Master thesis

Operational Excellence and the Applications in Mining Operations

Anna Felsner

Date(19/01/2015)

Chair of Mining Engineering and Mineral Economics
Department Mineral Resources and Petroleum Engineering
Montanuniversitaet Leoben

A-8700 LEOBEN, Franz Josef Straße 18
Phone: +43/(0)3842-402-2001
Fax: +43/(0)3842-402-2002
bergbau@unileoben.ac.at

Declaration of authorship

„I declare in lieu of oath that this thesis is entirely my own work except where otherwise indicated. The presence of quoted or paraphrased material has been clearly signaled and all sources have been referred. The thesis has not been submitted for a degree at any other institution and has not been published yet."

Anna Felsner

Acknowledgement

I would like to express special thanks to my advisor Professor Dr. Manfred Hoscher, head of the Chair of Mining Engineering and Mineral Economics at the Montanuniversitaet Leoben, for encouraging my research and for enabling me to write this thesis. Furthermore I would like to thank Dipl.-Ing. Markus Schenkl, employee of the Chair of Mining Engineering and Mineral Economics, for his input and feedback. I also want to express appreciation to my family and friends, who supported me in every step of my study.

Abstract

During the time of industrialisation mass production with automated and work-sharing processes supported the reduction of costs and therefore provided a competitive advantage. Over time many companies caught up with this trend and produced their products predominantly in large quantities. The market conditions at that time, a limited amount of consumer and maximum sales volumes for the products, led to the saturation of the market. Thus, the supplier market turned into a demand-driven market. According to literature, two strategies can be applied to deal with this development: first the differentiation of products or secondly the improvement of products. Approaches for both strategies are summarized in Operational Excellence.

This thesis comprises a general definition of the term Operational Excellence as well as a description of concepts, methods and tools developed and applied to achieve Operational Excellence in different parts of an organization. Based on a literature research the development and the implementation of these approaches are explained and further advancement like for example the combination of two methods is described.

The second part of the thesis concentrates on Operational Excellence in the mining industry. Personalities in leading positions of the raw material sector were asked about their understanding of Operational Excellence as well as their experience in applying the different approaches. The conducted interviews have shown that the application can especially be found during the mining operation and the activities linked to it, like asset management and inventory management. After adapting the concepts to the specific circumstances of the raw material sector the implementation in these areas has been successful. Further it shows that many companies have not yet taken advantage of the potential to include Operational Excellence in the strategic formulation process and in this way to include it in every activity of a company.

Zusammenfassung

Während der Industrialisierung führte Massenproduktion geprägt durch stark automatisierte und arbeitsteilige Prozesse zur Reduktion der Kosten und galt somit als Wettbewerbsvorteil. Im Laufe der Zeit folgte jedoch der Großteil der Unternehmen diesem Trend und produzierte vornehmlich in großen Stückzahlen. Die damaligen Marktbedingungen mit limitierter Käuferanzahl und mit Erreichung eines maximalen Marktvolumens der Produkte führten zu einer Marktsättigung; somit wandelte sich der Anbietermarkt wandelte sich in einen Nachfragemarkt um. In der Literatur werden zwei Strategien angeführt, um sich dieser Entwicklung anzupassen: einerseits die Differenzierung der Produkte durch neue Produktmerkmale oder Produktvarianten, andererseits die Verbesserung der bereits bestehenden Produkte. Operational Excellence umfasst Ansätze zur Umsetzung beider genannten Strategien.

Diese Arbeit beinhaltet eine allgemeine Definition des Begriffs Operational Excellence sowie die Beschreibung bestehender Konzepte, Methoden und Werkzeuge, die entwickelt und angewandt werden, um Operational Excellence zu erzielen. Auf Basis einer Literaturrecherche wird sowohl die Entstehung als auch Umsetzung dieser Ansätze erklärt und ihre Weiterentwicklung, wie etwa die Kombination zweier Methoden, beschrieben.

Der zweite Teil der Arbeit konzentriert sich auf Operational Excellence in der Bergbauindustrie. Führende Persönlichkeiten aus dem Rohstoffsektor wurden zu ihrer Auffassung von Operational Excellence sowie ihrer Erfahrung mit der Implementierung verschiedener Ansätze befragt. Die geführten Interviews zeigen, dass Operational Excellence besonders im operativen Bereich sowie bei Tätigkeiten, die eng damit verbunden sind, wie etwa Anlagenwirtschaft und Bestandsverwaltung, Anwendung findet. Durch eine Anpassung der Konzepte an die spezifischen Gegebenheiten im Rohstoffsektor konnte eine erfolgreiche Umsetzung in diesen Bereichen erreicht werden. Die Arbeit zeigt außerdem auf, dass viele Unternehmen noch keinen Nutzen daraus ziehen, den Operational Excellence Gedanken bereits in den strategischen Planungsprozess und somit firmenweit zu integrieren.

Scope of the Thesis

This thesis deals with the basic considerations concerning Operational Excellence and further its relevance in the mining industry. Depending on the industrial sector, the company's focus and the corporate values the term Operational Excellence is associated with different objectives and areas of an organisation; therefore, one objective of the thesis is to find a definition which is as general as possible and does not only describe the overall goal but also the basic approaches of implementing Operational Excellence in an organisation.

The implementation of Operational Excellence requires the knowledge of various concepts, methods and tools which have been developed over the last decades in order to redesign and control company-internal processes and procedures as well as the corporate organisation. In order to achieve excellence in all areas the approaches have to be applied in a structured and sustainable way. This thesis picks out concepts as well as the derived methods and tools to explain their purpose and the field of application. As the number of approaches, their variations and combinations is considerable, this thesis raises no claim to completeness. Furthermore this thesis does not cover the targeted application of Operational Excellence as a strategic management tool which would also consider different activities and approaches depending on the cycle of economy.

Most of the concepts, methods and tools found in literature were developed out of necessities of the automobile industry or the producing industry in general. One additional objective of this work is to study their applicability in the mining industry and further the future potential of their implementation in this industrial sector. To determine the current application of the different approaches, interviews with personalities in leading positions of the raw material sector were conducted. Based on the knowledge gained in these interviews as well as the personal opinions of the interviewees the future potential of implementing Operational Excellence in the mining sector was determined.

Table of contents

1 Definition of Operational Excellence

It repeatedly becomes apparent that out of the huge number of organisations worldwide only a few can be characterized as excellent. Due to studies provided by the Business School of London an organisation is excellent when achieving world market leadership at least in one branch of its businesses. (May & Schimek, 2009, p. 12)

Before starting with the description of the concepts, methods and tools helping to achieve Operational Excellence, it is necessary to define the term itself. Searching in literature or the World Wide Web, various definitions of Operational Excellence can be found; the differences between the definitions can be attributed to the general difficulty of explaining Operational Excellence in a few words. Therefore, this thesis picks out three definitions to describe Operational Excellence:

1) *"Operational Excellence is to be understood as an integrative framework which comprises a coordinated management of the value chain in order to implement the corporate strategy."* (Gleich & Sauter, 2008, p. 24)

2) *"The basis of Operational Excellence is an extensive tool box including improvement approaches like TQM, Six Sigma, Lean Management or the Toyota Production System. The content of this tool box is formed by well-established best practice approaches as well as specific tools like 5S, N5W analysis, SMED, Value stream mapping, PM analysis etc."* (May & Schimek, 2009, pp. 16,17)

3) Operational Excellence is *"a philosophy of the workplace where problem-solving, teamwork, and leadership results in the ongoing improvement in an organization. The process involves focusing on the customers' needs, keeping the employees positive and empowered, and continually improving the current activities in the workplace."* (WebFinance Inc., 2014)

According to Samuel Ho corporate strategy consists of three phases: first, the determination of a corporate mission statement setting the common value for everyone in the organisation. The mission statement or vision of the firm should remain unchanged for a decade or more. Secondly, the strategic options are defined and the optimum one is chosen. Normally, this will become the three to five year plan for the organisation. The third phase is the strategic implementation which is also known as operations management; it also defines the short term (three months to one year) plan for the organisation.

Where does Operational Excellence fit into corporate strategy? The answer is given in definition 1) saying that Operational Excellence helps to *implement the corporate strategy*; hence, it supports the third phase of corporate strategy. This implementation can be achieved through the targeted application of *well-established best practice approaches as well as specific tools*, mentioned in definition 2). However, the second definition may create the impression that only the systematic approach of process oriented and quantifiable measures is required to achieve Operational Excellence; this does not go far enough and therefore will not generate long lasting competitive advantages. Since one of the most important requirements for gaining competitive advantage is the adaption of the corporate culture (source: (Treacy & Wiersema, 1993) according to (Gleich & Sauter, 2008)). This is included in definition 3), where the term Operational Excellence is widened to a philosophy affecting not only processes, quality and costs but also including the participation of employees, the behaviour of leaders as well as the satisfaction of customers; living this philosophy will result in continuous improvement. So Operational Excellence is not only linked to the operations management of a company but it influences the strategic formulation process; hence Operational Excellence is integrated in the key mission statement and strategic option. This relationship between the corporate strategy and Operational Excellence is illustrated in Figure 1.

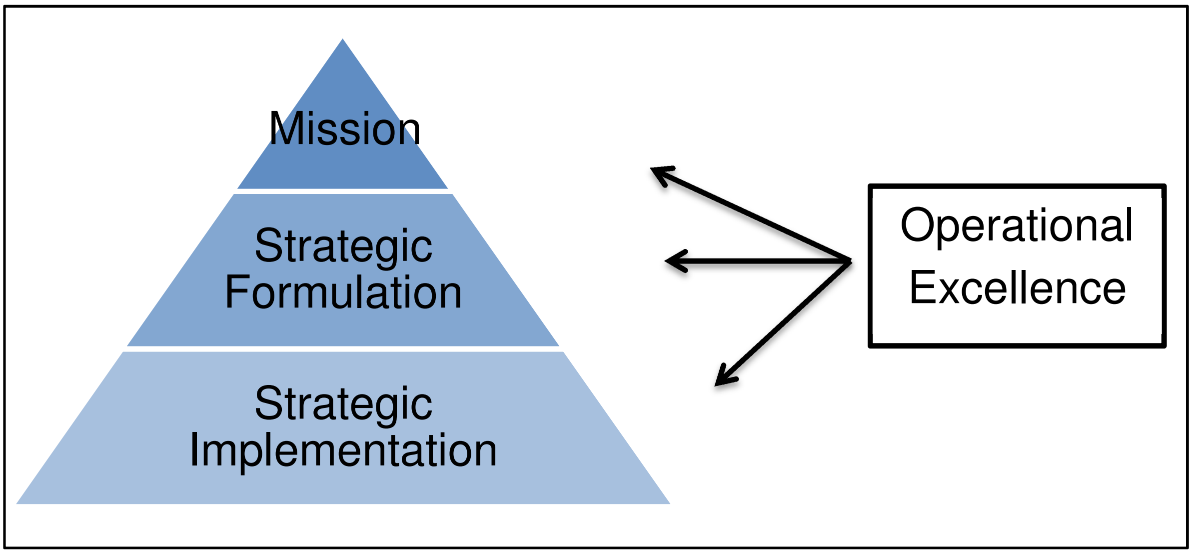


Figure 1: Relationship between Corporate Strategy and Operational Excellence

2 Concepts, Methods and Tools

As defined in Chapter 1, the basis of Operational Excellence is an extensive tool box including improvement approaches as well as specific tools which support the implementation of the corporate strategy. The purpose of Chapter 2 is to give an overview over the concepts, methods and tools included in this tool box and further to explain their objectives and implementation.

The chapter starts with the explanation of the Toyota Production System (TPS) as this concept has a long history and includes the basic thoughts also for the other methods. The following two subchapters contain the concepts Total Management System (TPM) and Lean Management due to the fact that they were both developed based on Japanese approaches (partially included in the TPS). The fourth subchapter deals with the difficulties involved in the Planning process while the last subchapter covers further concepts, methods and tools connected to quality issues which have not been amplified before. Because the number of approaches, their variations and combinations is considerable, this thesis raises no claim to completeness.

2.1 Toyota Production System (TPS)

In his work “Toyota Production System”, Taiichi Ohno explains that the Toyota Production System was developed out of the necessity to manufacture small quantities of various models at low demand. Its main objective is the increase in production efficiency through consequent and careful elimination of any kind of waste. The concept was designed right after the Second World War but only after the first oil crisis in 1973 it attracted the attention of the entire Japanese industry. (Ohno, 1993, p. 19)

The Toyota Production System was illustrated as a house to underline that it only operates fully if all the elements work together (see Figure 2). Just-in-time (see Chapter 2.1.1), attributed to Kiichiro Toyoda, and Jidoka (see Chapter 2.1.2), attributed to his father, Sakichi Toyoda, are the two pillars holding up the house. Two conditions must be fulfilled to turn the system into high performance instead of an exercise in futility. The first is a rock-solid foundation of stability in normal conditions requiring extremely well-trained people who aim to perform their jobs perfectly and extremely well-maintained equipment that seldom breaks down. The second condition is the way people behave in case of problems. Toyota trains employees in problem solving to jump into action, first to contain the problem and restart production, and further to deal with the root cause of the problem so that it will not keep coming back. Kaizen (see Chapter 2.1.3) turns this painful interruption of production into exceptional people and processes for competitive advantage. (Liker & Convis, 2012, pp. 92,93) The roof of the house represents the focus of the Toyota Production System, meaning its goals: Quality, Cost, Deliver, Safety and Morale

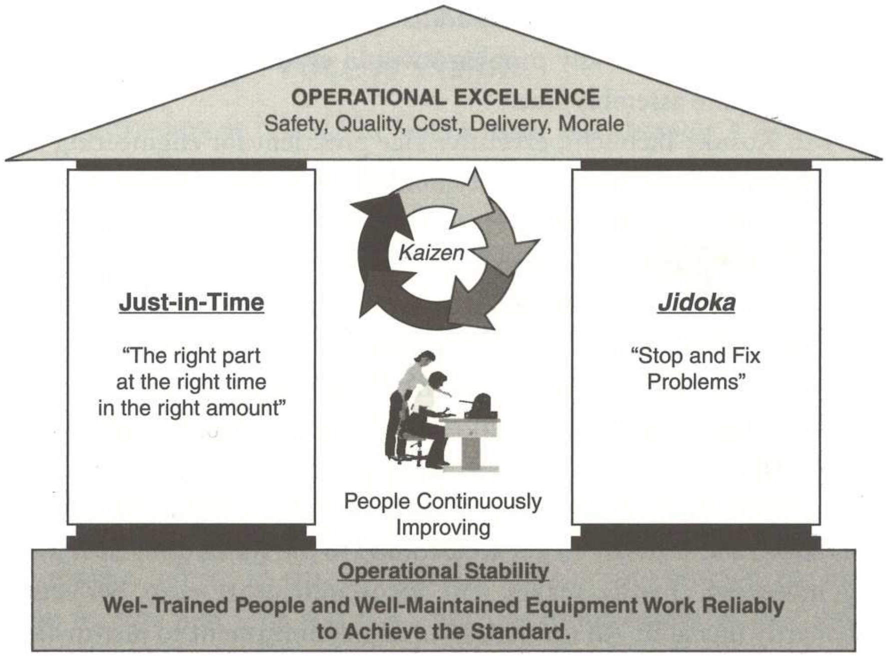


Figure 2: The Toyota Production System House (Liker & Convis, 2012, p. 93)

A more detailed illustration of the TPS-house can be found in the appendix.

