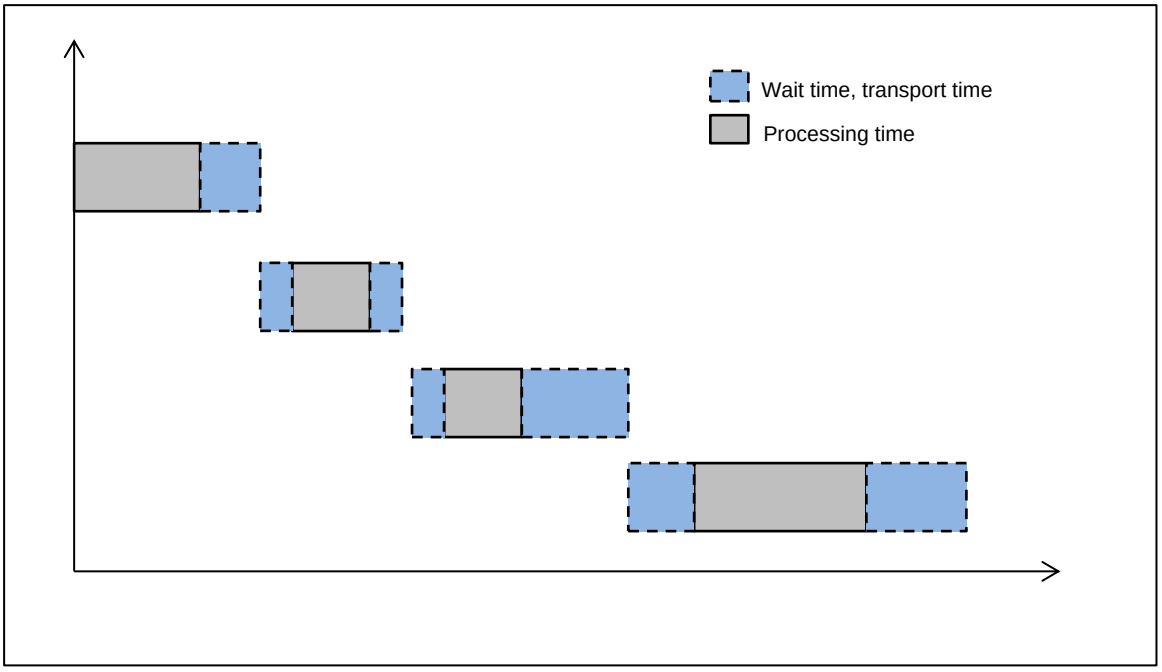


Image 85: Possible isualization of the "cycle time"[427]

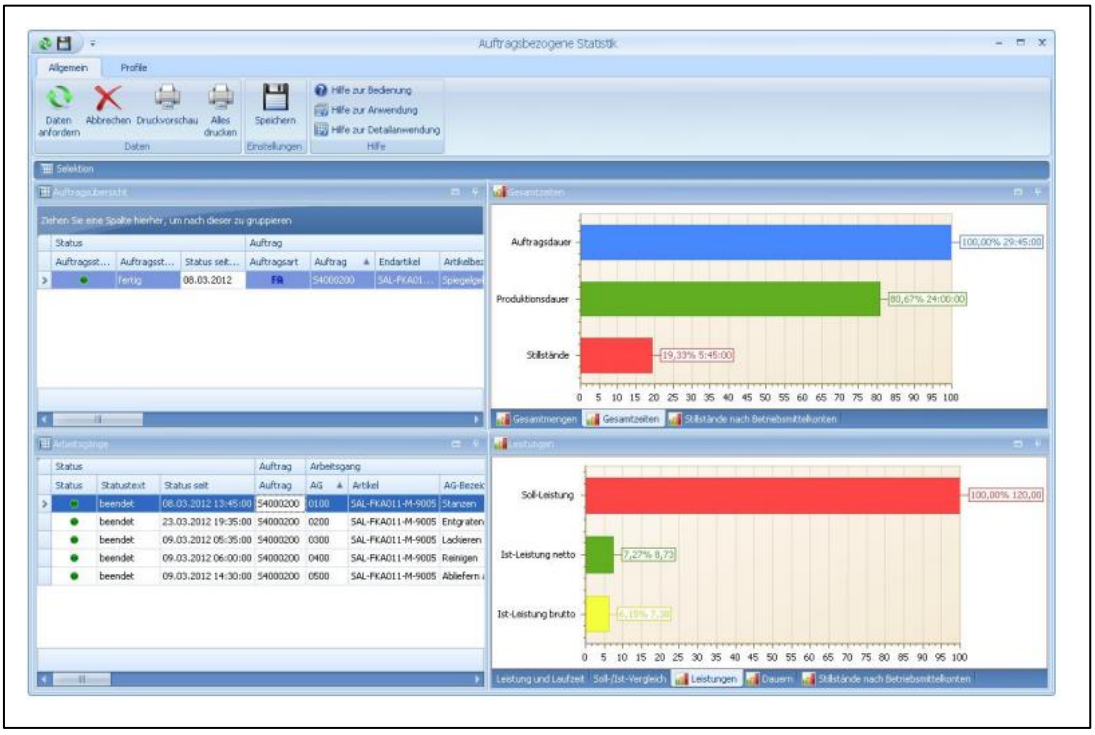
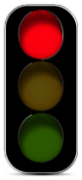


Image 86: More detailed view of the different times which aggregate to the “cycle time”[428]

427 cf. http://www.haeufle-optimierung.de/documents/Haeufle_ThielFachartikel04REFAZeitstudienFERTIG.pdf [read on: 20.04.2015]

428 http://www.refa-nordwest.de/fileadmin/user_upload/luedenscheid/PDF/Petzel_REFA_NW_LGS_140625.pdf, p. 28. [read on: 20.04.2015]

If it is possible that the workers on the shop floor intervene for theirselves on the cycle time, a visualization of the cycle time through a so-called target-result monitor is suitable. On this screen it can easily be seen whether the process is working in the targeted time or not. This illustration [see image 87] reveals immediately (at a glance, because of the traffic lights) whether the predetermined period is kept or not. The target priority value specifies the importance of the current given cycle time. In some cases, not only the cycle time is visualized on this monitor. Values, such as punctuality, order backlog, etc. come in addition. They have also a certain attached priority.[429]



Cycle time

TRV: 62h, TV: 60h, TD: +2h, TPV: 5

TRV: Target result value
TV: Target value
TD: Target deviation
TPV: Target priority value

Image 87: Target-result monitor[430]

[429] cf. Bullinger/Warnecke/Westkämpfer (2003), p. 1145.
[430] cf. Bullinger/Warnecke/Westkämpfer (2003), p. 1145.

10 Conclusion / Outlook

As mentioned in the introduction of this thesis, this work was part of a larger research project with participants from industry and academia. This work represented the second part of the research project. With the help of obtained knowledge from the literature, the current implementation of the theory into the practice, within involved industrial partners, should be examined more closely. This research project was canceled in the middle of processing. For this reason, no comparative study was carried out with participating industrial partners and their implementation, especially its visualization. The thesis was changed that more attention is paid to the characterization and the present knowledge of visualization. Finally, selected indicators should serve as a model.

First of all, if it is dealt with indicators in a closer way, immediately a problem is noticed. These are the inconsistencies in the literature [see chapter 4]. Above all, the differences between German and English Literature catch the eye. In the literature review on key figures, it is striking that German literature differs from the English literature very strongly. But not only from country to country they are obvious. Differences in the definition can be seen almost everywhere, also in domestic literature. However, the biggest difference is in transnational comparisons. So when some German authors distinguish meticulously between “hard” metrics, “soft” metrics and indicators, in the English literature only the word “Indicator” is often found. In other books there is a precious separation between KRI (Key result indicator), RI (Result indicator), PI (Performance indicator and KPI (Key performance indicator). The closest match can be found in the KPIs. But the definition differs as well, although not as strong. This made it difficult to deal with the classification of indicators in the present thesis, because the criteria catalog mainly dependents on definitions.

Every successful company must have an efficient information system. Only with an appropriate information system, a company can operate economic successfully [see chapter 2,3]. Information systems are the medium for decision-making and enforcement of management and are therefore the basis for the entire management process. In the information system, the information process takes place.[431]

If a company established an information-system, indicators or key figures are included in the daily work. Key figures are so important, because with them it can be alerted to a positive or negative development of the company. They make information available. If it is possible, quantitative information is preferred to the qualitative information. Indicators should represent complex operational issues, structures and

[431] cf. http://wirtschaftslexikon.gabler.de/Archiv/9241/informationssystem-v14.html; [read on: 28.12.2014]

processes in a relatively simple manner and thus to ensure the most comprehensive and quick overview. They should serve the decision making body in the analysis and help the decision making bodies in the ongoing planning, implementation and control by eliminating irrelevant data.[432]

Often individual indicators do not suffice in companies to be able to assess many situations accurately. It is therefore advisable to use multiple measures. For a detailed analysis of the company, however, a great amount of measures is not particularly helpful. These circumstances may increase the risk that the respective user selects any indicators and interpretation that best meet its goals. Therefore, a certain classification is required. A performance measurement system is an ordered set of metrics, which are interrelated and completely about an issue.[433]

However, key figures and their systems do not always have the desired effect. They are not automatic and guarantee for economic benefits [see chapter 7 particularly chapter 7.4]. It has to be focused on essential key indicators. Not everything, which is measured, is also needed. But this way of thinking is very well represented in businesses. The thought is too fascinating. Instead of endless discussions and subjective statements in the management, executives can see at a glance how and where the company is. Everything can be seen with the help of a *"corporate cockpit"*, which take over the IT-based compressed representation of key figures. This reflects the idea of a *"lovely new world"*. However, in many cases, the expected benefits do not occur. The failure can be recognized mainly on three errors.[434]

- **Error No. 1: Number cemetery instead Management System**
  In the first place there should be a company's strategy. In the next step the questions should be clarified, with which methods the fulfillment can be measured. It depends on the relationship between the strategy on the one hand and the indicators on the other hand. This relationship often is not given. Rather, many measurements are a simple conglomeration of key figures. In some cases the method of creation is almost the opposite of the concept. The logical consequence. It is pointless to follow the numbers. They may be diligently collected, stored, and displayed. However, they are relatively irrelevant. In other words, the performance measurement systems are only a number cemetery in the company.

- **Error No. 2: Trench warfare at the highest levels**

[432] cf. Gladen (2011), p. 11.
[433] cf. http://www.controllingportal.de/Fachinfo/Kennzahlen/Kennzahlen-Systeme.html; [read on: 28.12.2014]
[434] cf. http://www.pf-mi.de/angewandte_forschung_wissenschaft/wann_kennzahlen_schaden.htm [read on: 25.04.2015]

Performance measurement systems should substitute objectively measurable variables instead of subjective judgments. However, how the key figures are defined and how they are measured that decision decision stays by the managers, with all their judgment and personal motives. Performances of managers are judged to achieve the highest possible value. Whether a value is reported high or low, it is primarily a question of scale and the definition. Consequently, there is a clear interest to come to an appropriate definition. This is not assumed that numbers would be forged. But between objective representation, legitimate protection of interests of a fair representation and manipulation there is a large gray area.

- **Error No. 3: Blinders instead of openness**
  No performance measurement system provides a completely entity over a company. Soon, the problem arises that employees focus only on their key figures. No more additional tasks are adopted that do not affect their own indicators in a direct manner. Often, not the arrangements, which are directly readable from the indicators, make up a successful business. On the contrary, it is the flexible, non-bureaucratic handling of problems, which results in competitive advantage. Workers may not always ask how they can influence their own key figure in the best possible way. The first thought should be always on the customer, who ensures the survival ultimately.

This does not mean in any way, that indicators are bad. It only needs to be thoughtful dealt with them. Indicators are very valuable for identifying problems and to counteract early enough. However, the approach, bad indicators equal bad business and well indicators equal well business, is wrong.[435]

Another problem that occurred during the processing of this thesis was the division of the key figures in hierarchical levels. For some indicators, it is clear that they are located in the strategic area. For example the ROI [see chapter 9.1]. In others, however, the allocation is spongier. Thus, for example the “cycle time” or “scrap rate” can be assigned to multiple hierarchical levels [see chapter 9.2, 9.3]. They can be detected for individual machines as well as for entire departments. For this reason, it is difficult to identify indicators, which are intended solely for the production floor. Often they differ only in their resolution on the different levels of the hierarchy. However, a summary of the most common indicators is given in Appendix 5. These are key figures, which are commonly used in the production according to the literature.

[435] cf. http://www.pf-mi.de/angewandte_forschung_wissenschaft/wann_kennzahlen_schaden.htm [read on: 25.04.2015]

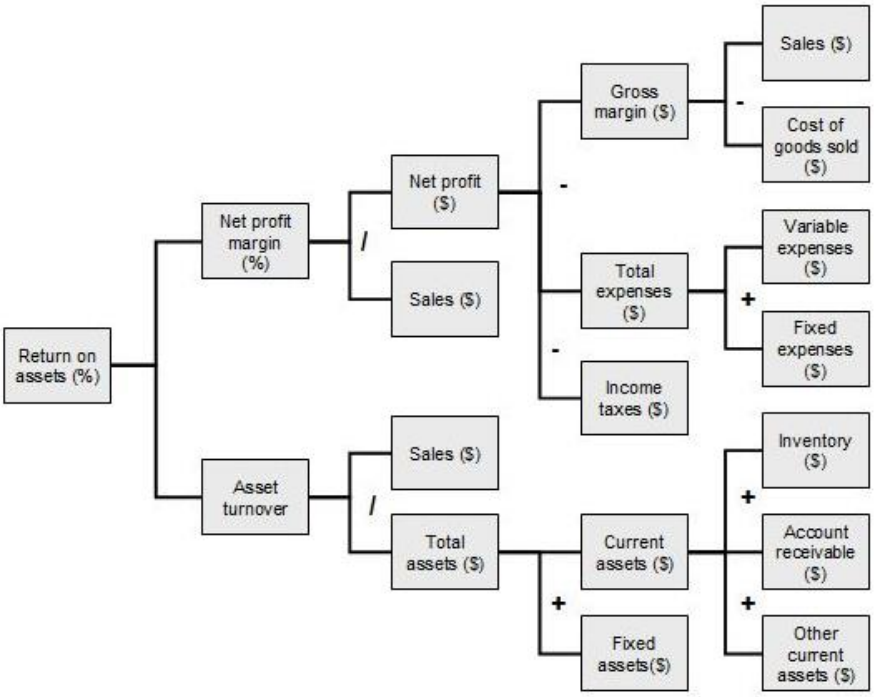
Also an acquisition of key figures in other companies is difficult. Each firm is structured differently. Be it by hierarchical levels or general the size of the company itself. Therefore, MES systems have established which are mostly introduced by external companies. Here, key figures can be seen in so-called "cockpits" and can be divided up into its individual data from which they are made. Unfortunately, often no insight was given, as this is part of the expertise of each company [see chapter 8.3].

In the next step the previous defined metrics must be brought to the workers. This is the task of the visualization. Here, many mistakes are made. It is not just to visualize a little picture quickly. There's a lot of reasoning behind this, and it must be regarded a lot of rules. It goes from the font size, over the font color, contrast, placement of individual figures up to the different understanding of colors in each culture. There have to be screens, which are not overloaded and on which the competent worker knows immediately, without great effort, the current status.

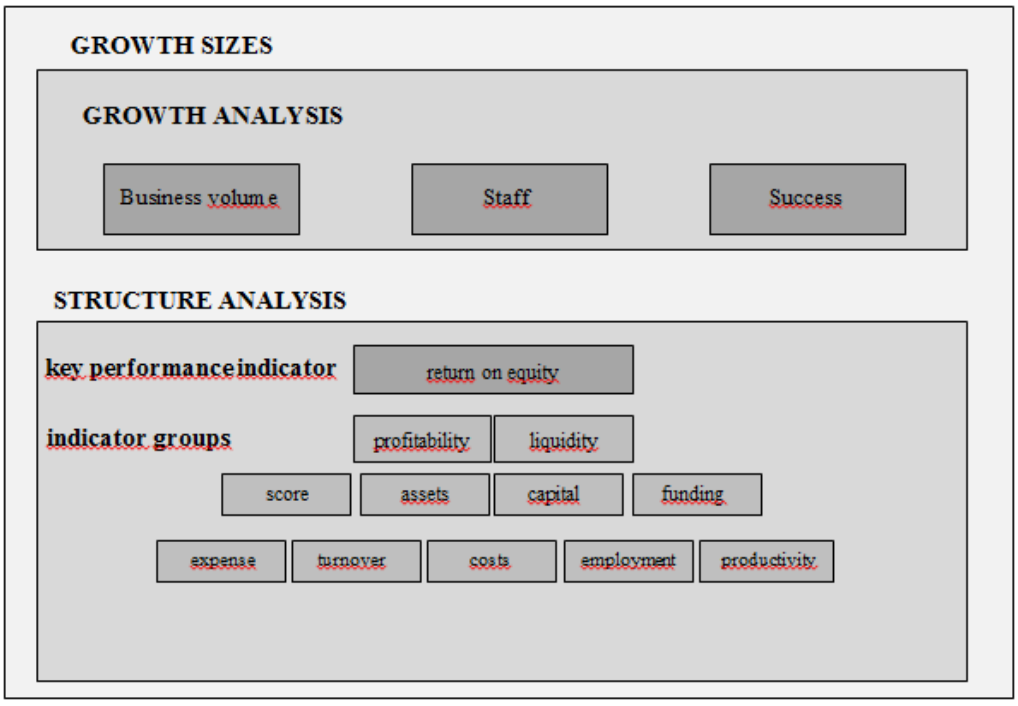
About visualization in the production sector or in companies in general, there is little informative literature. It often seems, if authors quote each other and then be forced to quote themselves in a new edition of their own books. The literature used in this work, however, is very timely. For this reason, the knowledge in this work is based on knowledge, which is not eternal in the past.

A great help to visualize complex subjects are the so-called MES. These are mainly offered by external companies. This makes it impossible to describe the exact structure of these programs, because these can only be purchased. So it only could be guessed based on public accessible brochures how these programs are structured.

11 Appendix

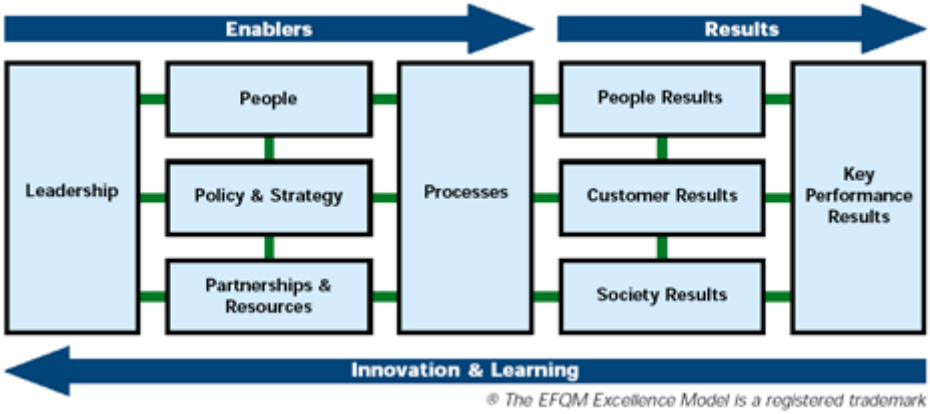


Appendix 1: DuPont system[436]



Appendix 2: ZVEI system[437]

[436] cf. http://www.niklasblanke.com/uploads/1/0/2/6/10267120/8777663_orig.jpg [read on: 17.03.2015]
[437] cf. Horvath (2002), p. 550.