The Evolution of the Toyota Production System

The TPS is based on the application and further development of the 5W approach (see Chapter 2.2.2.1) as the basis of the system is the elimination of waste. The following equation needs to be considered:

$$current\ capacity = work + waste \qquad (1)$$

This means that work only includes the work required for the job, everything else is waste. Hence, in production waste is everything which increases costs without creating value. Real improvement of efficiency can only be achieved by increasing the work to 100 %. The preparing step for the application of TPS is the full identification of waste in its seven forms of appearance:

- Overproduction
- Unnecessary transportation
- Unnecessary motion
- Waiting time
- Over-processing
- Excess inventory
- Defects and poor quality

(Ohno, 1993, pp. 43-45, 83)

The following chapters provide description and details of the mentioned methods included in the Toyota Production System.

2.1.1 Just-In-Time

"Just-In-Time means making only what is needed, when it is needed, and in the amount needed." (Toyota Motor Corporation, 1995-2014)

Just-in-time is one of the two pillars holding up the TPS-house (see Figure 2). The basic idea behind the Toyota Production System is the total elimination of waste (Ohno, 1993, p. 30). Just-in-time is a method to minimize inventory in the stockroom and factory floor. As high inventory is considered to be the origin of many kinds of waste it must be reduced: waste includes space occupied on the factory floor, quality defect, and inventory cost. Concerning this, the material in the production line should arrive just before it needs to be processed. This is achieved via the Kanban system. (Soin, 2012, p. 65)

2.1.1.1 The Kanban System

The term Kanban means signal or card (Soin, 2012, p. 66). The most common form is a piece of paper in a plastic jacket (Ohno, 1993, p. 54). In this text the term Kanban is used for both the card and the overall Kanban system.

Kanban is a scheduling system to coordinate production and withdrawals. The system is a pull system as the material is pulled to the production line only when required. The original Kanban system is a two-card system: after the material is received and placed beside the production line, the material handler (MH) separates the withdrawal cards and deposits them in a withdrawal bin (each pallet or container has one Kanban card attached to it). When a number of pre-determined cards are deposited in the withdrawal bin, the MH will go to the buffer store of a sub-assembly with the withdrawal card. He will take what he requires per the withdrawal card. (Figure 23 in the appendix shows examples of production and withdrawal cards.) The MH will remove the attached production start card and attach the previously collected withdrawal cards to the new parts, for each pallet or container. These production start cards are deposited in the production start bin at the buffer store. Afterwards the MH brings the new material to the final assembly line. Once the material is consumed, the withdrawal cards are again deposited in the withdrawal card bin. In the meantime, the production start cards are given to the production team to start the production of new assemblies; after the production is completed, these assemblies are stored in the buffer store with accompanying production start card. (Soin, 2012, p. 67)

The process described above is illustrated in Figure 3. It shows both, downstream processes which withdrawal material when needed and upstream processes which manufacture what has been withdrawn. (Soin, 2012, p. 67)

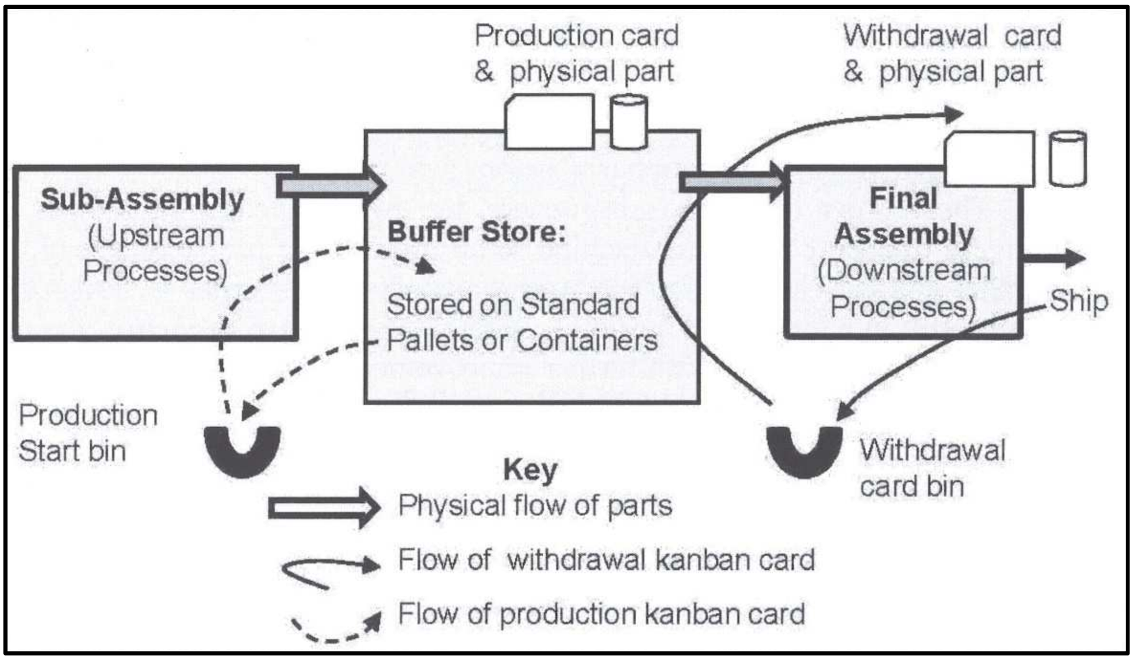


Figure 3: Two Card Kanban Pull System (Soin, 2012, p. 68)

The Kanban System Rules

1. The subsequent or downstream processes should withdraw only the parts they need from the preceding process.
2. The preceding process can only manufacture the exact quantity withdrawn.
3. Kanban works best when the production schedule is levelled.
4. The products manufactured and sent to the next process must be 100 % defect free.
5. The Kanban system must be continuously improved.

(Soin, 2012, p. 70)

2.1.1.2 Takt

Takt is a fundamental concept in just-in-time. Takt is German and means “rhythm” or “beat” (in music). While a metronome sets the Takt for a musician, in just-in-time Takt is the rate of customer demand. If customers, for example, buy a car every minute, the Takt time is one minute. In a just-in-time system, this would mean that every minute the production of one car has to be finished. Ideally also the preceding processes, like stamping and welding, would produce the parts for one car every minute. (Liker & Convis, 2012, p. 91)

Thus in manufacturing, Takt time sets the pace for production. The weakest link or slowest time in a series of manufacturing steps needs to be removed in order to remove bottle necks and speed up production. Therefore managing Takt time is an ongoing cycle of improvement. (Soin, 2012, pp. 45,46)

$$Takt\ Time, Tt = \frac{Ta\ (Available\ production\ time\ in\ a\ day\ or\ net\ available\ time)}{D\ (Customer\ demand\ or\ units\ required\ per\ day)} \qquad (2)$$

where:

- Tt Takt time [s or min]
- Ta Net available production time in a day [s or min]
- D Customer demand or unit required per day

Total Cycle Time and Cycle Time

However, the Takt time is not the time taken to produce the product; the total cycle time will be much longer as we include sub-assemblies that are purchased or built elsewhere. (Soin, 2012, p. 46)

Takt time is used to define and manage the overall assembly process; it is basically a customer parameter and is driven by customer demand or forecast for the product. Each individual workstation in the assembly process will have cycle time TC, the time taken to complete work per standard work at a workstation. Therefore on the assembly line and operation floor, the production lines, workstations, and equipment are measured by cycle times. (Soin, 2012, pp. 47,48)

$$Cycle\ time = arrival\ time + queue\ time + setup\ time + process\ time + batch\ time \quad (3)$$

where:

- Arrival time = time to move a job from the previous station and included walking time
- Queue time = time the job is waiting to be processed or to move to the next station (after processing)
- Setup time = time it takes to set up the equipment for doing the job
- Process time = actual time to process the job at the current workstation
- Batch time = average waiting time to batch the job into a quantity of more than one unit; this would be zero for one-piece-production (see Chapter 2.1.5)

Cycle time usually varies at each work station but it is always planned to be less than the Takt time of an assembly process: $T_c \leq T_t$. Assuming there are no operator, equipment, or quality issues, this will result in a smoothly running line.

(Soin, 2012, pp. 47-49)

Line Balancing

Figure 4 shows a situation where the line is unbalanced – this can happen for many reasons. Imbalances can be caused, for example, by introducing a new product or by changing, modifying and improving the production process. Variation between work stations causes waste for stations running cycle times below the Takt time and bottlenecks at stations running high cycle times (or even cycle time above the Takt time). Variation of overall manufacturing cycle time of a product results in unpredictability of production output and waste in the system. This will lead to unpredictable schedules, unplanned overtime, and work in process inventory buildups. On the other side, a well-balanced line allows maximum efficiency of operators and maximum output from the production line. It will result in proper distribution of work to ensure that all operators will be equally occupied and there is no wasted labour. Therefore cycle time must be monitored and tracked to minimize inefficiency. (Soin, 2012, p. 51)

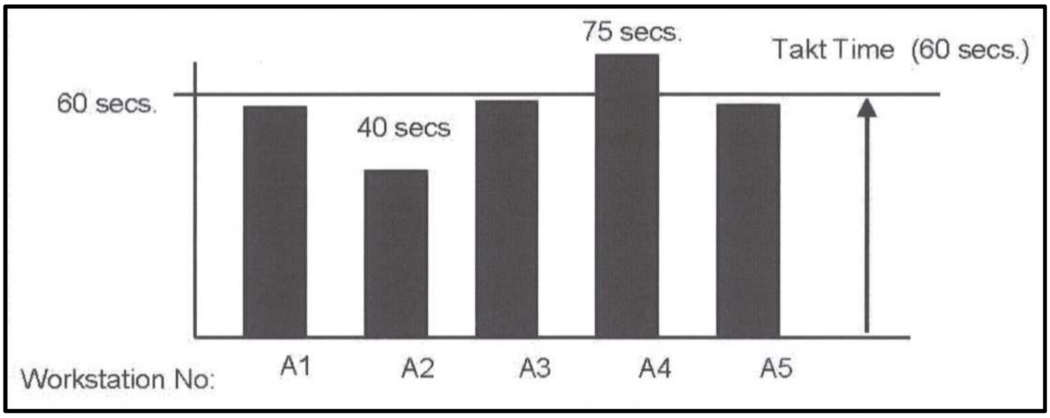


Figure 4: Unbalanced line, with A4 cycle time > Takt time (Soin, 2012, p. 48)

A common tool for Line Balancing, called Yamazumi Chart, is explained and illustrated in the appendix.

Overall Manufacturing Cycle Time

Overall manufacturing cycle time is the total time to manufacture a product. Managing and reducing it will reduce assembly costs, labour costs, and overheads. There are some specific areas to focus on. After balancing the production line, the production efficiency should be reviewed – one way is to determine the effective cycle time (ECT) of the production line:

$$The\ effectice\ cycle\ time, ECT = \frac{Operational\ cycle\ time}{Operational\ availability\ time} \quad (4)$$

Operational excellence requires an operational availability of 95 %. To achieve this all equipment and machines need to be well maintained, production material must not run out on the line, and quality issues have to be rare and managed by an effective Jidoka system (see Chapter 2.1.2).

To be able to improve the performance it is necessary to analyse and review the current situation. The PDCA improvement cycle (see Chapter 2.5.2) is a powerful tool to manage the process and understand the individual situation at each workstation. Improvement can be achieved by reducing the workstation cycle time, reducing variations in cycle time, reducing duplicate processes and also by outsourcing of complex assemblies.

A case of 100 % efficiency and routinely achievement of the Takt time goal may cause suspicion. It indicates that system cycle time is much lower than Takt time; hence there may be too much inventory or other waste in the line. 95-98 % efficiency means that the process is close to high efficiency even though some line stops are occurring – this requires review and improvement.

(Soin, 2012, pp. 59-61)

Leveled Production (Heijunka)

To achieve an efficiently working Takt time system the production demand needs to be stable for a reasonable period of time (a week, a month…). This is obtained by levelling production target despite demand fluctuations. There are several types of demand levelling:

- Levelling the daily production demand.
- Levelling the daily product mix within the daily demand.

To provide a levelled production target, typically, the daily production demand or forecast is reviewed and smoothened.

The benefits of levelled production can be found in a stable production and balanced, smoothly running production lines with good labour utilization. But levelled production may also result in excess finished goods inventory due to production target smoothening; however, this is acceptable due to the reduction on frequent line adjustments and production changes. The created inventory buffer will protect the production lines against surprise order. Toyota Motor Company does about half its business by built to order, the rest of production benefits from levelled production, resulting in some build to stock production. It can be resumed that the combination of levelled production and building to order keeps both work in process (WIP) and finished goods at a low level, and the production lines running smoothly.