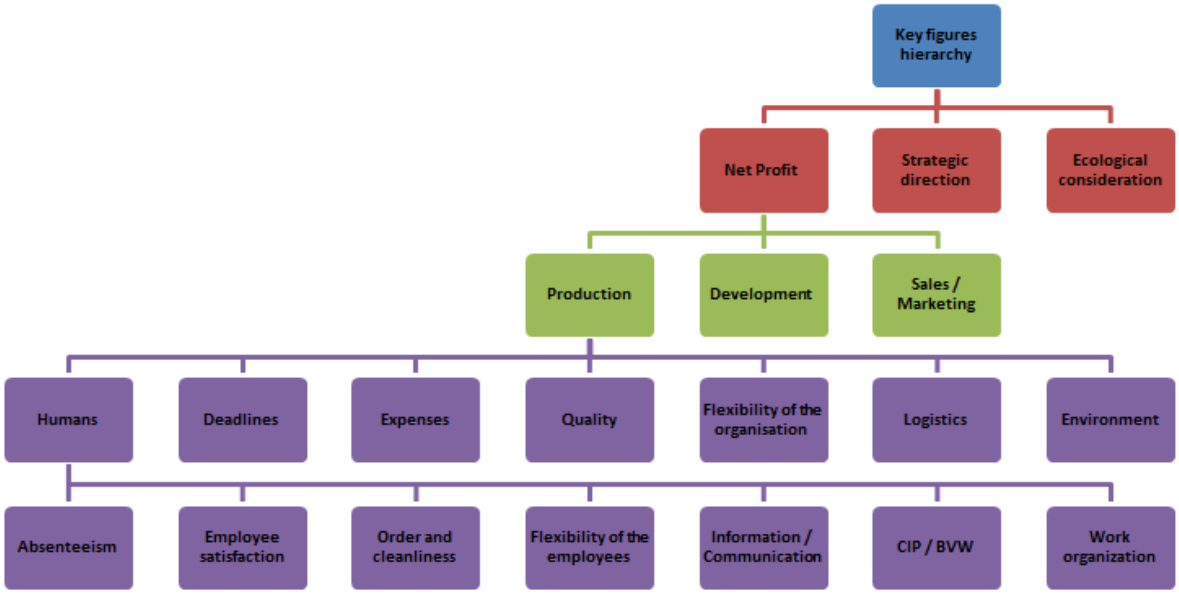


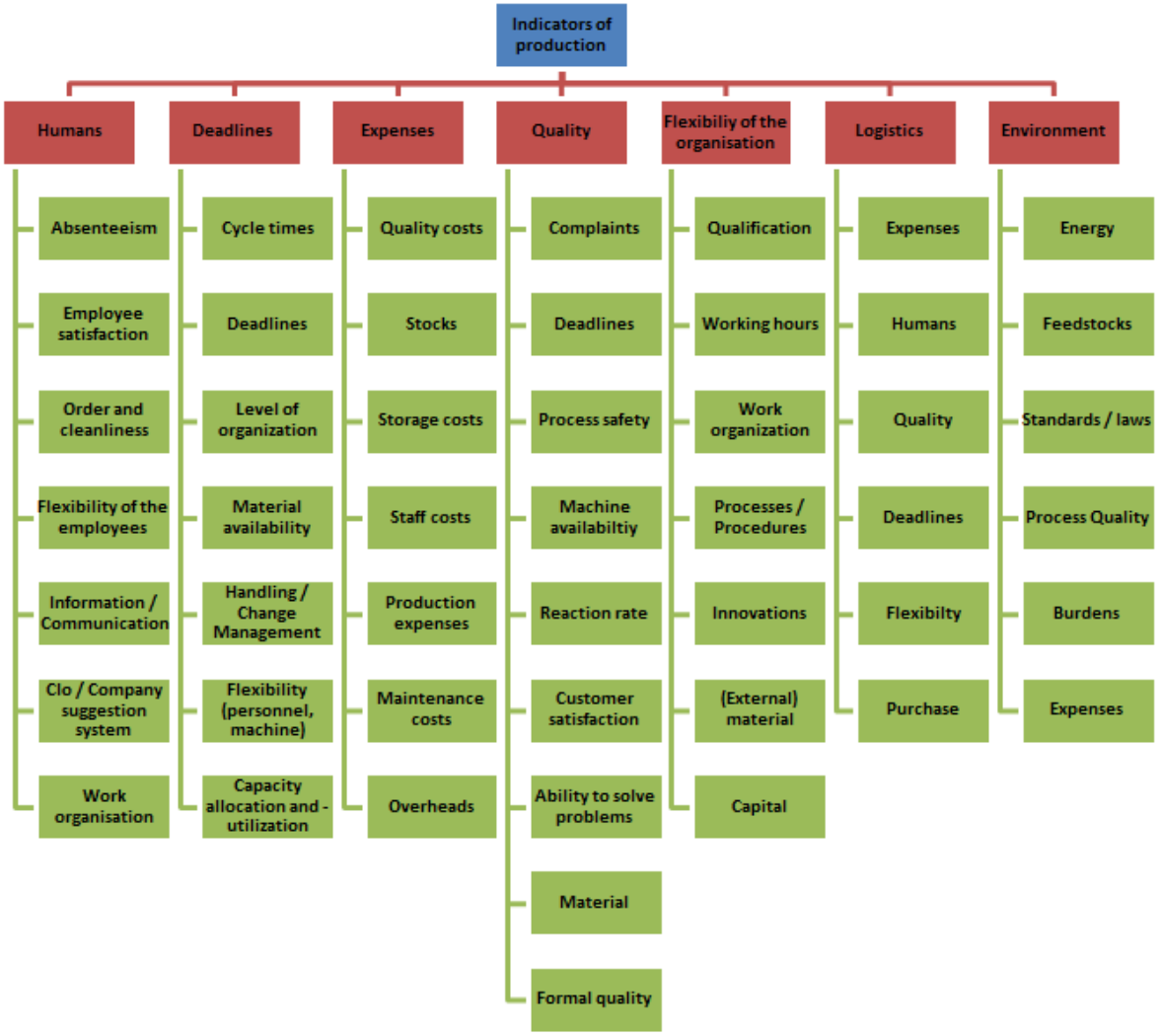
Appendix 3: EFQM model[438]

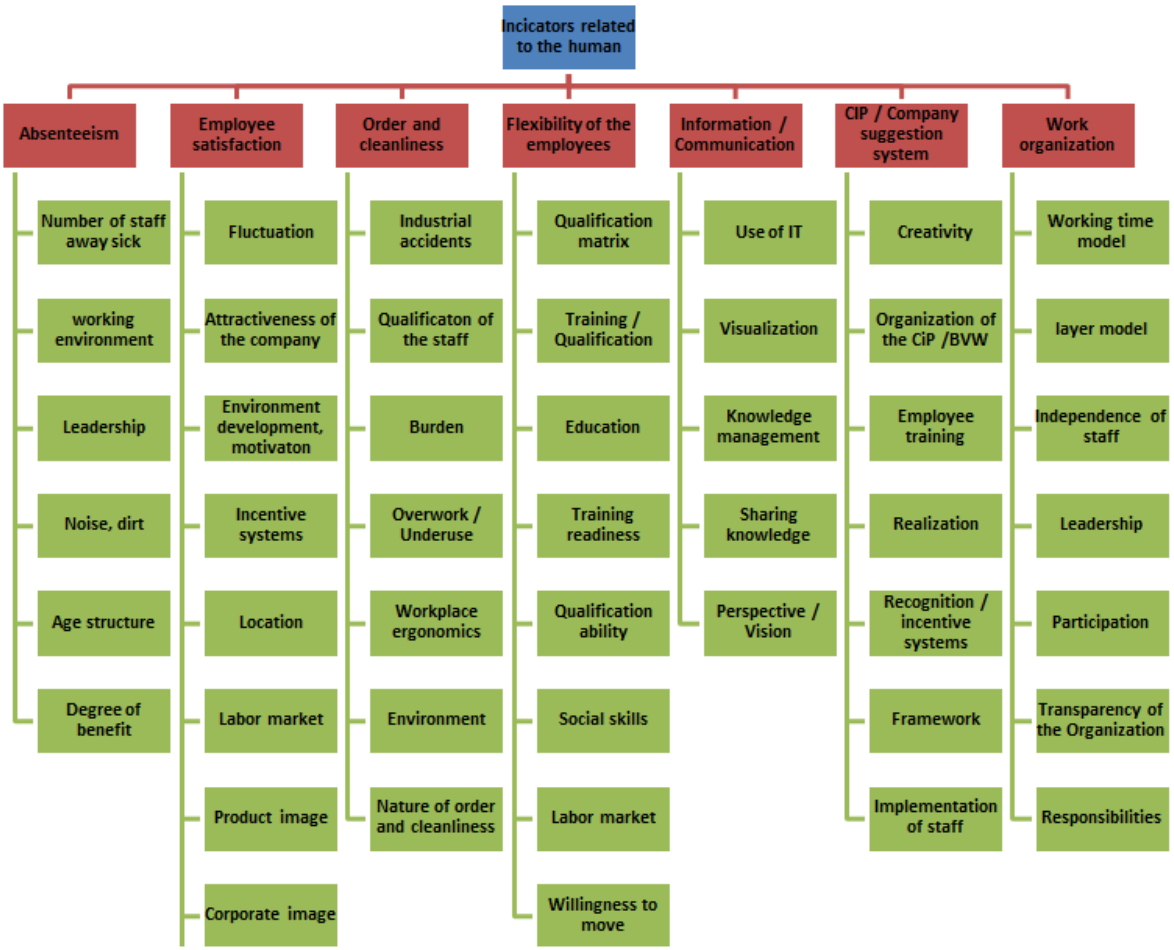
Appendix 4: Balanced Scorecard[439]

[438] http://www.exchange2improve.com/wp-content/uploads/2007/07/efqm-small.gif, [read on: 10.09.2014]