(Soin, 2012, pp. 61,62)

Just-in-Time at Toyota

The True North (see Chapter 3.2) vision is to have zero inventory between processes, although there often need to be some strategically placed inventory buffers. Through little inventory problems become painfully visible and they must be solved to prevent production stops. Adjusting inventory levels takes time and effort and furthermore many companies do not want to give up the safety of having extra inventory. The reason for Toyota taking these efforts is its aspiration for perfection – problems need to become visible as quickly as possible. "*An uncompromising commitment to just-in-time pushes everyone to pursue perfection because anything less than perfection becomes obvious very quickly*." (Liker & Convis, 2012, p. 94)

2.1.2 Jidoka

Besides Just-in-time (see Chapter 2.1.1), Jidoka is the second pillar holding up the TPS-house (see Figure 2). Jidoka is Japanese; in English the term autonomation is used to describe this process (Soin, 2012, p. 147). The principle of Jidoka describes machine capability with intelligent design to stop manufacturing process whenever abnormalities occur. Therefore, it is also often called "automation with human touch". (Ohno, 1993, p. 32)

After power-up, today's machines mostly work automatically; but they operate at such high capability that even small abnormalities may damage them resulting in hundreds of defective parts. At Toyota nearly every machine is equipped with a special device to stop in case of a problem. (Ohno, 1993, pp. 32,33)

An effective working Jidoka system undertakes supervisory function. This means that in case of an abnormality the machine stops and the operator will stop production. Therefore, the operator does not need to continuously judge or measure whether the machine is normal or defective but can focus on producing good parts. After discovering a defect, an Andon (Japanese for Lantern or light) display is triggered. Several types of Jidoka and Andon systems can be found.

(Soin, 2012, pp. 148,149)

2.1.3 Kaizen

The Japanese word Kaizen consists of the symbol KAI meaning "change" and the symbol ZEN meaning "good". So it has the meaning of "change for the better". In

Japan Kaizen is a common term and often used as a synonym for continuous improvement. (Brunner, 2008, p. 12)

Kaizen is not a method for solving problems but a process oriented way of thinking in the sense of a mentality, which describes the goal as well as the basic mode of behaviour in a company (Brunner, 2008, p. 12). At the root of Kaizen is the idea that nothing is perfect and everything can be improved (Liker & Convis, 2012, pp. 36,37). In principle Kaizen is a permanent journey of using PDCA cycles (Brunner, 2008, p. 12).

2.1.3.1 Basics of Kaizen

The Seven Quality Tools Q7

The seven quality tools are simple means to identify, analyse and solve problems. They are mostly based on graphics and are used to work with numerical data. With these tools it is possible to collect data, identify and analyse failures, find their causes and in the next step to solve problems, prevent failures and do improvement analyses. Illustrations of the following tools can be found in the appendix.

1. Defect Collection List or Check Sheet: Systematic registration and visualisation of a problem using specific data.

2. Histogram: Organization of data according to the frequency of their occurrence. Bar chart to visualize the frequency distribution of a huge amount of data, which has been separated into groups before.

3. Pareto (ABC-) Analysis: Prioritization of influences. Bar chart to display the causes of problems graphically depending on the importance of their impacts.

   The Pareto principle says that 20 % of all sources of problems cause 80 % of the resulting troubles. In a Pareto analysis the frequency of certain problems is documented and later visualized graphically. (May & Schimek, 2009, pp. 96,97)

4. Stratification: Separation and organization of data from different sources. Sometimes “brainstorming” is mentioned instead of “stratification”. Brainstorming is always a basic method when starting to work on a problem solution.

   (Ho, 1995) mentions “Process Flowchart” instead of “Stratification”.

5. Ishikawa or Cause and Effect Diagram or Fishbone Diagram: Analysis of the main sources of problems (man, machine, method, material, measurement, environment, management) according to their influence on the problem's origin.
6. Correlation Diagram/ Scatter Diagram: Graphic representation of a supposed relation between two equal characteristics which were measured or observed as a pair of values. Laws and tendencies can be derived.
7. Quality Control Chart: Regular monitoring if a process works within the tolerance limits to be able to intervene in time.

(Brunner, 2008, pp. 12, 13)

The Seven New Management Tools N7 or M7

The seven new management tools are used to support the processes of problem solving and taking decisions. Simple graphical means are used to organize a confusing wealth of information. This information is often not available in numbers but nevertheless needs to be organized in a meaningful way. Therefore the M7 are especially applied by groups during the development and planning phase where numerical data is often not yet available. Illustrations of the following tools can be found in the appendix.

1. Affinity Diagram: A variety of information is organized through aggregation.
2. Interrelation Chart: The chart shows the interrelation between different arguments and approaches.
3. Tree Diagram: Structure with different levels which provides an overview over means and measures to problem solving.
4. Matrix Chart: Relations and interrelations between two characteristic groups are organized and rated.
5. Portfolio: Compressed display of data related to two or three criteria, shown in coordinate axes.
6. Network Plan: Through logical linkage of process timing critical aspects become visible.

7. Decision Tree: Possible difficulties are considered in advance and countermeasures can be integrated.

(Brunner, 2008, pp. 17, 18)

Quality Circle (QC)

A Quality Circle is a small group consisting of five to ten workshop employees. They meet each other on a voluntary basis outside the paid working hour in an appropriate room to discuss problems in their working fields trying to find solutions. (In today's highly competitive environment, participation is no longer voluntary – it is essential for success that everybody chips in. (Soin, 2012, p. 181)

Although they are supported from outside the circle members are responsible for the choice of subject, the formation of groups and the realisation of the improvements. The groups are coordinated by trained circle leaders who mainly ensure the compliance with the basic rules:

- Formation of teams
- Brainstorming
- Application of methods for problem solving
- Support

The circle leaders meet with the coordinators on a regular basis in order to discuss results, realisation and opportunities for improvement as well as to provide support with more complex problems.

The total work of the quality circle is accompanied by a steering committee including quality management, human resources, general management and employee representative. This committee also hands in proposals for an award.

Originally quality circles where invented for the production floor. A company-wide implementation would also include the management and service departments. (Brunner, 2008, p. 29)

2.1.3.2 Suggestion Scheme

In Japan suggestion scheme programs are a popular and common Kaizen technic. The employees are motivated and trained to make suggestions.

There are single and group suggestions. Forms which can be filled out and brought to a near letterbox are provided at each work place. The suggestions include the following themes:

- Reduction of workload
- Resource savings
- Improvement of occupational safety
- Increase of productivity
- Quality Improvement
- Time and Money savings

(Brunner, 2008, p. 34)

Topics which are considered to be unsuitable for a suggestion scheme include suggestions that are within the direct control of the proposer, personnel policies and guidelines, salary and wage administration as well as personal grievances or conflicts. (Soin, 2012, pp. 184,185)

When implementing a suggestion scheme several guidelines need to be considered. It is important to keep the suggestion form simple: for operators who may not have access to PCs a paper format should be prepared, while professionals will prefer a form accessible and usable on a PC. Quick feedback is essential. The suggestion should be acknowledged verbally or via email within two days. Acceptance or rejection of the suggestion should be within a week in the same department and a maximum for two weeks across a company. Ongoing recognition and rewards are indispensable. The process and cost of reviewing each suggestions and giving small rewards may seem costly but the employee engagement and involvement is priceless. The rewards systems offer many opportunities and variety: accumulation of points during the year for each suggestions, a reward for the best five suggestions each year or awards based on the percentage of savings achieved through implementing the suggestion. Furthermore it is necessary to monitor the progress and to set metrics. In the initial phase the number of suggestions including the trend, the percentage of employees participating, the time to respond as well as the time to implement are observed, while later in the mature phase the focus is also on the quality of suggestions and cash savings per year. (Soin, 2012, pp. 181, 185-187)

In Japan, nearly $^{3}/_{4}$ of all employees make suggestions. In comparison, in the USA in the best case $^{1}/_{4}$ of all employees participate in the suggestion scheme program. In Japan, an average of 80 % of the employees' ideas are implemented – in the USA only 38 %.

(Brunner, 2008, pp. 33, 34)

2.1.3.3 Kaizen at Toyota

The vast majority of firms and senior executive leader at those firms misunderstand Kaizen. It is often seen as assembling a special team for a project using methods like lean Six Sigma (see Chapter 2.5.4) or also organizing a Kaizen "event" for a week to make a burst of changes. At Toyota, Kaizen is not an event or project but an integral part of leadership. "Kaizen mind" is a core value of Toyota. It's how the company operates at most fundamental level. (Liker & Convis, 2012, pp. 123,124)

There are two types of Kaizen requiring daily activity. The first type is maintenance Kaizen: the daily work of reacting to an unpredictable world. Maintenance Kaizen is the process of reacting to the unavoidable mistakes, breakdown, changes, or variations in order to meet the expected standard (productivity, quality, safety). The goal is to bring the system back to standard setting. For example, all andon calls (see Chapter 2.1.2) belong to maintenance Kaizen as they are designed to identify problem quickly. So maintenance Kaizen is urgent and immediate. (Liker & Convis, 2012, pp. 123,124)

The second type of Kaizen is improvement Kaizen (this is simple called "Kaizen" because it is the real goal). If the goal of a company is perfection, every process can be improved. No matter how many improvements have been made, every process is still full of waste and ripe. (Liker & Convis, 2012, p. 124)

2.1.4 Standard Work

Standard work or standardized work implements detailed and comprehensive work procedures. These procedures have to be well documented and training to employees must be provided to ensure good repeatable processes in manufacturing. Standard work will include all steps in the work sequence, the cycle time to complete the work, and the inventory necessary at the workstation.

As these standards are required for the simplest to the most complex job in the factory, they are an essential ingredient of manufacturing. They lay the foundation for further improvement or Kaizen (see Chapter 2.1.3). The ability to maintain good standard work, provide training, and ensure continuous improvement is the basis for high performance work and operational excellence. (Soin, 2012, pp. 27, 44)

The Concept of Standard Work and the procedure to prepare it can be found in the appendix.

Genchi Genbutsu: The Gemba Walk

The factory is the chief source of information for the manufacturer because it directly delivers inspiring up-to-date information about the management of the company (Ohno, 1993, p. 46). Improving standard work requires observation of work at hand, understanding current problems and also ways of improvement. This technique of observing is known as Genchi Genbutsu, which is Japanese for "go and see". Akio Toyoda, president of Toyota Motor Corporation, once stated:

> "*Genchi genbutsu [go and see the actual situation] means imagining what you are observing is your own job, rather than somebody else's problem, and making efforts to improve it. Job titles are unimportant. In the end, the people who know the gemba [where the actual work is done] are the most respected."* (Liker & Convis, 2012, p. 9)

This approach is also called Gemba, which is Japanese for "the place", or where it's happening. The Toyota Way underlines that the farer from the Gemba decisions are made, the poorer the decisions will be (Liker & Convis, 2012, p. XXIII).

Genchi Genbutsu is an important component of the TPS (see Chapter 2.1). The fundamental idea of this technique is, that any information about a process will be simplified and therefore lack accuracy from the original as a result of reporting through another person. To avoid inappropriate solutions and to understand the real problem, the person responsible must go see for himself at the location where the activity is occurring. Observing activities on the shop floor should be part of the daily routine of managers and engineers. A so-called Gemba walk can support them in identifying waste and potential areas for improvement.

(Soin, 2012, p. 37/38)

The Ohno Circle

According to Teruyuki Minoura (source: (Liker, 2004) according to (Soin, 2012)), who worked under Taiichi Ohno the originator of TPS, Mr. Ohno used to order his trainees to go on the shop floor and stand in a circle he has drawn. Before he goes away, Ohno would tell his pupil to observe the surrounding process, sometimes for hours. (Liker & Convis, 2012, p. 61) According to Mr. Ohno, staring at a situation long enough will always uncover useless practices or work and movements that create problems. What Ohno was teaching in his unique style was the power of deep and detailed observation of manufacturing process combined with analysis to find a better way of doing it. Mr. Ohno is reputed to have told his production staff: "*If standard work does not change for one month you are salary thieves.*" His point is that standard work and processes must be continuously improved. Anywhere in the company, wrong and right methods can be discovered and engineering professionals must take the proper approach to reduce waste and produce good standardized work with the requisite training. (Soin, 2012, p. 40)

2.1.5 One-Piece Production

One-piece production means processing and moving one job between workstation. The alternative is batch production where large batches are moved between work stations.