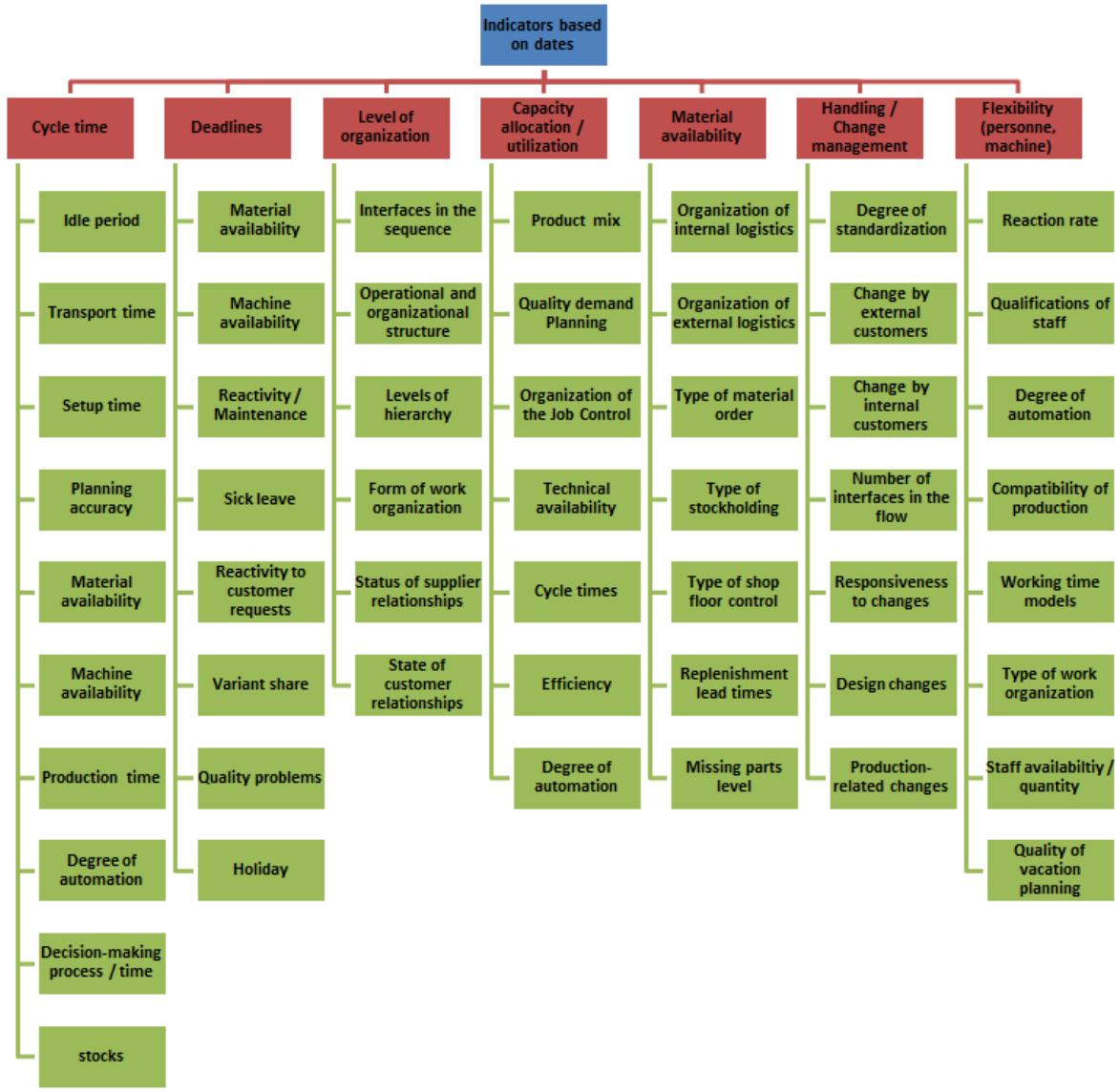
[439] http://bi-insider.com/wp-content/uploads/2012/05/Balanced-Scorecard-Four-Perspectives.png, [read on: 10.09.2014]

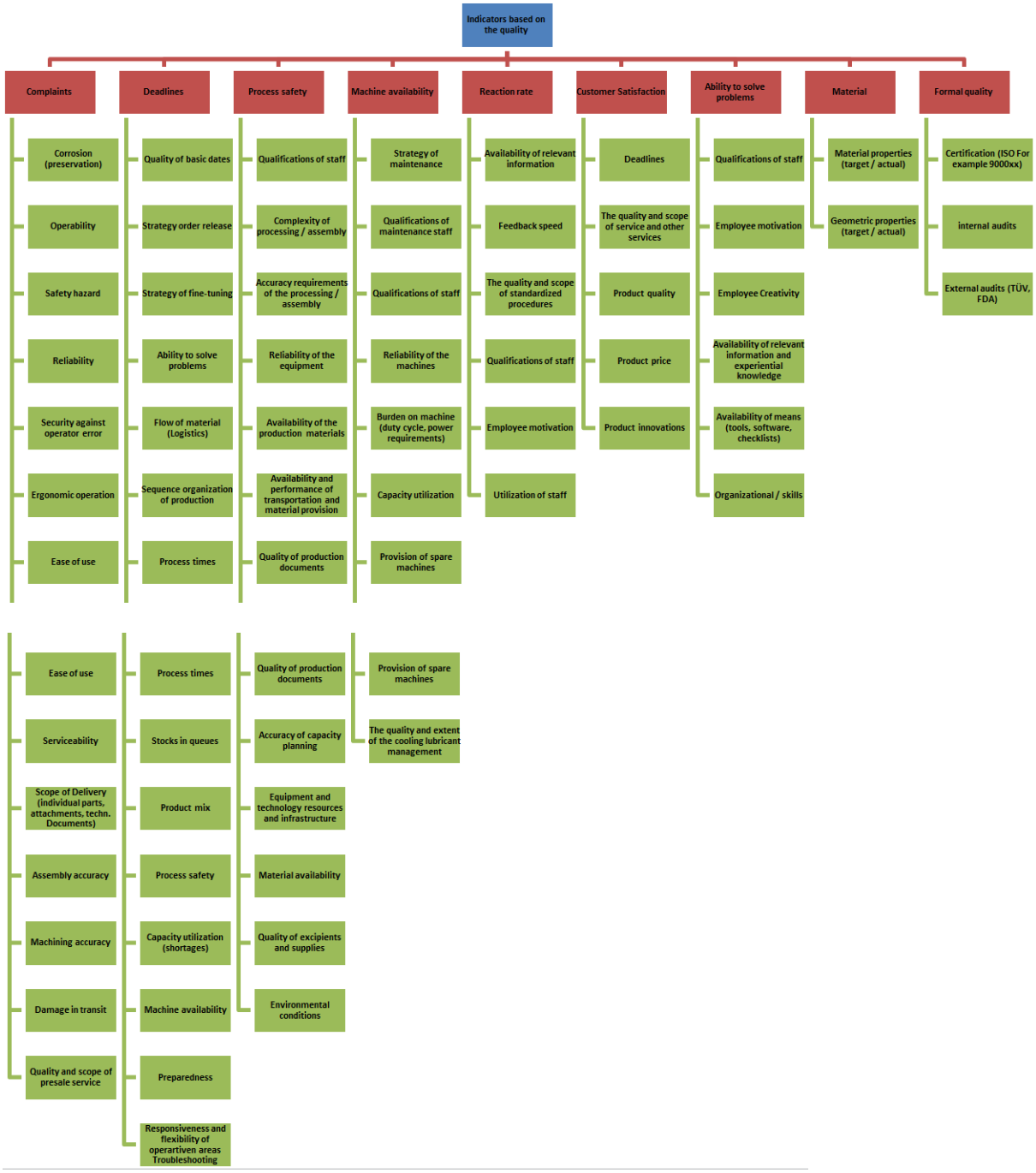

Key figures hierarchy
Net Profit
Strategic direction
Ecological consideration
Production
Development
Sales / Marketing
Humans
Deadlines
Expenses
Quality
Flexibility of the organisation
Logistics
Environment
Absenteeism
Employee satisfaction
Order and cleanliness
Flexibility of the employees
Information / Communication
CIP / BVW
Work organization