An example helps to see the difference of the two systems: Figure 5 shows how a batch of picture frames is processed through 5 workstations. If a batch consists of 5 pieces and the workstation cycle time is 1 minute for all stations, it will take 5 minutes to complete the batch. Therefore, after 25 minutes the first batch of frames is completed. The same work can be done with one-piece production meaning one frame is built at a time. The workstation cycle time is again 1 minute per station. Hence, as it takes 5 minutes to move through all five stations, the first finished frame leaves the production line after only 5 minutes. The 5th frame will be completed after 10 minutes which means finishing the first 5 frames in one-piece production will only take 10 minutes compared to 25 minutes using batch production. There is no magic here; it still takes 25 minutes of effort to complete the same 5 frames when one-piece production is used. But one-piece production is more efficient in case of small batches at each station. It is applicable for all types of small and large machine assembly, work cells, and final assembly lines. (Soin, 2012, p. 156/157)

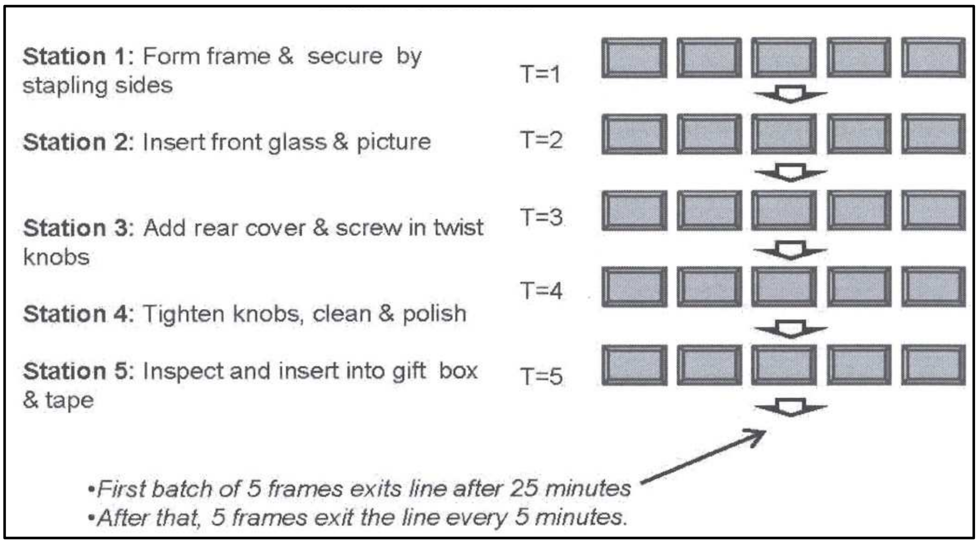


Figure 5: Batch Production (Soin, 2012, p. 156)

Successful One-Piece Production results in less work in process inventory, a reduction in factory space, a faster response to changing customer demand, an improved productivity and quality as well as a continuous flow in manufacturing.

(Soin, 2012, pp. 157,158)

Challenges with One-piece Production

Bad quality will cause frequent disruptions and line stops. In batch production good work pieces are moved to the next stage while defective work pieces are sorted out and resolved when time permits. In contrast, in one-piece production the line must be stopped to look for the cause of defect. Especially in case of untrained employees this process of analysing problems can cause confusion and especially at the start of one-piece production process may end up in frustration.
Unbalanced cycle time will create bottlenecks along the line. One-piece production requires an effective Takt time system (see Chapter 2.1.1.2) and accurate work standard (see Chapter 2.1.3). Otherwise, bottlenecks will cause delays where cycle time is too high and bored operators where cycle time is too low.

Furthermore, material shortages in one-piece production will result in line stops due to less WIP and fewer raw materials on the line. This requires the implementation of an effective Kanban system (see Chapter 2.1.1.1).

Line stops and disruption can also occur if a trained operator at a workstation is absent or missing. Hence, operators need to be cross-trained and able to multi-task. Often floating multi-skilled senior-operators are deployed for such a contingency.

Other challenges in one-piece production are lengthy changeover times as they can disrupt the continuous flow. Changeover becomes an issue during low volume production because the time taken may be very long compared to the time to build a small volume of production. Changeover time delays can be caused by equipment that is not designed for one-piece flow or by equipment which takes a long time for setup.

(Soin, 2012, p. 159)

Variability

Variability is always present in a manufacturing environment. Any variability in the operation will have a negative effect on the performance and will create bottlenecks. Hopp and Spearman (source: (Hopp & Spearman, 2001) according to (Soin, 2012)), have proposed the Law of Variability which states: *Increasing variability always degrades the performance of a production system.*

When fighting variability it is advisable to start at the beginning of the production process because variability early in the process spreads downstream and extends. Therefore, first incoming material quality must be reviewed and resolved. Next, to ensure that defective material is not sent downstream defect levels in machines and assemblies early in the production process must be reviewed and reduced as well. Finally bottlenecks or constraints along the line, like for example poor line balancing, need to be identified.

Reducing variability does not only help to improve factory output but is also a cheaper and quicker option to improve the quality of the product.

(Soin, 2012, pp. 174, 176, 177)

2.1.6 Value Stream Mapping

The value stream (source: (Womack & Jones, 1996) according to (Soin, 2012)) is the set of specific actions that are required to bring a specific product (goods or services) through the three critical management tasks of any business: The problem-solving task from concept to production, the information management task from order to delivery, and the physical transformation task from raw materials to finished product.

Value Stream Mapping (VSM) helps to map the current state of the design, information management, or physical transformation activities. When the current state is completely mapped, an enormous amount of waste can be identified and further the future state and action plans can be developed. VSM is a practical tool; it has the ability to put all necessary information of the current state of an operation into a visual form for management to see and analyse. The ultimate aim of value stream mapping is creating value, which is according to Womack and Jones the first principle of lean thinking.

(Soin, 2012, pp. 231, 232)

The procedure of Value Stream Mapping can be found in the appendix.

VSM is basically a waste identification technique. Hence, there is little focus on product quality and customer issues. Furthermore, it can be time-consuming and bureaucratic. Toyota and many teachers of TPS do not use this tool – they prefer the Genchi Genbutsu approach (see Chapter 2.1.3). (Soin, 2012, p. 238)

2.2 Total Productive Management (TPM)

In praxis, the abbreviation TPM stands for several conceptions like “Total Profit Management” or “Total Personnel Motivation”; but most common are “Total Productive Maintenance” and “Total Productive Management”.

TPM was developed on basis of the Toyota Production System (TPS) (see Chapter 2.1). “Total Productive Maintenance”, the approach to achieve a more efficient maintenance through including all employees, was first established in Japan in the 1970s. The focus was on improving the plant efficiency and the life-time extension of the plant. In the following years this concept was continuously enhanced to a comprehensive management system, affecting every sector of a company or organization. Today TPM contains of eight building blocks or pillars with its focus on the identification and elimination of losses and waste.

(May & Schimek, 2009, pp. 12-15)

2.2.1 The Eight Building Blocks of TPM

TPM is based on an 8-pillar-model (JMA Consultants Inc, n.d.). Out of this model the so-called Operational Excellence Reference Model (source: (May, 2007) according to (May & Schimek, 2009)) can be built through supplementing the 8 pillars by the basis, the tools, the targets and the meta-targets (see Figure 6). In order to create a solid foundation the following conditions need to be fulfilled:

- Total commitment of management
- Hoshin Kanri (see Chapter 2.4)
- Genba Kanri or Shopfloormanagement
- Empowerment of the employees
- Cross-functional teamwork
- Standard work (see Chapter 2.1.3)
- Visual Management

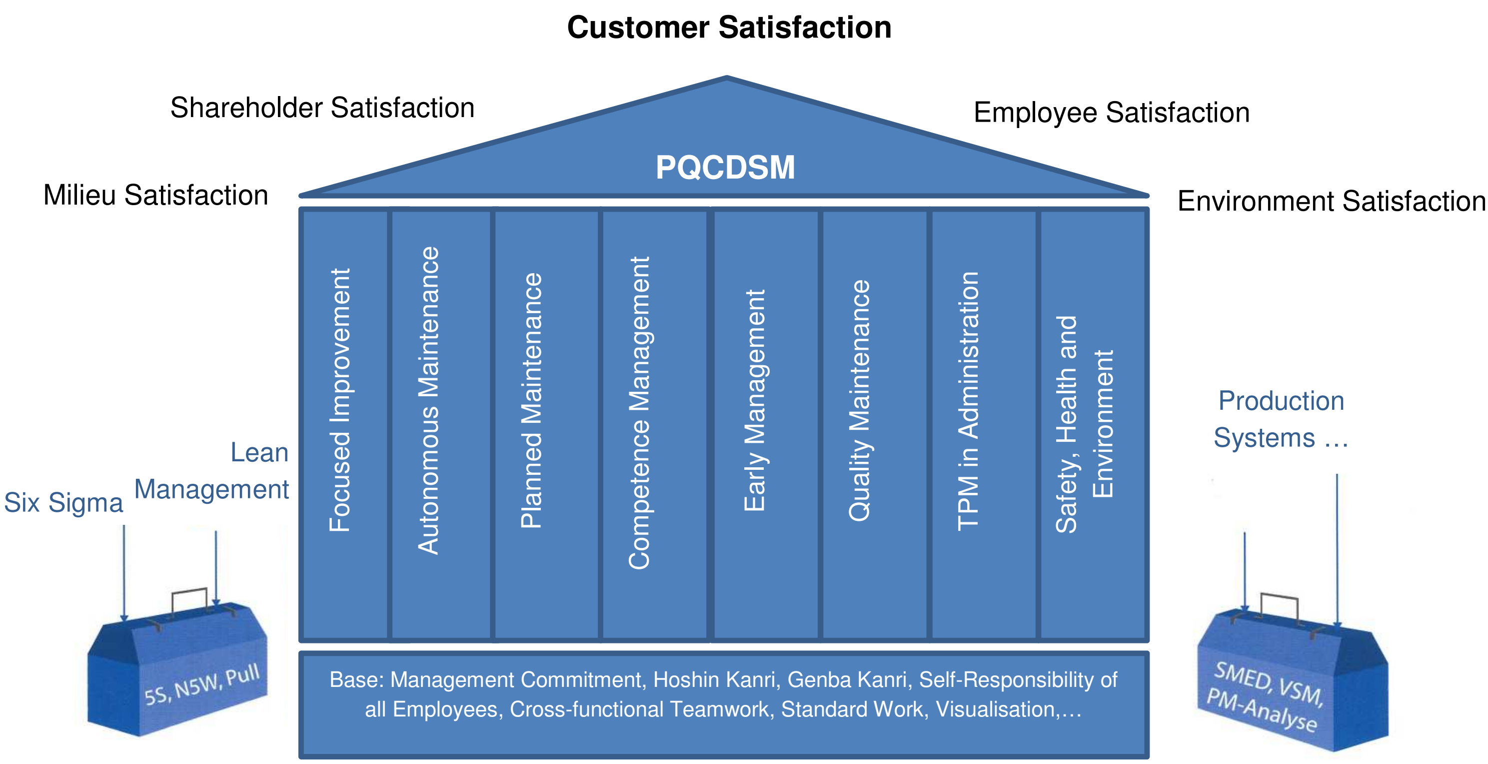


Figure 6: TPM in the Operational Excellence Reference Model (May & Schimek, 2009, p. 19)

1. Focused Improvement

This building block is also often called “continuous improvement process”. The objective is to maximize the efficiency and effectiveness of machines /plants, processes, as well as administrative procedures through eliminating of losses and waste. The basic idea is that a high number of small improvements have a greater effect on the process efficiency than a few comprehensive changes. Figure 7 illustrates the 16 different types of waste with all having different impacts in the productivity (source: (Shirose, 2005) according to (May & Schimek, 2009)). They are separated into three categories “machine/plant”, “employees” and “resources”. The focus is on technical and human aspects.

The first seven wastes impair the efficiency of the production facilities (source: (Shirose, 2005) according to (May & Schimek, 2009)). They directly affect the Overall Equipment Effectiveness (OEE), a key figure to identify and reduce machine losses. The OEE includes the parameters time, quantity and quality and makes them comprehensible for the production team; all parameters can be influenced directly or indirectly by the production team, hence, the production team can steer the OEE. The ideal machine runs continuously at maximum speed only producing products free from defects. This can never be achieved in praxis; therefore three areas of waste are distinguished:

- Availability: availability loss = time, where machine is available for production, but no products are produced
  Types of losses: malfunctioning, waiting time, line constraint (e.g.: no material is available)
- Performance: performance loss – machine is running but not at maximum speed
  Types of losses: short shutdown, reduced speed
- Quality: Quality loss – machine produces defective products
  Distinction: rejects, rework

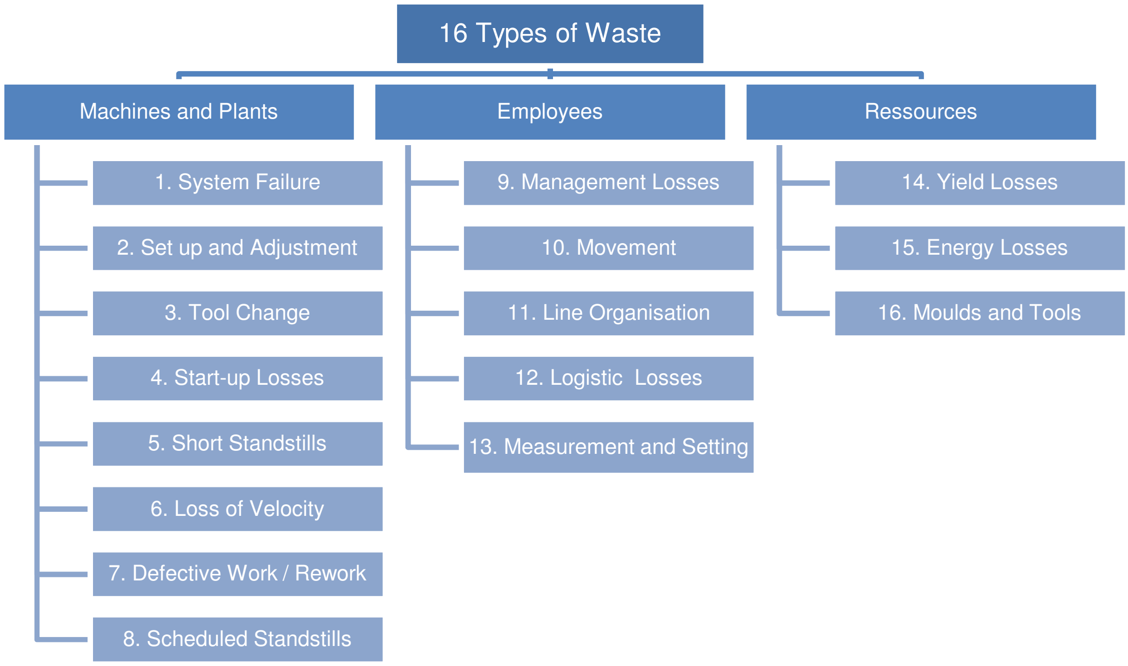


Figure 7: 16 Types of Waste (May & Schimek, 2009, p. 27)

The basis of the OEE calculation is the production time, meaning the available time minus the unplanned downtimes.

$$OEE = Availability * Performance * Quality \quad (5)$$

The OEE compares the machine only with its theoretical ideal. Primarily, it is a tool in the manufacturing sector supporting the production team to identify existing losses.