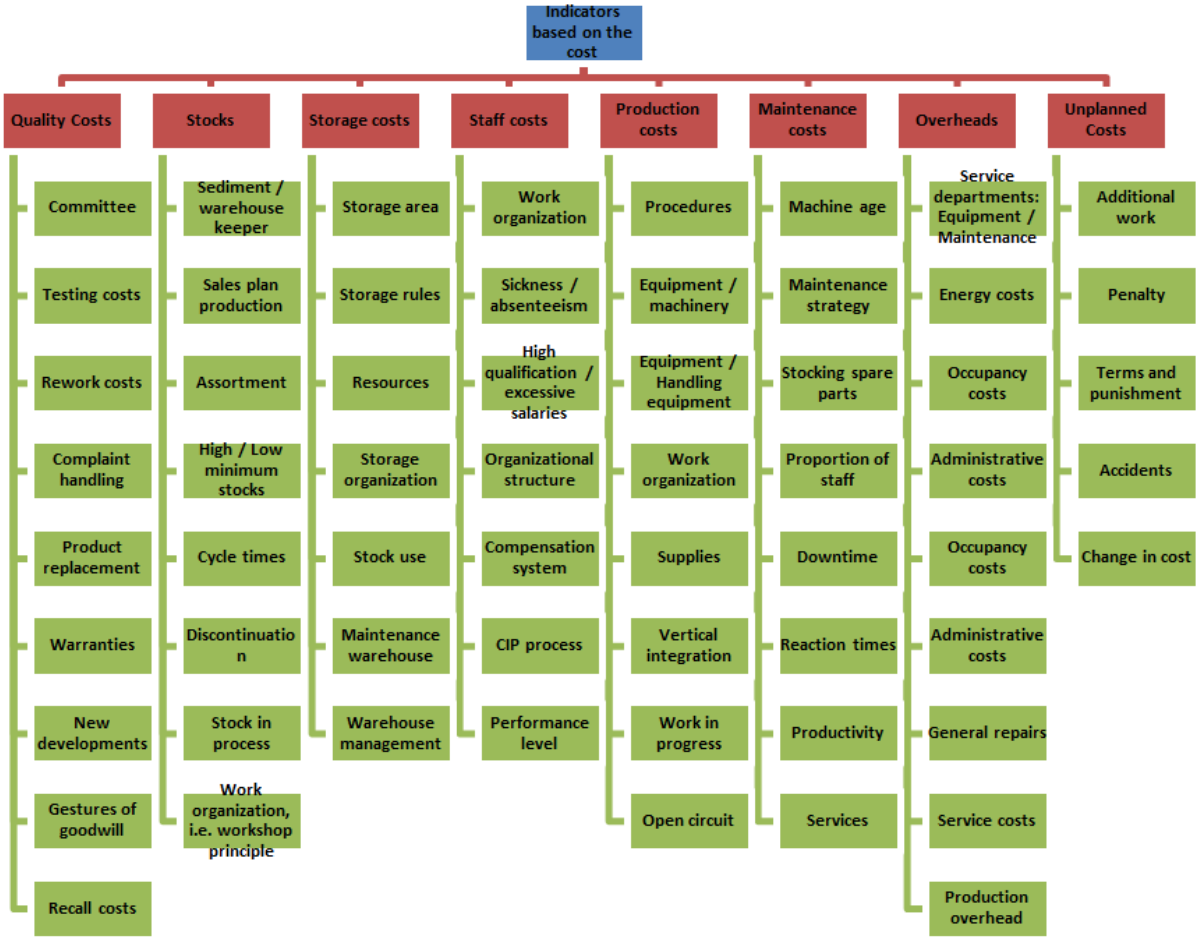

Indicators of production
Humans
Deadlines
Expenses
Quality
Flexibiliy of the organisation
Logistics
Environment
Absenteeism
Employee satisfaction
Order and cleanliness
Flexibility of the employees
Information / Communication
Clo / Company suggestion system
Work organisation
Cycle times
Deadlines
Level of organization
Material availability
Handling / Change Management
Flexibility (personnel, machine)
Capacity allocation and - utilization
Quality costs
Stocks
Storage costs
Staff costs
Production expenses
Maintenance costs
Overheads
Complaints
Deadlines
Process safety
Machine availabiltiy
Reaction rate
Customer satisfaction
Ability to solve problems
Material
Formal quality
Qualification
Working hours
Work organization
Processes / Procedures
Innovations
(External) material
Capital
Expenses
Humans
Quality
Deadlines
Flexibilty
Purchase
Energy
Feedstocks
Standards / laws
Process Quality
Burdens
Expenses

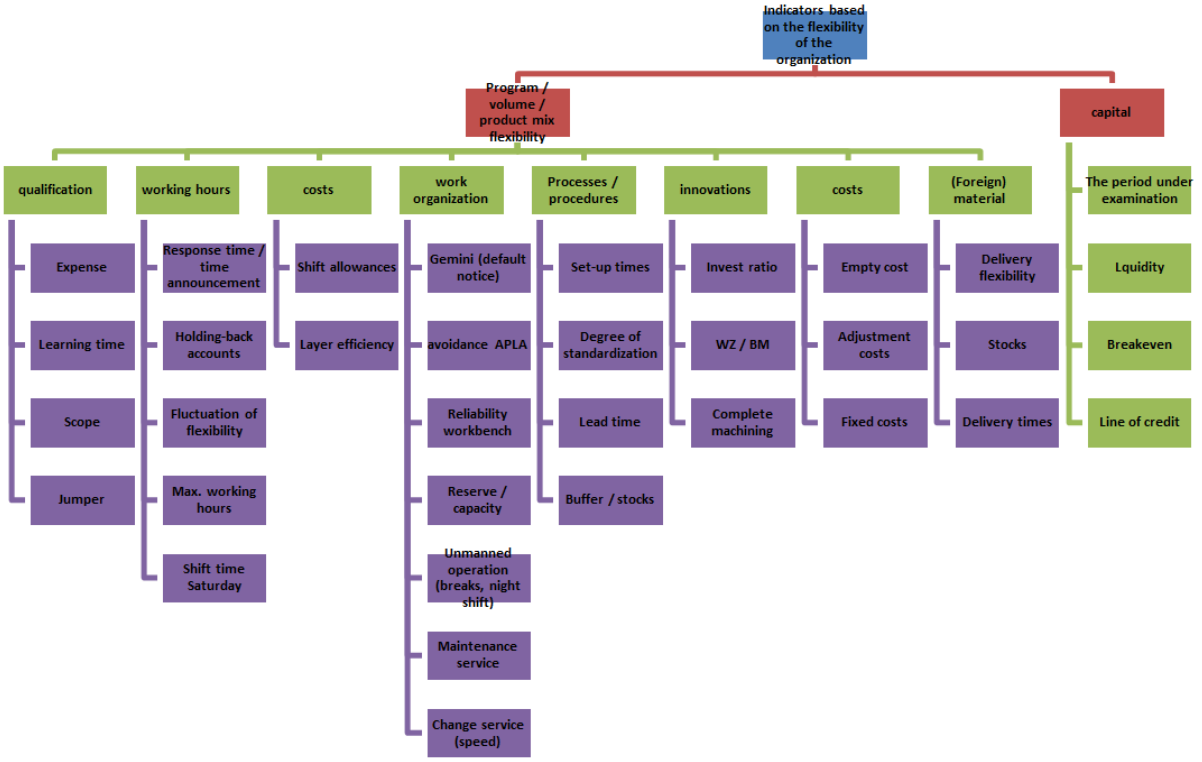

Incicators related to the human
Absenteeism
Number of staff away sick
working environment
Leadership
Noise, dirt
Age structure
Degree of benefit
Employee satisfaction
Fluctuation
Attractiveness of the company
Environment development, motivaton
Incentive systems
Location
Labor market
Product image
Corporate image
Order and cleanliness
Industrial accidents
Qualificaton of the staff
Burden
Overwork / Underuse
Workplace ergonomics
Environment
Nature of order and cleanliness
Flexibility of the employees
Qualification matrix
Training / Qualification
Education
Training readiness
Qualification ability
Social skills
Labor market
Willingness to move
Information / Communication
Use of IT
Visualization
Knowledge management
Sharing knowledge
Perspective / Vision
CIP / Company suggestion system
Creativity
Organization of the CiP /BVW
Employee training
Realization
Recognition / incentive systems
Framework
Implementation of staff
Work organization
Working time model
layer model
Independence of staff
Leadership
Participation
Transparency of the Organization
Responsibilities

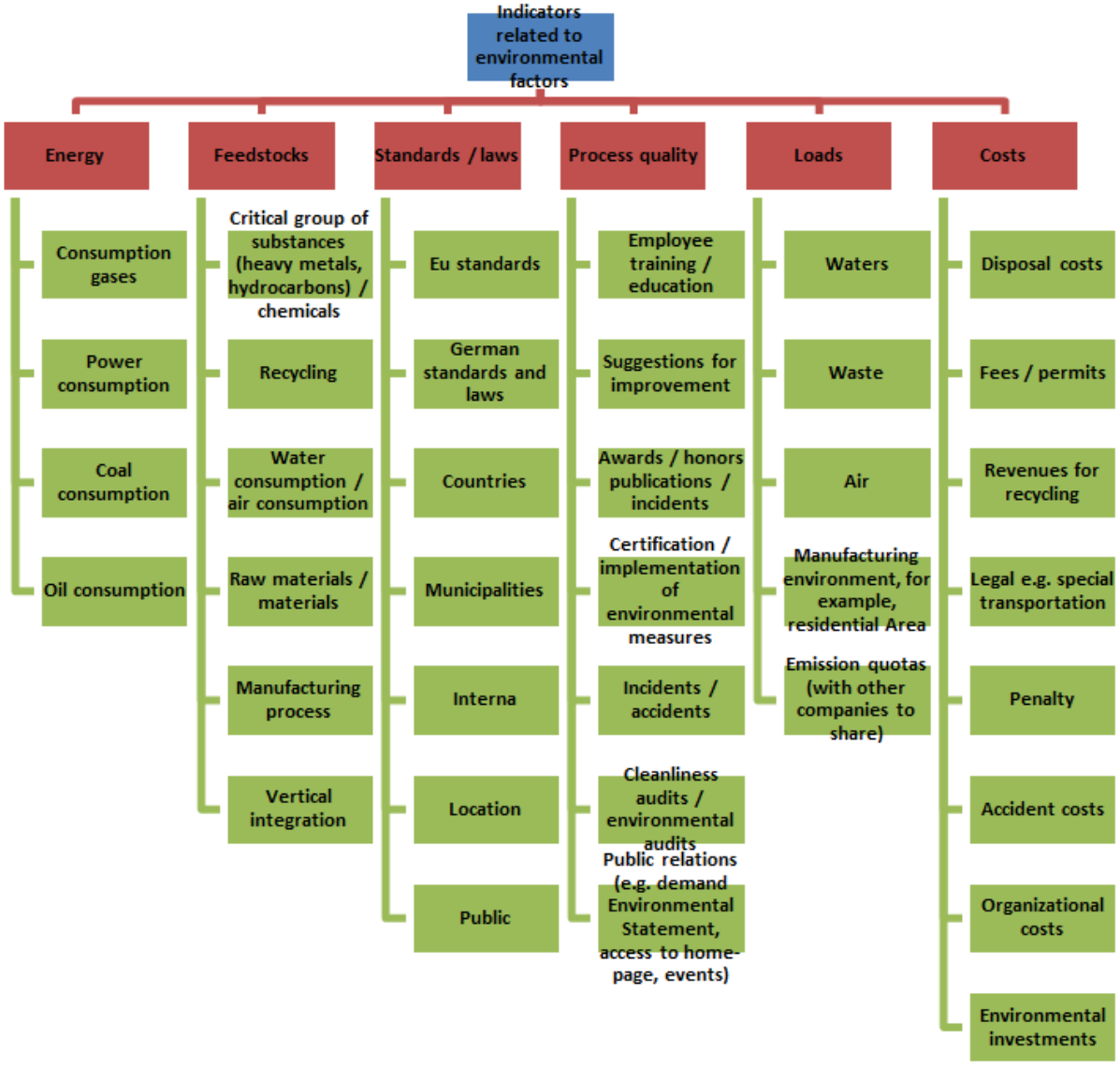

Indicators based on the (production) logistics
Expenses
Humans
Quality
Deadlines
Flexibility
Purchase
Service equipment (mobile)
Disposition costs
Transportation costs
Storage costs
Service equipment (immobile)
Maintenance costs
Staff costs
Inventory costs
Removal / Supply costs
Qualification
Responsiveness
Flexibility
Absenteeism
Admission
Information / Communication
Availability
Deadlines
Shipping damage
Extended workbench
quality assurance agreement
Ready positioning times
picking times
Waiting times
Transport times
Organizational structure
Forecast planning
Feedback system
Compression strategy
Process safety
Date security / Start new parts
Control flexibility
Work organization
Organizational structure
Working hours
Capacity
Employee
Logistics strategy
Procurement costs
Suppliers flexibility
Replenishment lead times
Systematic retrieval
Suppliers Deadlines
Spare parts organization
C-parts management
Auxiliary / Working supply
Supplier selection and evaluation