The step-by-step approach within the first building block is explained in the appendix.

(May & Schimek, 2009, pp. 18, 26-39)

2. Autonomous Maintenance

The objective of this building block is to avoid machine failures. All employees working at the production plant should take over responsibility and prevent malfunctions. The basic idea is a change in task sharing – specially trained production workers do parts of the maintenance work on their own. Difficult and complex repairs and measures are still done by the maintenance department.

The following conditions need to be fulfilled:

- Production workers understand the operation of the machine and plant.
- Appropriate training and education is provided.

- Concerning the maintenance work the responsibility of the different departments is clearly defined.
- The plant is maintained properly.
- Employees are trained in identifying failure and abnormalities on their own.
- The OEE and the productivity are continuously improved.

The recommended step-by-step approach can be found in the appendix.

(May & Schimek, 2009, pp. 18, 40-49)

3. Planned Maintenance

The objective is, equal to the second building block, to avoid machine failures. The basic idea is, to shut down the machines scheduled in order to do preventive maintenance work. In addition a proper management of replacement parts is implemented to maximize the availability.

Measures and activities:

- Maintenance with special tools
- Inspection using specific measurement tools
- Shut-Down Maintenance
- Time controlled maintenance
- Foresighted maintenance
- Maintenance with special attention to the operational safety (e.g.: heavy current, electronics)

Measurement of success:

- Mean time to repair (MTTR)

$$MTTR = \frac{Total\ repair\ time}{Number\ of\ failures}\ [\text{hours}] \tag{6}$$

MTTR is the average repair time required in case of unplanned shutdowns to restart the machine/plant. The repair time is not only influenced directly by the machine but also by the following components:

  - Coordination of a shut down: communication, approach
  - Identification of the root cause
  - Availability of personal

- Procurement of replacement parts and specific tools
- Start-up of the maintained machine

- Mean time between failures (MTBF)

$$MTBF = \frac{operating\ time}{number\ of\ failures}\ [\text{hours}] \qquad (7)$$

MTBF is the average operating time between two shutdowns.

Following measures can be taken to improve the MTBF:

- Analysis of breakdowns and failures
- Preventive maintenance: time controlled or foresighted
- Training
- Lubricant management

- No-Touch-Time (NTT)

The NTT is the period of time in which no operator activity is necessary.

The appendix provides the recommended approach for planned maintenance.

(May & Schimek, 2009, pp. 18, 20, 50-55)

4. Competence Management (Education and Training)

Education and training is a part of every building block in TPM. At the beginning, the level of knowledge of the employees is determined to determine the training requirement. The necessary competences cover functional, methodical and social aspects. These competences must be trained in different hierarchy:

- Functional responsibility is knowledge directly connected to executive activities (like knowledge of maintenance, care or the hydraulic system) but no special TPM-knowledge (like TPM basics, wastes or the OEE).
- Methodological competence is necessary to solve problems fast, structured and sustainably; team work is essential. Training should cover TPM basis, required aids and important tools.
- Social competence: the learning of soft skills is the basis for group work and team formation.

If these three competences mentioned above are trained sufficiently another competence is achieved, the action and implementation competence. The employee is able to implement the gained knowledge; this encourages the employee in analysing and solving even complex problems.

(May & Schimek, 2009, pp. 20, 56-59)

5. Early Management

The objective of this building block is to shorten start-up phase. 70 % of the problems occurring during commissioning or shortly thereafter are originated in the design phase.

Measures to achieve this objective include early cross-departmental planning of new product, processes and plants as well as early involvement of suppliers in the planning process. The development time and the implementation time of new products, processes and plants needs to be reduced and further the required maintenance work should be minimized.

The step-by-step approach within the fifth building block can be found in the appendix.

(May & Schimek, 2009, pp. 20, 68-71)

6. Quality Maintenance

The objective of the building block “quality maintenance” is the elimination of losses due to poor quality resulting in absolute customer satisfaction (including also internal customers).

Action contents:

- Setting of Quality standards
- Implementation of systems to detect defects early
- Systematic trend analysis
- Implementation of systems to prevent defects
- Systematic analysis of approaches for improvement
- Implementing a quality matrix
- Implementing so called zero-defect lines

- Follow the principle of Poka Yoke[1]

Common tools which are used in quality maintenance are explained in the appendix.

(May & Schimek, 2009, pp. 20, 21, 72-76)

7. TPM in Administration

"TPM in Administration" includes the application of TPM tools in non-producing sectors like purchasing, logistic or human resources.

Action contents:

- Analysis and elimination of losses in administrative processes
- 5S action (see Chapter 2.2.2.8)
- Implementation of a comprehensive time management
- Improvement of culture in meetings
- Analysis and improvement of all business processes in production, purchasing, human resources, IT, planning, controlling, etc.
- Active involvement of management
- Visualisation of key parameters (targets and results)

The step-by-step approach is contained in the appendix.

(May & Schimek, 2009, pp. 21, 76-81)

8. Safety, Health and Environment (HSE)

The objective of this building block is to have zero accidents. Activities to achieve this include analysis of risks and health hazards, detailed documentation of pollution sources, analysing the health situations of employees, implementation of action programs and monitoring, visualisation as well as regular communication between leaders and employees.

In occupational safety a detailed analysis of all potential sources for accidents is necessary. Furthermore, all incidents need to be documented; according to

---

[1] Poka Yoke (Japanese for mistake-proofing) is a method to eliminate defects caused by human errors. The process can be implemented within a wide range of options from machine forced quality (machines with limits, automatic shutdowns, warnings) to simple performance checklists. (Soin, 2012, p. 146)

Herbert William Heinrich, there is a relationship between the number of fatalities, the number of heavy accidents and the number of near misses and dangerous situations. The documentation can be done based on standardized questionnaires, this makes it easier to categorize, describe and analyse a certain incident. Tools like N5W-analysis (see Chapter 2.2.2.2) or Ishikawa diagrams (see Chapter 2.1.3.1) support the analysis while Pareto analysis (see Chapter 2.1.3.1) can be used for visualisation.

The goal in health is to prevent occupational illnesses. Therefore the focus is on developing working conditions based on ergonomic, psychological and climatic aspects. The involvement of employees, for example through forming of work groups dealing with special topics, is essential.

Other challenges in HSE are sensible topics like for example the absence rate. Employees often do not want to talk about such critical themes. One successful approach for dealing with issues like that is forming a special group of persons that addresses to these problems. This group comprises for example the work council but not leaders or managers; this circle of person can be additionally supported by appropriate institutions. Most important, anonymity must be guaranteed.

The cooperation of the company with appropriate competent authorities and institutions is especially important in environment protection where, for example, disaster response exercises are an essential part of the necessary preventive work.

(May & Schimek, 2009, pp. 21, 83-89)

A company will not start with all building blocks at the same time; usually, after successes have been achieved in the first four blocks, the company will continue with the remaining ones.

2.2.2 TPM Tools

2.2.2.1 5W Method

The 5W method helps to find the root cause of a problem. The detection is done by asking Why 5 times where the answer always forms the content of the next question. This scheme is repeated until the origin of the problem is found, in general, at least 5 times. An Example can be found in the appendix. (May & Schimek, 2009, pp. 94, 95)

2.2.2.2 N5W Analysis

The N5W analysis is based on the 5W method (see Chapter 2.2.2.1). The revision includes the interconnection of the 5 questions and the related answers in order to visualize the circumstances which caused the problem; the reviser is then forced to investigate every single cause.

(May & Schimek, 2009, p. 96)

2.2.2.3 5W1H Analysis

The objective of this method is the detailed and structured description of a problem and approaches to solve this problem.
Asked Questions:

- What: With which products/materials was the problem detected?
- When: When did the problem occur?
- Where: Where did the problem occur?
- Who: Is the problem connected to skills?
- Which: Is there a trend?
- How: How does the deviation from the normal state look like?

(May & Schimek, 2009, pp. 95-96)

2.2.2.4 Pareto Diagram

This tool is already explained in Chapter 2.1.3.1.

2.2.2.5 Ishikawa Diagram

This tool is already explained in Chapter 2.1.3.1.

2.2.2.6 Makigami

The objective of Makigami is the visualization of workflows in administration in order to analyse and optimize the operation. Non value adding activities are identified and minimized. (May & Schimek, 2009, pp. 99-101)

The basic procedure starts with the detection of the current state in a so called current-state-map followed by the development of the future-state-map. A detailed description including an illustration is provided in the appendix.

2.2.2.7 5W2H Method

This procedure helps to drill down into the problem by studying its effects.
Questions:

- Who: identification of effected individuals, processes, and products
- What: description of the problem – data collection, Pareto diagram (see Chapter 2.1.3.1).
- Where: Identification of the part or location where the problem occurs – use of photos, check sheets, or diagrams; checking if it is geography or demographic related.
- When: Identification of the time the problem occurs (e.g. during first or second shift operation, time of month or year).
- Why: why is it happening?
- How: What procedure was used to cause this to happen?
- How: How large is the problem? Is the process in or out of control?

(Soin, 2012, p. 111)

2.2.2.8 5S System

The 5S creates an environment where problems can be easily identified and corrected. Therefore, it is seen as the basis for good manufacturing practices. It helps to organize and clean the work environment and supports discipline in the workplace.

The objective of the system is the elimination of mess and waste in 5 steps:

1. Seiri = Sort and Organize
   The first step is to spate items that are required from those that are not used regularly. This means looking at excess furniture, tools, equipment, operating supplies (like chemicals), and WIP (work in process) inventory.
2. Seiton = Stabalize or Set in Order
   The goal is a so called “visual factory”, a clean, well-organized factory with little WIP, no visible rework and good signage of all activity. Good layouts of

equipment and processes as well as intelligent use of conveyor lines and storage racks help to maximize the utilization of factory floor space. Questions to be asked are “what is needed?”, “How much is needed?”, “Where is it needed?” “What’s the use of it?” (May & Schimek, 2009, pp. 101-103).

3. Seiso = Shine

   The third stage includes thoroughly cleaning areas and equipment as well as ensuring a regular cleaning process in the factory. The involvement of all employees is essential as cleaning becomes part of their daily activities. The cleanup and shine process helps to uncover many issues and problems. It is important to determine the right method, frequency and ownership of cleaning for each item. In addition, proper tools need to be provided.

4. Seiketsi = Standardize

   The system must be maintained via standards.

5. Shitsuke = Sustain

   The fifth step is probably the most difficult. As people often tend to resist change and revert back to bad habits, specific objectives need to be set to maintain the 5S momentum. Once started, a 5S system needs to be promoted, encouraged, and cultivated. Therefore, conditions to sustain a 5S system include the involvement of the senior management via meetings and audits, the encouragement of all employees, the training of new employees as well as regular re-training of employees. The company’s top management must set the expectations and benefits of the 5S effort. Hence, it sets up a 5S committee which includes representatives of all departments and helps to drive the process.

   Improvements identified in a 5S audits should be implemented and in order to motivate the team, results should be published and maybe also a reward system for good work established. The recognition process has to be transparent and communicated to all employees.

(Soin, 2012, pp. 10-19, 26)

2.2.2.9 Audit

The objective of audits is to ensure sustainability and to suggest continuous improvement. They can be applied during all building blocks of TPM. To guarantee their effectiveness they should be challenging for employees who are motivated to pass them as well as for leaders who are animated to conduct them.

An approach in 3 steps is recommended. At the beginning, the employees at a machine or plant audit themselves, meaning they are doing a self-audit using a form which includes certain criteria. Through this audit they need to achieve minimum 90 % of the points in order to go on to the next step. The second audit is conducted by the direct supervisor. If 85 % of the points are achieved, the last audit can be requested. The final audit is conducted by the plant manager, general manager or the head of department. If the employees achieve 80 % of the points the audit stage is finally determined; badging this audit stage for example via stickers has resulted in positive feedback. The presence of the TPM coordinator or the person responsible for a certain building block is recommended during the second and third step.

(May & Schimek, 2009, pp. 103-105)

Chapter 2.5.3.1 describes the classification of quality audits according to the ISO International Standards.

2.3 Lean Management

The term “lean” comes from the popular MIT-study “The machine that changed the world” by Womack, Jones and Roos of the year 1992. The authors analysed the background of the striking advantages in production and quality of Japanese automobile producers: doubling of results while halving the efforts. This revolution was called “Lean Production Management (LPM)”.

The goal of Lean Production is the prevention of defects and the elimination of waste. Therefore it is necessary to define processes and process owners and to summarize them to process chains connected via internal and external customer-supplier-relations. Each process owner is responsible for optimal process control and defect-free quality. Lean structures lead to reduction of inventory and buffers and provide the customer the right amount at the right place at the right time; They also include re-orientation of processes like Business Reegineering (see Chapter 2.5.3.1). The term “Lean Production” has become a corporate design philosophy resulting in an increased competitiveness by involving all levels of the company, from the management down to the production floor.

(Brunner, 2008) summarizes the 6 basic ideas of Lean Management as follows:

- Continuous material flow: Just-in-Time and Kanban (see Chapter 2.1.1)
- Effective Quality Management everywhere in the company
- Simultaneous Engineering: fast and safe development and implementation of new products
- Proactive Marketing: Wining and keeping customers
- Strategic Capital Investment
- Company similar to a family: Company involved into society

(Brunner, 2008, pp. 57-59)

As the basics of Lean Management can be described in several ways, Figure 8 illustrates the lean management toolsets and processes allocated to different application areas.

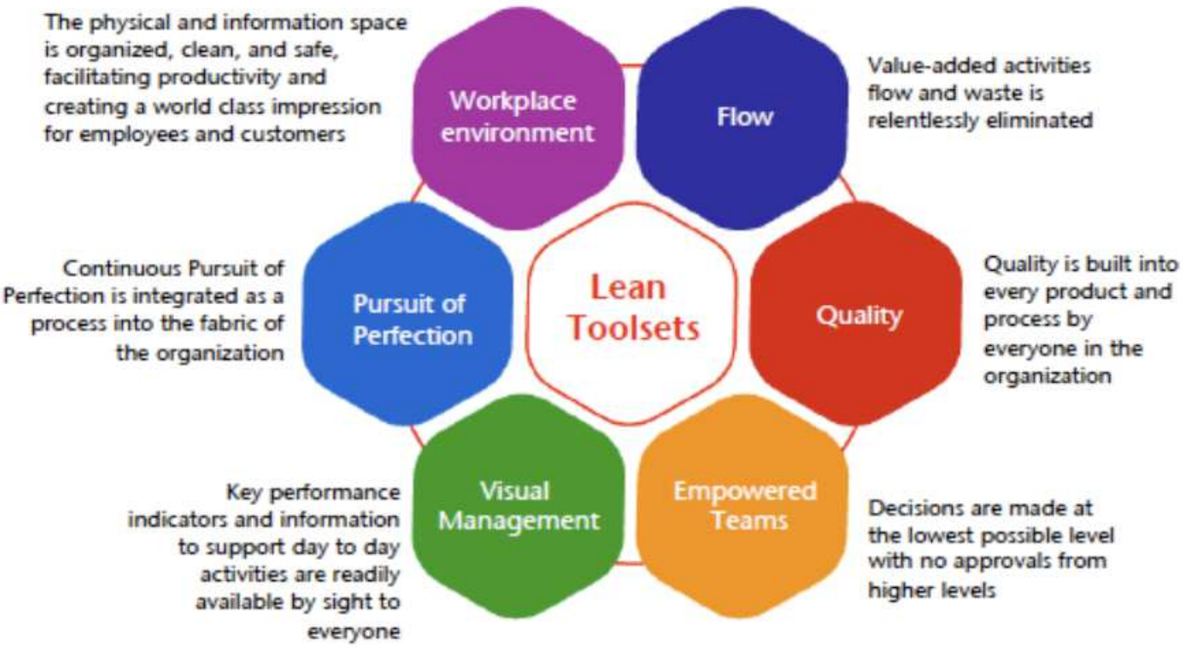


Figure 8: Lean Management Toolkits (Advantage Business Media, 2014)

A clear distinction between Lean Management and other approaches of Operational Excellence is hardly possible; hence, further aspects of Lean

Management as well as more detailed concepts and tools used to implement lean structures are included into subchapters of Chapter 2.

2.4 Planning Process

"*The future can be shaped through careful planning and execution.*" (Soin, 2012, p. 193)

2.4.1 Hoshin Kanri Planning

Planning is required in every organization. A good planning process will be a standard process including a long range, strategic plan and annual plan. (Soin, 2012, p. 194). Hoshin Kanri is Toyota's approach to the challenge of coordinated, directed action across the company. Literally translated, Hoshin means "compass", or "pointing the direction", while Kanri means "management" or "control". Hoshin Kanri is the process of setting goals and targets and, most important, the concrete plans for reaching those targets. Together with daily management and Kaizen (see Chapter 2.1.3), it is part of the company's commitment to continuous improvement. (Liker & Convis, 2012, pp. 148, 149)

2.4.1.1 The Planning Process

The Hoshin Kanri process follows the PDCA cycle (see Chapter 2.5.2).The start of the process is the review of the following items:

- Company and organization vision: the vision is reviewed, discusses, updated, or improved.
- Long-range plan: after establishing the long-range plans, they are reviewed and relevant strategies are incorporated into the annual Hoshin plan.
- Specific customer inputs: customer inputs, issues and needs, collected from meetings, visits, or letters, are reviewed.
- Current economic situation: after reviewing the necessary response to the economic situation is discussed and planned.
- Review of the previous year's plan: the lessons learned will have an influence on the upcoming year's plan.

Figure 41 in the appendix shows the flow in Hoshin planning. The chart illustrates the sequence of activity for generating a Hoshin and Daily Management plan.

(Soin, 2012, pp. 194, 195)

Based on the items, mentioned above, a list of key issues is formed to prepare the Hoshin plan. Typically, the entity General Manager will prepare the annual Hoshin plan providing broad objectives, strategies and performance measures. Afterwards, the next level managers - like marketing, finance, research and development, operations or manufacturing, and quality - will develop a more specific plan referring to discussions with their department managers. Further, the department managers will prepare an implementation plan. This process of management discussion is often called "catch-ball" – coming from the term used in baseball: where outfielders may throw the ball to the pitcher and both players must ensure that the ball is caught successfully. In Figure 41 in the appendix the catch ball symbol of two closed circuits denotes management discussions. (Soin, 2012, pp. 195, 205) In general, the catch-ball process is characterized by a lot of discussion and planning because high-level goals are cascaded down through the organization and turned into more specific, actionable plans (Liker & Convis, 2012, p. 167).

The movement down the organization can be illustrated as a big triangle with the broad goals at the top leadership level and concrete actions taken and measured by working teams (see Figure 9). Vertically, goals cascade down the organization leading to innovative thinking how to achieve the goals. Horizontally, different functions coordinate their plans in order to achieve the broader goals. However, this chain is only as strong as the weakest link in the chain. While the maybe ten-year-vision is definitely set at the top, it is based on input and information from throughout the company. So, the process can be said to be bottom-up as well. (Liker & Convis, 2012, pp. 149, 160)

Referring to Figure 41 in the appendix, the next step in process planning is launching the plan. The plan is often presented during a facility wide meeting; at a minimum the plan should be presented to all management and supervisory staff. What follows are the Hoshin plan reviews which are held regularly – monthly or quarterly. If everything is on track, it's business as usual. Otherwise, plans have to be corrected and the root causes of the problem need to be found. The annual review is done during the last month of the planning year in order to set the stage for staring the next planning cycle. (Soin, 2012, pp. 195, 197)

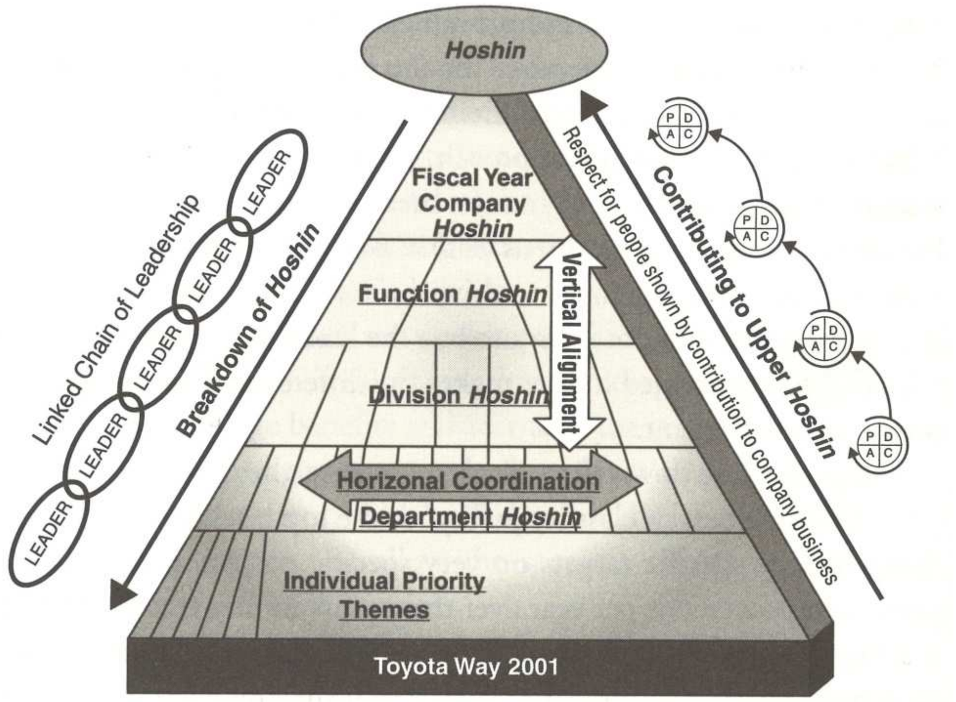


Figure 9: Hoshin Kanri: Direction Mangement Vertically and Horizontally (Liker & Convis, 2012, p. 150)

2.4.1.2 Annual Hoshin Plan

The Annual Hoshin Plan summarizes the breakthrough objectives for the entity or organisation. Accomplishing these objectives often requires more than the ordinary sustaining effort and may also involve the collaboration of several departments.

Generally, the plan comprises 4 elements (see Figure 42 in the appendix):

1. Objective: this describes the aim to be achieved – an aggressive or breakthrough statement.

   Before preparing objectives, an issue list should be developed based on the review of the company's vision and long-range objectives, specific customer inputs, the current economic and market situation as well as new areas or direction for the company. In addition to these reviews, successes and failures of the previous year are analysed as well. The objectives will determine the direction in which the company is heading. As a guide, the plan should cover four categories:

- Quality (Q): including customer satisfaction and product/process quality
- Cost (C): all costs including administrative expenses, manufacturing costs and productivity issues
- Delivery (D): including new product design introduction, R&D and manufacturing product commitments, and delivery of products to the customer
- Education (E): including human resource training and education

The concept of QCDE prevents that something important is overlooked. It doesn't mean that a number of four objectives is suggested but that all four categories are considered. Experience has shown that an individual manager can only focus on one or two objectives in a large organization. So in fact, the number of objectives should ideally be limited to no more than two. This can be achieved by focusing only on "breakthrough" objectives. Therefore a hierarchy in setting objectives is important.

2. Target or Goal: this is a broad indicators measuring accomplishment of an objective; it must be quantifiable and established for every objective.
3. Strategy: this describes the procedure of achieving the goal

   An average of three to five strategies per objective is recommended where the actual number depends on the complexity of the objective. There are two common techniques for generating strategies:

   The first method starts with a list of the objective and its goals. In the next step, strategies which can help to achieve the goal are collected by brainstorming; this requires the understanding of constraints, roadblocks, technology need, and success factor. What follows is the ranking of the choices according to its contribution towards limiting factors like fulfilling the objectives, its cost, or its feasibility. The choices are then selected based on the ranking and after discussion with relevant staff.

The second method is more scientific and data driven. After the objective and goal is determined, a cause and effect diagram (see Chapter 2.1.3.1) is prepared – where the effect is the selected objective. The causes are determined by brainstorming and further, the most likely causes affecting the objective should be identified and verified with data. At the end, these verified causes can then be converted into strategies.

4. Performance Measure: this determines the progress or completion of a strategy; it consists of a statement and number indicating the target to be achieved.

Two types of performance measures exist (Soin, 2012, pp. 199-207):

- Result-oriented or end-of-process performance measure: to measure the outcome or desired result of the strategy; for example an action plan, increased sales or higher production line yield.
- Process-oriented on process tracking performance measure: to measure the progress of the strategy; for example phased results, interim action steps, or targets for each step of process.

2.4.1.3 Daily Management Plan

The Daily Management plan (sometimes called Business Fundamentals plan or KPI - key process indicators) focuses on controlling or “keeping the house in order” through monitoring and managing the day-to-day metrics – for example, cost controls, employee morals, process of selling or manufacturing a product, or controlling a product or process. It tracks annual repetitive tasks. The final plan should have both Annual Hoshin and Daily Management plans.

(Soin, 2012, p. 195)

The appendix explains the elements as well as the recommended format of a Daily Management plan (see Figure 43).

The Daily Management plan (or KPIs) should be displayed at each department or production line. The relevant metrics should be posted on the production line to give real-time information to the operators, supervisors, and engineers on their daily performance. As a result the daily progress, issues and countermeasures taken can be tracked. (Soin, 2012, p. 217)

2.4.1.4 Implementation or Project Plan

After Hoshin plans have cascaded down several layers of management, at the last layer, there needs to be an implementation plan. This plan summarizes detailed steps necessary to accomplish a strategy in the Hoshin plan. Typically, implementations plans are prepared by the employees who must ensure that the plans are successfully completed – at lower management levels or by professionals. The implementation plan format is illustrated in Figure 44 in the appendix. In the plan each strategy from Hoshin plan is listed with the corresponding performance measures. In addition, the implementation of each strategy should be planned in detail – there are two choices:

- Gantt chart format: a list of all steps needed to be done to complete the strategy including a timeline
- PDCA format: a list of all steps in the PDCA cycle (see Chapter 2.5.2)

Finally, every Hoshin strategy ends up as a detailed implementation plan with owner and timeline. This is the evidence that the Hoshin plan has cascaded down into actual work. As a result the process can be measured through checking against the timeline and identified deviations can be corrected.

(Soin, 2012, p. 213)

2.4.1.5 Putting All the Plans Together

Figure 10 shows the cycle of activities included in the discussed planning process. At the beginning are the company's vision, economic factors, and customer and market requirements. The process continues with the preparation of the Hoshin plan, Daily Management plan, and the Implementation Plan. It finishes with regular reviews of progress. The critical step in this cycle is the preparing of the implementation plan; here all the best laid plans will culminate into results. As the budget must support the planned activity, the annual budget and sales targets must be tied closely to the planning process.