Indicators based on dates
Cycle time
Idle period
Transport time
Setup time
Planning accuracy
Material availability
Machine availability
Production time
Degree of automation
Decision-making process / time
stocks
Deadlines
Material availability
Machine availability
Reactivity / Maintenance
Sick leave
Reactivity to customer requests
Variant share
Quality problems
Holiday
Level of organization
Interfaces in the sequence
Operational and organizational structure
Levels of hierarchy
Form of work organization
Status of supplier relationships
State of customer relationships
Capacity allocation / utilization
Product mix
Quality demand Planning
Organization of the Job Control
Technical availability
Cycle times
Efficiency
Degree of automation
Material availability
Organization of internal logistics
Organization of external logistics
Type of material order
Type of stockholding
Type of shop floor control
Replenishment lead times
Missing parts level
Handling / Change management
Degree of standardization
Change by external customers
Change by internal customers
Number of interfaces in the flow
Responsiveness to changes
Design changes
Production-related changes
Flexibility (personne, machine)
Reaction rate
Qualifications of staff
Degree of automation
Compatibility of production
Working time models
Type of work organization
Staff availabiltiy / quantity
Quality of vacation planning


Indicators based on the quality
Complaints
Corrosion (preservation)
Operability
Safety hazard
Reliability
Security against operator error
Ergonomic operation
Ease of use
Deadlines
Quality of basic dates
Strategy order release
Strategy of fine-tuning
Ability to solve problems
Flow of material (Logistics)
Sequence organization of production
Process times
Process safety
Qualifications of staff
Complexity of processing / assembly
Accuracy requirements of the processing / assembly
Reliability of the equipment
Availability of the production materials
Availability and performance of transportation and material provision
Quality of production documents
Machine availability
Strategy of maintenance
Qualifications of maintenance staff
Qualifications of staff
Reliability of the machines
Burden on machine (duty cycle, power requirements)
Capacity utilization
Provision of spare machines
Reaction rate
Availability of relevant information
Feedback speed
The quality and scope of standardized procedures
Qualifications of staff
Employee motivation
Utilization of staff
Customer Satisfaction
Deadlines
The quality and scope of service and other services
Product quality
Product price
Product innovations
Ability to solve problems
Qualifications of staff
Employee motivation
Employee Creativity
Availability of relevant information and experiential knowledge
Availability of means (tools, software, checklists)
Organizational / skills
Material
Material properties (target / actual)
Geometric properties (target / actual)
Formal quality
Certification (ISO For example 9000xx)
internal audits
External audits (TÜV, FDA)
Ease of use
Serviceability
Scope of Delivery (individual parts, attachments, techn. Documents)
Assembly accuracy
Machining accuracy
Damage in transit
Quality and scope of presale service
Process times
Stocks in queues
Product mix
Process safety
Capacity utilization (shortages)
Machine availability
Preparedness
Responsiveness and flexibility of operartiven areas Troubleshooting
Quality of production documents
Accuracy of capacity planning
Equipment and technology resources and infrastructure
Material availability
Quality of excipients and supplies
Environmental conditions
Provision of spare machines
The quality and extent of the cooling lubricant management


Indicators based on the cost
Quality Costs
Committee
Testing costs
Rework costs
Complaint handling
Product replacement
Warranties
New developments
Gestures of goodwill
Recall costs
Stocks
Sediment / warehouse keeper
Sales plan production
Assortment
High / Low minimum stocks
Cycle times
Discontinuation
Stock in process
Work organization, i.e. workshop principle
Storage costs
Storage area
Storage rules
Resources
Storage organization
Stock use
Maintenance warehouse
Warehouse management
Staff costs
Work organization
Sickness / absenteeism
High qualification / excessive salaries
Organizational structure
Compensation system
CIP process
Performance level
Production costs
Procedures
Equipment / machinery
Equipment / Handling equipment
Work organization
Supplies
Vertical integration
Work in progress
Open circuit
Maintenance costs
Machine age
Maintenance strategy
Stocking spare parts
Proportion of staff
Downtime
Reaction times
Productivity
Services
Overheads
Service departments: Equipment / Maintenance
Energy costs
Occupancy costs
Administrative costs
Occupancy costs
Administrative costs
General repairs
Service costs
Production overhead
Unplanned Costs
Additional work
Penalty
Terms and punishment
Accidents
Change in cost


Indicators based on the flexibility of the organization
Program / volume / product mix flexibility
capital
qualification
Expense
Learning time
Scope
Jumper
working hours
Response time / time announcement
Holding-back accounts
Fluctuation of flexibility
Max. working hours
Shift time Saturday
costs
Shift allowances
Layer efficiency
work organization
Gemini (default notice)
avoidance APLA
Reliability workbench
Reserve / capacity
Unmanned operation (breaks, night shift)
Maintenance service
Change service (speed)
Processes / procedures
Set-up times
Degree of standardization
Lead time
Buffer / stocks
innovations
Invest ratio
WZ / BM
Complete machining
costs
Empty cost
Adjustment costs
Fixed costs
(Foreign) material
Delivery flexibility
Stocks
Delivery times
The period under examination
Lquidity
Breakeven
Line of credit



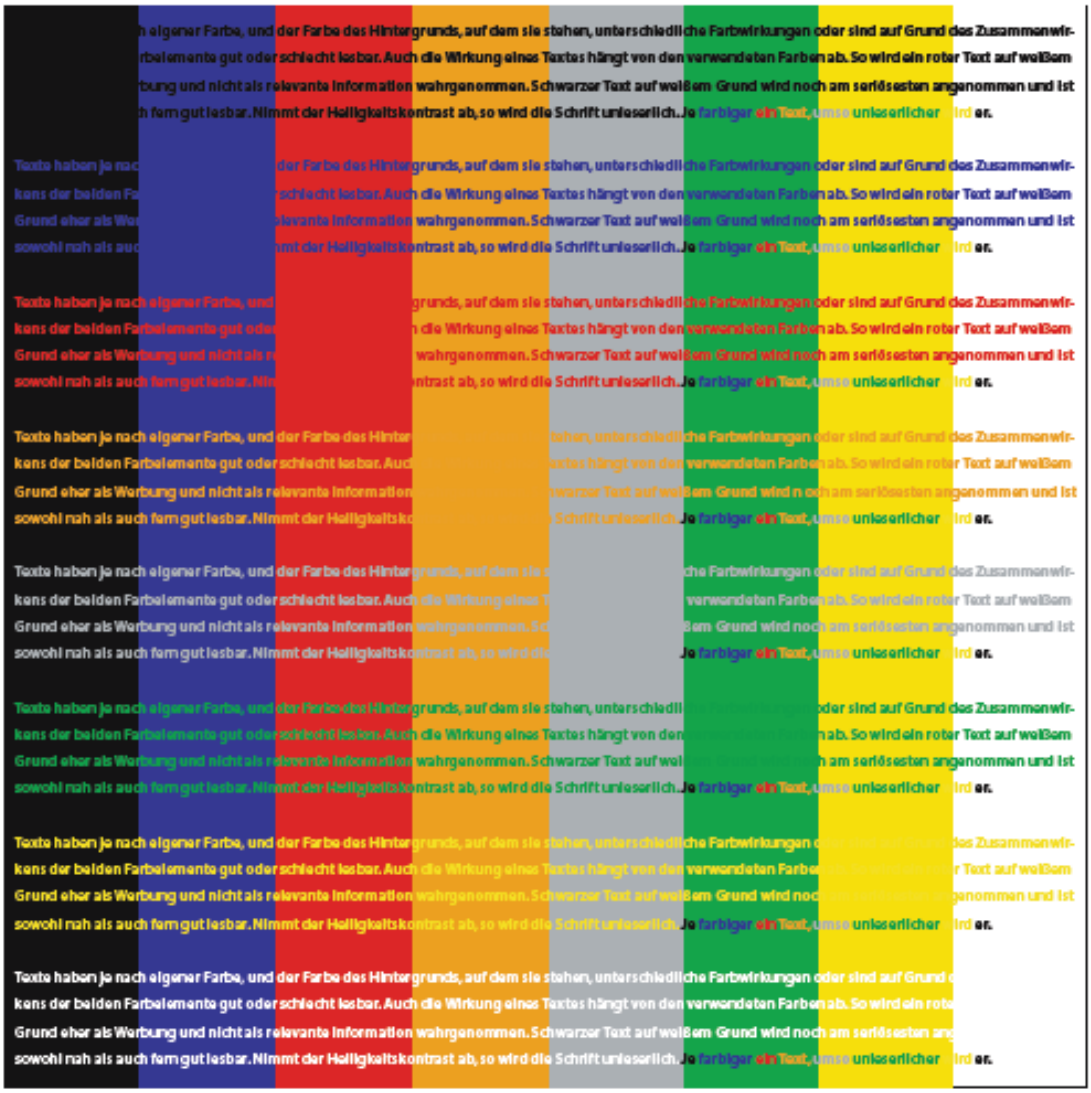
Appendix 5: Overview about key figures in the production[440]

[440] cf. http://www.awf-arbeitsgemeinschaft.de/download/Kennzahlen-in-der-Produktion-awf.pdf, p. 8 ff., [read on: 06.06.2014]

Color	Importance in Europe	Meaning in other countries, regions and cultures								
		Security	Virtue	Mourning	Modernity	Danger	Strength	Prosperity	Happiness	Religion
	Strength Sympathy Harmony Friendliness Friendship Longing Distance Trustworthy Cold		Arabic Countries				USA		Ghana	
	Danger Love Excitement Sexuality Energy Heat Anger Active Warm			Africa Egypt		Japan USA	Malaysia		China	
	Security Nature Hope Vitality Fresh Fed up Tart Immature	USA			Japan		Arabic Countries Egypt Japan	India	Pakistan	Islam
	Modernity Enthusiasm Pleasure Young Optimistic									Buddhism
	Happiness Sun Intellect Light Energy Funny Undecided Sour							China	Egypt Brazil Japan	
	Mourning Elegance Loneliness Functional Objectively			USA						
	Virtue Perfection Order Objectively Innocent Honest		India USA	China India Japan						

Appendix 6:[441]

[441] cf. Stapelkamp (2007), p. 84.