(Soin, 2012, p. 222)

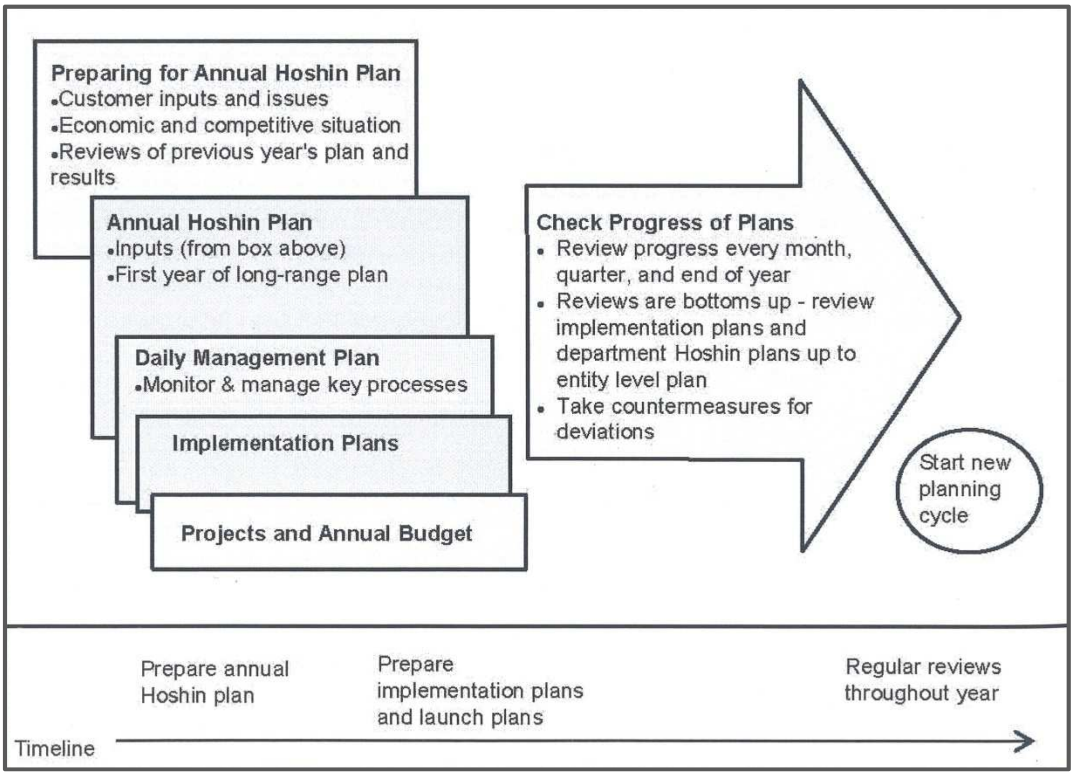


Figure 10: Putting all the plans together (Soin, 2012, p. 222)

2.4.2 Theory of Constraint

The theory of constraints (TOC) was expounded by Dr. Eli Goldratt. In his business book "The Goal" he discusses the concept of the system constraint that hinders progress and profit in a business. The theory behind "The Goal" derives from the manufacturing theory of managing Takt time (see Chapter 2.1.1.2). In order to tackle bottlenecks and speed production the weakest link or slowest time in a series of manufacturing steps need to be removed; this is an ongoing cycle. Goldratt expands this principle to the business organization. In TOC, businesses are viewed as systems rather than a set of processes; these systems consist of company processes, policies, and the entire eco-system including customers, distribution channels, government policy, suppliers, and competitors. According to Goldratt, business leaders often fail in focusing on the right goals. For example, if management focuses on cutting cost instead of increasing "throughput" – depending on the focus problem solving requires a different frame of mind. However, the point is to find the constraint and resolve it by using TOC planning.

(Soin, 2012, p. 225)

Using TOC for Business Planning

Typically, two different situations can be found in a business. In the following, both situations are reviewed.

> Situation A: the business is going well – in this case management must create a plan to keep profitability growing. Future constraints need to be predicted and resolved. The tool for developing the resolution plan is called "prerequisite tree"; it is a cause and effect analysis done "backwards from the future".
>
> Situation B: the business is in trouble – in this case management must create a plan to get back growing profitably. Constraints must be identified and resolved.

In both situations, the next step in TOV planning is to establish the goal. It should be the primary goal for the entire company – in a profit business the only goal is having throughput and making money.

In situation A this is followed by the determination of critical success factors and necessary conditions. Critical success factors must be achieved to reach the goal, for example customer satisfaction or product quality, while necessary conditions are the measurable attributes of these critical factors, like "ranked in top 3 vendor list" for customer satisfaction. In addition, the obstacles that prevent the business form reaching the necessary conditions need to be determined, for example poor customer service. In this phase, the root cause can be found through using a "logic tree" of cause and effect, similar to the Ishikawa diagram (see Chapter 2.1.3.1).

In situation B the establishing of the goal is followed by the determination of the constraint. This is done by rigorous cause and effect analysis through the system to ensure that the true root cause is found. Further the obstacles that prevent the company from eliminating the root cause must be identified in order to develop a proper plan.

The next steps for both situations are to define the plan in order to overcome the obstacles, to execute the plan while everything is subordinated and finally, to review the progress and to fine-tune the strategy based on planned milestones and towards meeting the goal. Goldratt recommends a cyclical approach (like the

PDCA cycle described in Chapter 2.5.2). This means that after achieving the goal the next constraints will appear somewhere else, and the cycle is started again.

(Soin, 2012, pp. 225-227)

Comparison to Hoshin planning

The steps described above look a lot like Hoshin planning but there is one major difference: TOC planning only emphasizes one goal while Hoshin Planning allows more than one.

A possible combination of both systems is called “Super Hoshin” plan. In case of merging the two systems, the efforts would be focused with one goal which is centred on increasing revenue or profit for the business. Therefore customer satisfaction or quality won’t be business planning goals but critical success factors or necessary conditions to achieve higher profit; they are identified through the steps of TOC planning and must be supported by Kaizen projects. The Hoshin plans will be merged under one goal but to ensure good process implementation plans and regular reviews will still be needed.

(Soin, 2012, pp. 227-229)

2.5 Quality: Improvement and Control

2.5.1 The Kano Model

In literature, numerous definitions of quality can be found, for example: *Products and services that meet or exceed customers’ expectations*. The key words here are exceeding customer expectations.

The Kano Model describes what is required to ensure high customer satisfaction. Both, reactive and proactive activities are important:

- The reactive approach helps to understand and resolve challenges and problems arising from current product and services. Therefore, reactive activities include a system to manage and resolve customer issues and complaints as well as competitive benchmarking.
- The proactive approach is essential for influencing and creating new products and services. Proactive activities include the development and

implementation of “Attractive Quality” or the “Total Product or Service” concept.

The idea of “Total Product Concept” was provided by Harvard Business School Professor Ted Levitt: it comprises four concentric circles – the inner one is labelled “generic product”, next comes “expected product”, then “augmented product” and the last without boundary is “potential product”. In manufacturing, the “generic product” is a product which is achieved by every manufacturer but the customer appreciates additional services. Hence, the “expected product” can also include excellent safety record, excellent work environment, ability to prevent potential quality or manufacturing issues, working with and managing processes per product safety and ISO requirements, continuous cost reduction, and improving customer satisfaction. The “augmented product” can additionally include the ability to forecast and manage supply and demographic issues, manage attrition with no impact to product or process, direct delivery to end-customers, as well as a full review of manufactured products to improve productivity, quality and cost. “Potential product” finally means total product and process management with no further R&D or customer involvement required, complete handling of reverse logistics until product obsolescence, and design services. The customer wants a total product, not just basic manufacturing capability.

Dr. Noriaki Kano has proposed a two dimensional model of quality (source: (Kano, 1984) according to (Soin, 2012)): “Must be Quality” and “Attractive Quality”. Figure 11 illustrates the so called Kano Model, where the vertical axis represents the customer satisfaction level or performance and the horizontal axis represents the degree of availability of the characteristics.

“Must be Quality” is the aspect of a product or service expected by the customer. If this aspect is not fulfilled, the customer will be extremely dissatisfied; it is the minimum acceptable standard. “Attractive Quality” is the aspect of a product or service exceeding current needs. The customer does not expect this quality or value but receives it as a bonus. If he doesn’t get it, he has no comment. With time, “attractive quality” often becomes “must be quality”, for example the anti-lock braking system which is an essential quality item in most of today’s cars.

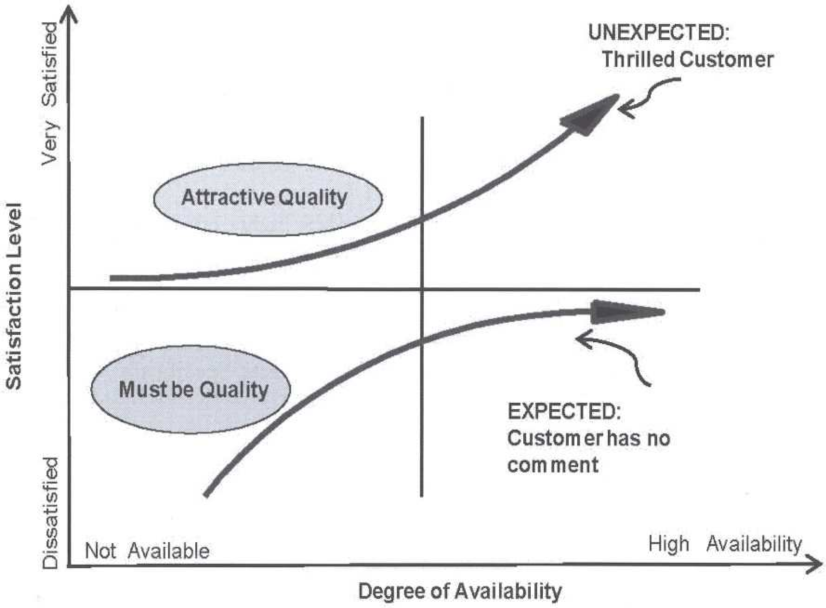


Figure 11: The two dimensions of quality (Soin, 2012, p. 104)

A well designed product or service has both dimensions of quality as this strongly influences the customer's buying decision and satisfaction. Based on these dimensions, a customer satisfaction model can be created; the first step is to understand the Voice of the Customer, meaning the quality characteristics needed by the customer. If the Voice of the Customer is understood, it can be translated into quantitative terms in the product or service offering.
(Soin, 2012, pp. 104-107)

2.5.2 The PDCA Cycle

The PDCA (Plan, Do, Check, Act) cycle is a systematic, data driven, analytical, and scientific process used to improve or manage products, services, or processes. It is illustrated as a circle or wheel to indicate the ongoing process of continuous improvement (see Figure 12). Originally, the PDCA cycle was developed by Walter Shewhart, the originator of Statistical Process Control (see Chapter 2.5.5). Further, it was popularized by Dr. Edwards Deming (source: (Deming, 1982) according to (Soin, 2012)) and is therefore often called the Deming Cycle.

The PDCA cycle is illustrated in Figure 12 and is stated as follows:

Plan: Determine goal and methods to reach the goals (Step 1 to 3)

Do: Educate employees and implement change (Step 4)

Check: Check the effect. If the goals have not been achieved return to the Plan stage (Step 5)

Act: Take appropriate action to institutionalize the change (Step 6 and 7)

(Soin, 2012, p. 107)

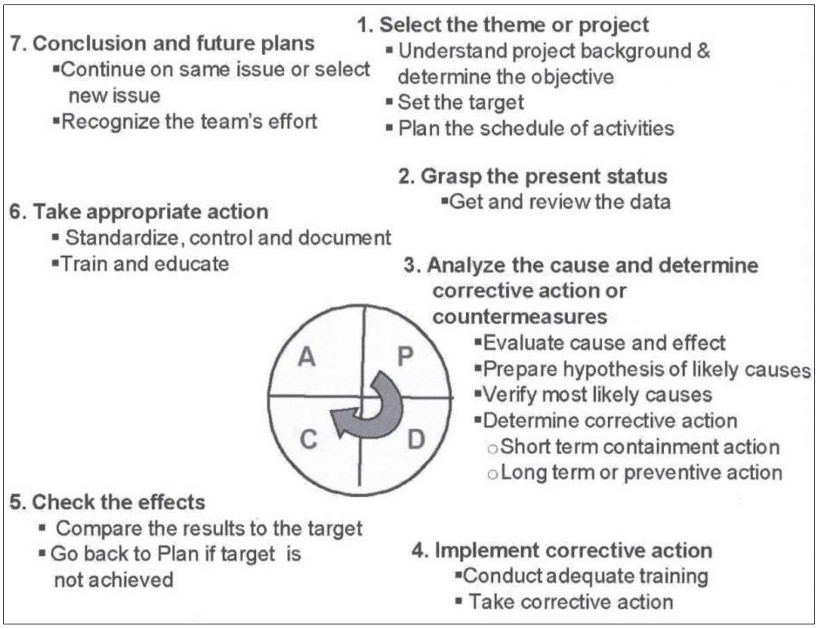


Figure 12: The PDCA Cycle (Soin, 2012, p. 110)

The appendix contains the detailed description of the PDCA cycle including the tools required for each step.

2.5.3 Total Quality Management (TQM)

The objective of Total Quality Management (TQM) is the total satisfaction for both the internal and external customer; key aspects are the prevention of defects and emphasis on quality in design. An explanation of the term TQM can be found in (Ho, 1995, p. 4):

- Total: Everyone associated with the company is involved in continuous improvement (including its customers and suppliers if feasible).
- Quality: Customers' expressed and implied requirements are fully met.
- Management: Executives are fully committed.

The four pillars of TQM

Pillar 1: Satisfying Customer

The aim is not just to meet customer requirements but to achieve customer satisfaction. Customer requirements may include availability, delivery, reliability, maintainability and cost effectiveness. Hence, the price of quality is the continual examination of the requirements and the ability of the company to meet them. Only the smooth functioning of the internal customer-supplier chain will ensure that quality is included in each stage of the business for the benefits of the external customers.

Pillar 2: System/Process

The initial building block of TQM is the establishment of a quality management system such as ISO 9000 series (see Chapter 2.5.3.2); this ensures that preventive measures are in place, and the culture of continuous improvement exists to enable processes to deliver quality products and services.

Pillar 3: People

Key elements of TQM are employee development and participation, starting at the top and permeating via a chain of customer/supplier relationships throughout the whole organisation and beyond. Hence, management commitment, reining, teamwork, leadership, motivation, etc. play a complementary role in establishing a total quality environment.

Pillar 4: Improvement Tools

For TQM, it is vital to recognise the need for continuous improvement. This will be supported by the ISO 9004-4 Guideline for Quality Improvement (see Chapter 2.5.3.2).