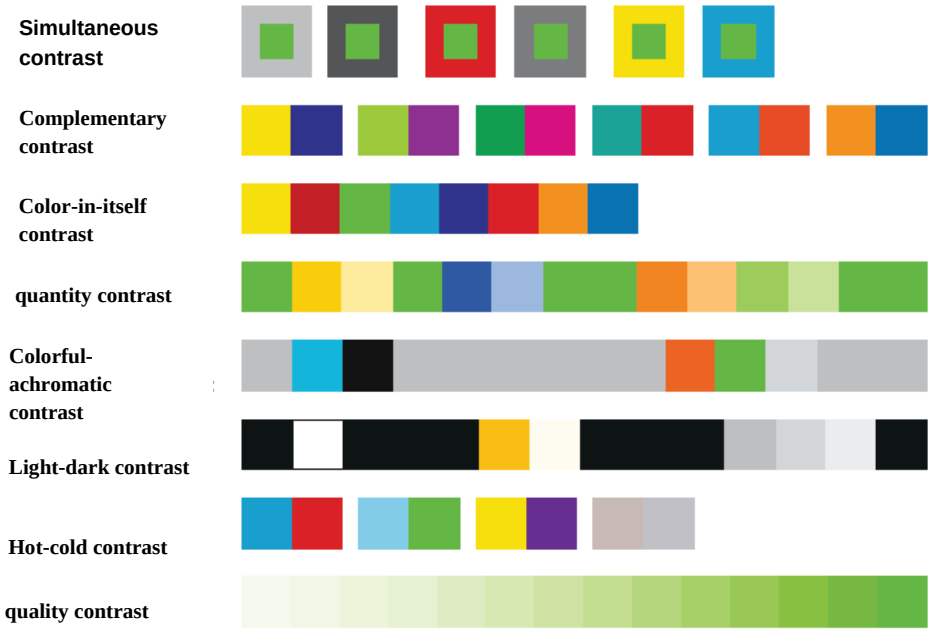


Appendix 7:[442]

[442] Stapelkamp (2007), p. 85.

Percentage occurrence of defective color vision			
		Men (%)	Women (%)
Protanopie	Red-blindness (red tap is missing)	1,0	0,02
Protanomaly	Be confused: red with yellow, brown with green, purple with blue and red with black		
Deutanopie	Red amblyopia (red tap degenerated)	1,0	0,02
Deutanomly	Green color blindness (green tap is missing) Be confused: same colors as in Protanopie with the exception that dark red and black are not confused	1,1	0,01
	Green amblyopia	4,9	0,38
Red-green color blindness		8,0	0,43
Tritanopie	Blue-blindness Be confused: red with orange, blue with green, green-yellow with gray and purple and light yellow with white		
Blue-blindness		0,002	0,001
Stick monochromes: no color can be realized			
Color-blindness		0,003	0,002

Appendix 8:[443]

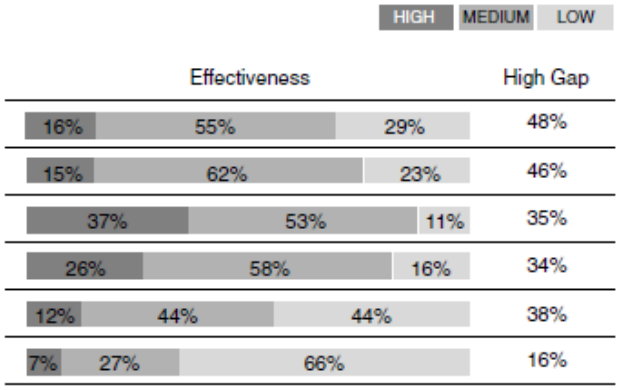


Appendix 9:[444]

[443] cf. Stapelkamp (2007), p. 87.
[444] cf. Stapelkamp (2007), p. 91.

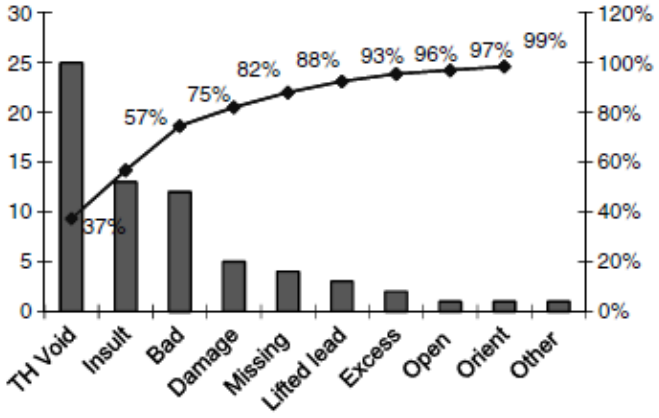
STACKED BAR CHARTS

Like pie charts, stacked bar charts also show the relationship of a part to the whole. However, unlike pie charts, the individual parts don't have to equal 100%. They are also more compact than pie charts, making it easier to display multiple stacked bar charts side by side. However, it is difficult to visually ascertain the relationships among parts in different stacked bar charts, except the first variable in each one.



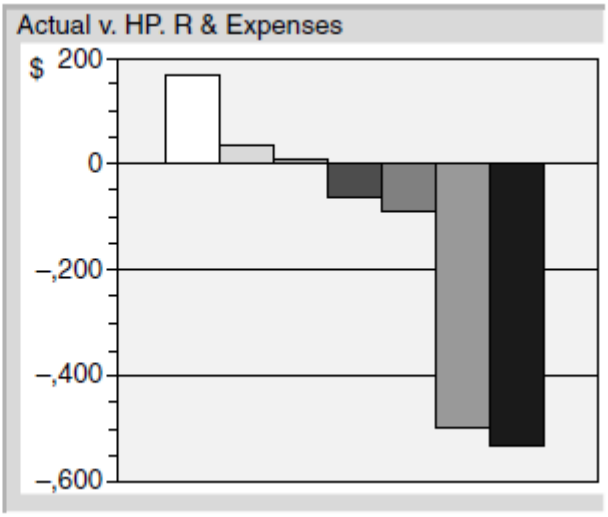
PARETO CHARTS

A Pareto charts is a bar and line chart that shows the 80-20 relationship among categorical items. Items represented by bars are arranged from biggest to smallest with the line representing the cumulative sum of item values. Pareto charts are one of the few bar and line charts that work effectively.



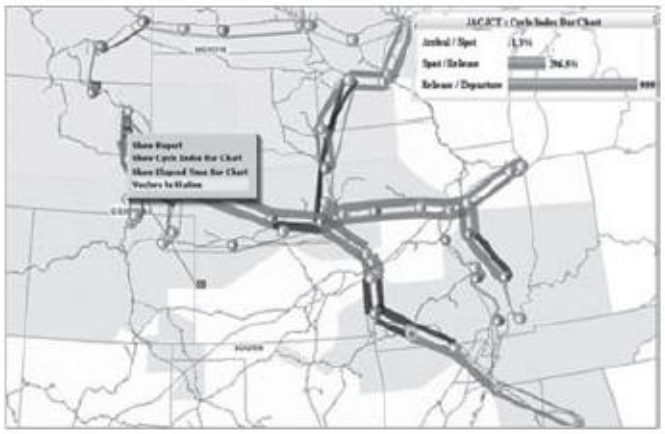
VARIANCE CHARTS

A variance chart is a bar chart that provides a great way to highlight variance between two variables, such as actuals and plan or forecast. A variance chart more clearly depicts variance than if the two variables are depicted in a time-series line chart or a table of numbers. A variance chart is a great way to complement a table of numbers.



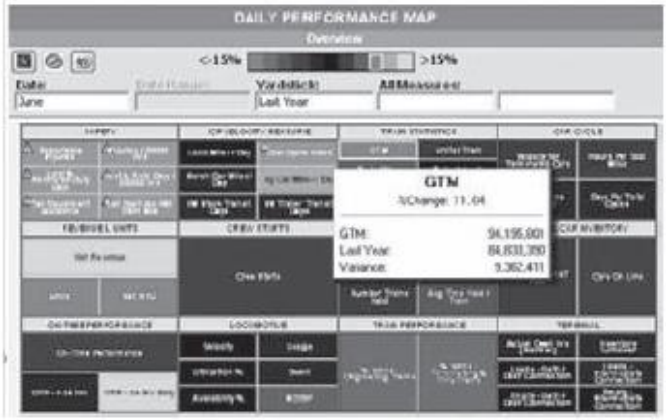
SPATIAL MAPS

Maps can be an ideal way to depict geographical trends quickly, such as the performance of rail lines serving a coal mine (see right). However, maps are often misused. They are overkill when used to depict non-geographical trends or when other displays would be more compact or meaningful to viewers.



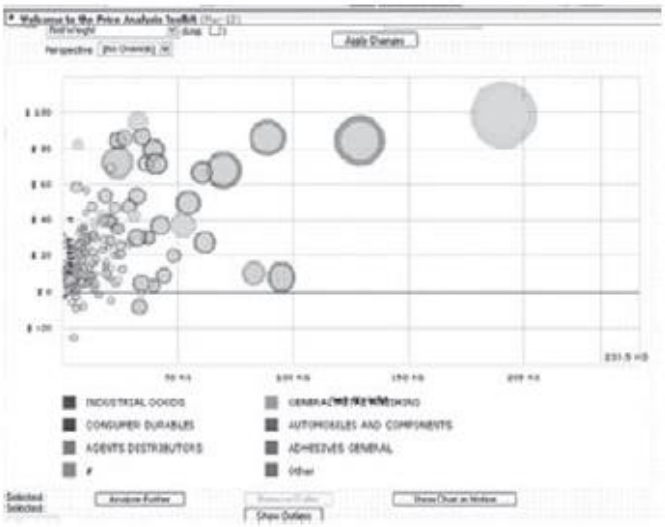
TREE MAPS

A popular newcomer to the visualization scene, tree maps display categorical data as a series of nested rectangles in which the size of the rectangle represents one attribute and color another. Heat maps are a compact way to expose hidden trends quickly. For example, the chart at right shows the performance of more than 45 metrics in a railroad company. A hover over exposes underlying metric values.

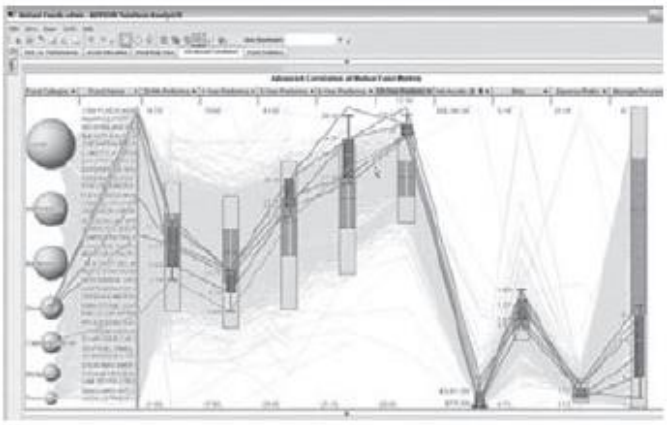


SCATTER PLOTS

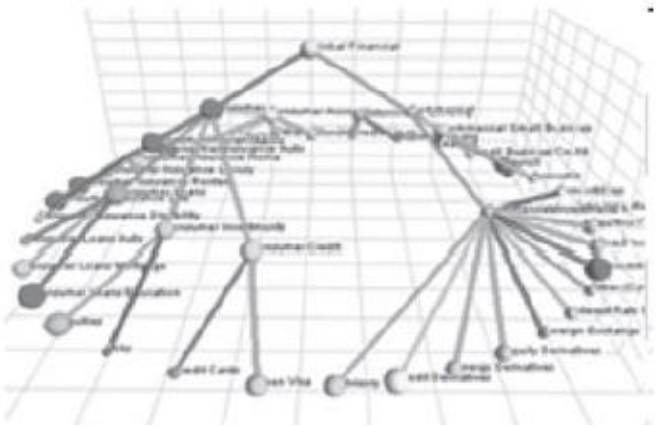
Also known as bubble charts, scatter plots display the values of two variables as dots or bubbles on an X/Y axis. One variable determines the position on the X axis and the other the Y axis. A scatter plot makes it easy to visualize the correlation between two variables, which is usually depicted as a straight or curved trend line.



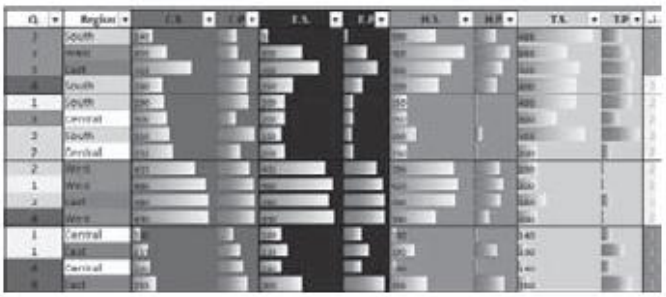
PARALLEL COORDINATE CHARTS
These graphs show how items or groups of items compare across a series of metrics represented as box plots. They are ideal for visualizing large numbers of items and how they change and compare over time or a series of metrics.



DATA CONSTELLATION
A data constellation chart shows multiple levels of a hierarchy and relationships among items in a single view. Users can examine the details of a subset of elements without losing view of the entire data set. Moving a cursor across the chart magnifies the area under the cursor while minimizing the other parts, enabling users to quickly drill into detail and view relationships.

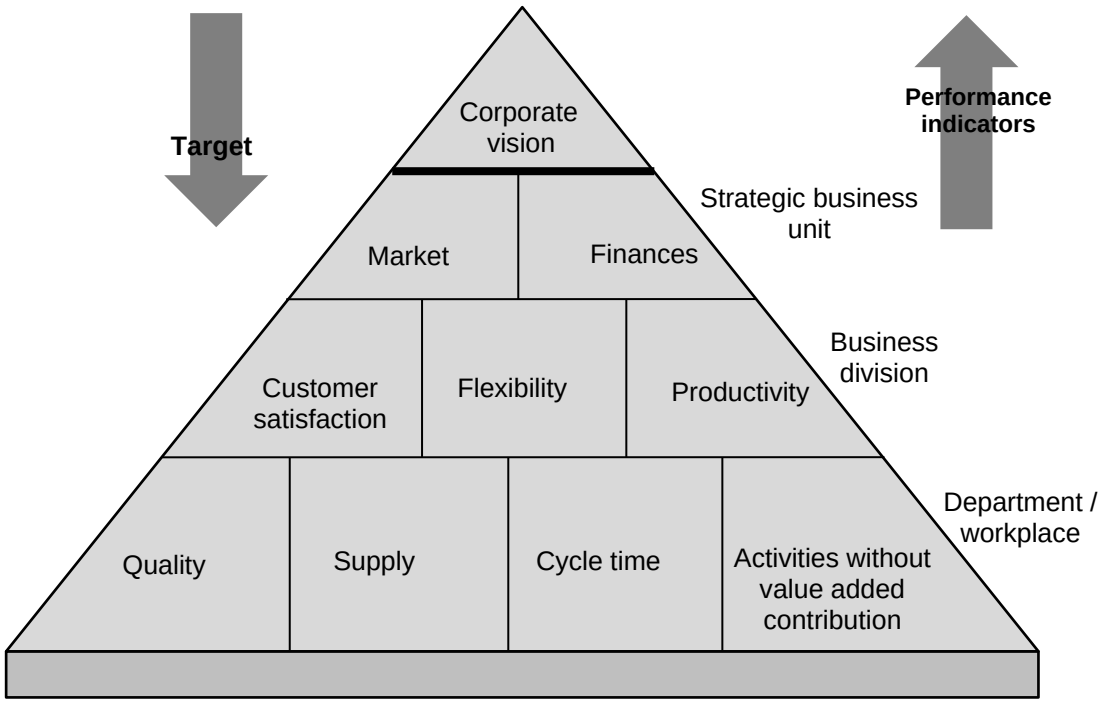


DATA BARS
Data bars visualize values in one or more columns of data, bringing visual life to a table of numbers. By sorting the columns and scrolling, users can quickly view patterns and anomalies in large volumes of data. Data bars work equally well on summarized or detailed data.

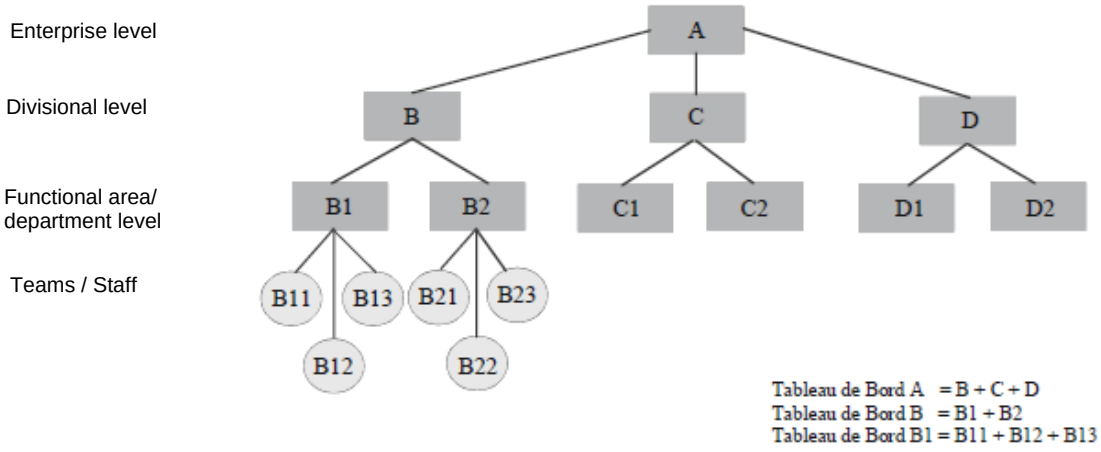


Appendix 10: Not so common graph types[445]

[445] Eckerson (2011), p. 246 ff.



Appendix 11: Performance indicators by hierarchy levels[446]



Appendix 12: Tableau de Bord[447]

[446] cf. Kobrin (2010), p. 31.
[447] cf. Giese (2011), p. 51.

Appendix 13: Skandia Navigator[448]

Quantum Performance			
	Value	Service	
	Costs	Quality	Time
Organisation	Financial Operational Strategically	Empathy Productivity Reliability Credibility Competence	Speed Flexibility Responsiveness Mobility
Process	Input Activities	Agreement Productivity	Speed Flexibility
Staff	Remuneration Development Motivation	Reliability Credibility Competence	Responsiveness Mobility

Appendix 14: Quantum Performance Matrix[449]

[448] http://www.12manage.com/images/figure_skandianavigator.gif [read on 30.05.2015]
[449] cf. Griese (2011), p. 58.

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13 List of images

14 List of tables

15 List of formulas

16 List of abbreviations

ASP.net	Active Server Pages. NET
BSC	Balanced Score Card
CEO	Chief Executive Officer
CFO	Chief Financial Officer
CFROI	Cash flow return on investment
CIP	Continuous Improvement Processes
CVA	Cash Value Added
DCF	Discounted Cash Flow
DCS	Data Collection System
EBIT	Earnings before interest and taxes
EFQM	European Foundation of Quality Management System
ERP	Enterprise Resource and Planning System
EVA	Economic Value Added
ISA	International Society of Automation
IT	Information Technology
KPI	Key Performance Indicator
KRI	Key Result Indicator
KSI	Key Success Indicator
MES	Manufacturing Execution System
MESA	Manufacturing Execution System Association
OEE	Overall Equipment Effectiveness
PI	Performance Indicator
PLC	Product Life Cycle
REFA	Verband für Arbeitsgestaltung, Betriebsorganisation und Unternehmensentwicklung
RI	Result Indicator
ROACE	Return on Average Capital Employed
ROCE	Return on Capital Employed
ROI	Return On Investment
RONA	Return On Net Assets
SHV	Shareholder Value
TMS	Transport Management System
VDI	Verein Deutscher Ingenieure
WMS	Warehouse Management System