(Ho, 1995, pp. 50-52)

Samuel Ho also states the need for a full application and integration of 4Cs of TQM: Commitment to quality work, Competence to build quality into a product or service, Communication to achieve mutual understanding and Continuous Improvement (Kaizen, see Chapter 2.1.3) as a driving force to excellence. (Ho, 1995, pp. 52-56)

2.5.3.1 Business Process Re-engineering (BPR)

Business Process Re-engineering is a management process to re-define the mission statement, analyse the critical success factor, re-design the organisation structure and re-engineer the critical process with the aim of improving customer satisfaction. In simple terms, it is the radical redesign of business as a whole or individual work processes. The contrast to continuous improvement, BPR challenges the need for the current process in the first place. If the process is indeed needed, BPR produces breakthroughs in process design. Its primary thrust is to alter processes, not to change an organisation's culture. Continuous improvement and BPR often occur separately. While each approach delivers benefits of its own, experience has shown that when they are done simultaneously the beneficial effects are magnified.

Before initiating process improvement efforts some strategically important questions need to be asked covering three areas:

1. The nature of the business
2. The critical success factors
3. The processes to be improved

The answers to these questions will help to determine whether and where process re-engineering should appropriately replace continuous improvement. Normally, re-engineering is required if:

- The process is strategic.
- There is a high correlation between customer defined key success factors and the company's weaknesses.
- The process has a high price of non-conformance attached to it.
- The process may soon become strategic due to change.

As quality depends on the value of the service delivered to the customer BPR includes identifying how well service performance is being achieved. In organisations which listen to their customer and take actions from what they learn, change happens quickly. Through the accumulation of service performance data key issues can be identified and change instigated. The Velocity Ratio is one measure of the dynamics of change, defined as:

$$Velocity\ Ratio = \frac{Value\ Added\ Time}{Total\ Elapsed\ Time} \quad (8)$$

Velocity Ratio is a critical performance measure, estimated to be around 0.05 to 0.07 for many manufacturers (source: (Wong, 1995) according to (Ho, 1995)). This means, that 5-7 % of time is spent doing things the customer is paying for. Both BPR and Kaizen (see Chapter 2.1.3) can help; BPR focuses on the basics of the problem and tackles it in a radical way, while Kaizen prefers many small steps to achieve the objective. World leaders therefore should apply Kaizen, whereas organisations are far behind the world standard in some or all processes should consider BPR. (Ho, 1995, pp. 100-103)

Table 1: Kaizen vs. BPR (Ho, 1995, p. 102)

		Kaizen	**BPR**
Starting Point		No competitive pressure to take action immediately	The company has the resources to handle the transformation
Common Point		Focus on customer	
Differences	Strategy	Continuous in small steps	Infrequent big leaps
	Approach	Start with what is available	Starting with ‘clean sheet’
	Methodology	Change what is already there	Forget and start again
	Process	Simultaneous processes	Selective, one at a time
	Value Added	Elimination of non-value added processes	Minimising inputs, adding value to outputs
	Human Resource	People involved in operations	BPR project team
	Technology	Less technology required	More technology required

BPR uses recognised techniques for improving business results. It starts off with a well understood vision including a clearly defined Corporate Mission Statement. Through breaking down internal barriers arising from line organisation, BPR leads to cross functional teamwork within the entire organisation. The work focus is not on managing functions but on managing processes. Therefore process owners, accountable for the success, need to understand how their individual work affects customer satisfaction.

The aim of BPR is to increase the value of the products and services to the customers. Value Engineering (VE) helps to achieve this goal. Value is defined as the ratio of the output (functions) of the process to its input (costs). So VE is the process to improve the value of goods and services, hence it is often called Value Analysis or Value Added Analysis.

$$Value = \frac{Functions}{Costs} \tag{9}$$

(Ho, 1995, pp. 103, 104)

BPR in the Service Industry

Traditionally, quality has been related to the manufacturing industry. Improvement in technology and automation in the last century caused that the workforce have shifted towards the service industry in both developed and developing countries. As this trend will continue it is essential to understand the special characteristics of quality as applied to the service factor. The challenge is to deal effectively with customers. Usually, customer standards are vague, transitory, and changing. Therefore, the challenge of service is translating customer needs such as timeliness, cleanliness, and friendliness into service standards.

Many service organisations used the manufacturing model approach and profited by it. The competitive advantage in the service organisations lies in its quality leadership in the market place. The major issue is the way the service is delivered by the front-line person. For example, McDonald's is fully aware of this; make the hamburger efficiently, with low skill and minimum pay, and then market it heavily. *The most important thing about intangible product is that the customers usually do not know what they are getting until they don't get it.*

(Ho, 1995, pp. 104, 105)

2.5.3.1.1 Best Practice Benchmarking (BPB)

Successful companies around the world in all sectors of business use Best Practice Benchmarking in order to become as good or better than the best in the world. To achieve profitability and growth it is essential to compare the business not just to the previous year's performance but also against the best measurable.

BPB is done in many forms but it will always involve:

- Determining the difference in the customers' eyes between an ordinary and an excellent supplier.
- Setting standards in each of the areas according to the best practice.
- Finding out how the best companies meet these challenging standards.
- Applying both the experience of others and the own ideas to meet the new standards – and, if possible, to exceed them.

At the end, BPB offers a better understanding of customers and competitors, fewer complaints, reduction in waste, reduction of quality problems and reworking, faster awareness or important innovations and as a result it leads to increased profit and sales turnover. Benchmarking needs to be continued to keep up with the improvements of others. At the same time the best practice of the company also needs to be improved using ideas generated by the employees.

The process of BPB is explained in the appendix.
(Ho, 1995, pp. 114-116)

2.5.3.1.2 Total Quality Marketing (TQMar)

TQM includes applying Total Quality to all aspects of management; hence, marketing function (but not exclusively marketing department) is also charged with the objective to search for real customer needs. Identifying the needs must be seen as the first step towards BPR and is not only a responsibility of the marketing department as everybody should be involved in this process. This approach is often called Total Quality Marketing (TQMar) (source: (Witcher, 1990) according to (Ho, 1995)).

Modern marketing considers the customer in all its working and operations. The marketing concept exceeds market segmentation and targeting. A truly marketing oriented management must fulfil three related conditions:

Condition 1: The company's strategy must be externally focused on customers in all aspect of organisation and operation.

Condition 2: The company's operations must be co-ordinated and matched with the needs of target customers.

Condition 3: Everybody who works for the company must participate in a total marketing environment.

(Ho, 1995, pp. 120,121)

The process of TQMar is explained in the appendix.

2.5.3.1.3 Total Quality Purchasing (TQPur)

In general, the development of products can be classified into pre-development and post-development stages. Purchasing should be involved in the pre-development stage of new product or projects; this will result in suggestion for product, materials, and/or design alternatives. In addition, purchasing should ensure that the ordered goods are delivered according to specifications in the post-development stage of new products or projects. Hence, Total Quality Purchasing (TQPur) is the organisation-wide participation in the improvement of the logistic process to meet the needs of the customers.

In manufacturing firms, over half of the cost of the final product comes from purchasing. In contrast, for services organisation it is mostly seen as a low profile activity. In fact, it is of no less importance than in manufacturing, as the recruitment of human resources can be considered as part of the purchasing function.

TQPur has to adopt a new strategy of operation with focus on quality rather than price. Additionally, quality has become the most important factor in the selection and evaluation of suppliers. Purchasing professionals are responsible for improving supplier relationship and quality; this includes supplier certification, reduction of supplier base by moving towards single sources of supply, investment in the training and support of suppliers, involving suppliers in the product design, and sharing information and rewards with suppliers.

(Ho, 1995, pp. 125-127, 129)

2.5.3.2 The ISO 9001 Quality Management System (ISO)

The International Organisation for Standardisation developed the ISO 9000 series, a family of quality management and quality assurance standards comprising of 17 standards. Out of these 17 standards, only the ISO 9001, ISO 9002 and ISO 9003 are quotable standards, meaning, they can be audited against; the other standards are guidelines only. ISO 9002 and ISO 9003 are sub-sets of ISO 9001.

A definition can be found in the Scope of the ISO 9001: 1994: ISO 9001 is the "*Quality systems – Model for quality assurance in design, development, production, installation and servicing. It is the most comprehensive model of quality systems offered by ISO."* The requirements specified are aimed "*primarily at achieving customer satisfaction by preventing nonconformity at all stages from design through to servicing*." ISO 9001 provides a comprehensive approach to documenting quality processes and assessing their performance. ISO 9001 requirements are complementary, not alternative, to technical (engineering) standards' requirements.

ISO 9004-4:1993 is the Quality management and quality system elements – Part 4: Guidelines for quality improvement. It includes suggestions for effective quality management and supports organisations in developing their quality system.

ISO standards provide benefits to both the company and the customer. Through reduction of waste and re-work or re-check the company increases its productivity, efficiency, profitability and performance. Quality image and trust is established resulting in marketing advantages. The customer benefits in terms of increased fitness for use and satisfaction; he saves time to recheck the work done because of the developed confidence and trust.

(Ho, 1995, pp. 48, 176, 178, 179)

Quality Audit

Definition to ISO 8402:1994, Quality Audit is *a "systematic and independent examination to determine whether quality activities and related result comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives."*

Quality audits can be classified into three different types:

1st Party Audit – also known as Internal Quality Audit.

An ISO 9000 firm (registered or to be registered) does this regular quality audit internally to control the effective implementation of the quality management system. It is a continuous process, done at least once every six months by a few trained people from each department; the auditing function should be undertaken by personnel independent of the tasks to be audited.

2nd Party Audit – also known as Vendor Quality Audit.

In a Vendor Quality Audit, a firm audits its suppliers. The audit should be carried out according to the purchaser's quality manual and the procedures should be communicated to the suppliers well beforehand. Normally this type of audit is only required if the suppliers are not registered.

3rd Party Audit – also known as Adequacy, Compliance or Surveillance Audit.

This type of audit is done by a certified agency. An Adequacy Audit is a mock audit which takes place previous to the actual audit. The Compliance Audit is then the actual audit. After the firm has already obtained the ISO 9000 certification, the Surveillance Audits are carried out for reasons of control and in order to renew the certificate annually.

(Ho, 1995, pp. 181, 182)

Chapter 2.2.2.9 describes the necessity of audits in Total Productive Management (TPM).

2.5.4 Six Sigma

Six Sigma is a method for managing project which combines proven elements of quality management. The objective is the reduction of deviations and cycle times for products, processes and any kind of transactions which are critical for customer satisfaction; in addition it helps to increase the level of use and the efficiency of all input factors. The concept Six Sigma characterized by statistical criteria and requirements has become a new philosophy of quality management and is meanwhile an essential component of the corporate management.

Many components of Six Sigma are already known from other management systems. What is new is the intended quality level of 3.4 defects per one million opportunities (DPMO) for products as well as service activities; applying a Gaussian distribution with specification limits based on the 6-σ-level, this means ensuring a quality level of 99.99966 % for all processes. A defect occurs if the specification levels are exceeded. Hence, the scatter of the features, characterized by their standard deviation σ around the mean or expectation µ, should be small. In other words, to achieve good quality all features should be inside the specification limits at a distance of 6 σ to the mean value. The higher the sigma-level the higher is the quality level, the lower the tolerance range and the lower the acceptable number of defects.

The philosophy can be classified whether the aim is to improve already existing products or to improve new products. In the first case the focus is on "backwards oriented" analysing and improving the customer satisfaction through the DMAIC-process (see Chapter 2.5.4.2); in the case of new products the focus is on analysing and satisfying future customer needs through the DMADV-process (see Chapter 2.5.4.3) – the involvement of Six Sigma in the development stage is called "Design for Six Sigma".

The core element of Six Sigma is the process optimization. This does not only affect the process itself but also the interfaces between the processes. At these interfaces the potential for improvement is especially high. Therefore, the origin and number of actors of Six Sigma depend on their functions as well on the cross-functional processes which need to be managed.

(Töpfer, 2003, 2004, 2007, pp. 3, 4, 7, 10, 49)

2.5.4.1 Key figures of the Sigma-level

In order to analyse the process quality in detail and to identify the causes for deviations, the actors need to determine the parameters and key figures of the Sigma-level in a first step. Hence, a measuring equipment which guarantees a sufficient measuring accuracy is a basic requirement.

Defects Per Million Opportunities (DPMO) is the number of possible defects which is determined previous to the development of the production process (see formula (10)). The **Opportunities For Defects (OFD)** measures the locations where defects can occur; whereas the **Parts Per Million (PPM)** is the calculated number of defects which have really occurred (see formula (11)). DPMO and the PPM will be only the same if the product or process has only one feature. As in reality a product is produced in several steps, therefore the possible number of defects is normally higher than the occurring and measured number of defects.

$$DPMO = \frac{number\ of\ defects}{number\ of\ units * number\ of\ opportunities\ per\ unit} * 1\ 000\ 000 \qquad (10)$$

$$PPM = \frac{number\ of\ defects}{number\ of\ units} \qquad (11)$$

The relationship between DPMO and PPM is given through:

$$DPMO = \frac{PPM}{number\ of\ opportunities\ per\ unit} * 1\ 000\ 000 \qquad (12)$$

The result of involving the number of opportunities is that the DPMO is always smaller than the PPM; hence, PPM is a more critical measure for unsufficient quality. However, the DPMO is often used to compare and evaluate the quality level of complex processes. After calculating the DPMO, the Sigma-level can be determined according to a conversion table. While the DPMO just focuses on discrete characteristics, continuous characteristics, like the cycle time, are measured and evaluated through the comparison with a normal distribution.

(Töpfer, 2003, 2004, 2007, pp. 53, 55, 57)

In case of continuous characteristics the measurement is done using process capability indices which also consider the mean value and the scatter. The quality of a processing step is determined by two quality measures: Process Variation Index Cp and Process Capability Index Cpk. Cp characterizes the quality of the distribution or the magnitude of scatter with regard to the range of tolerance. Cpk determines the location of the distribution or scatter regarding the range of tolerance.

$$Cp = \frac{USL - LSL}{6\sigma} \tag{13}$$

$$Cpk = \frac{\min(USL - \mu, \mu - LSL)}{3\sigma} = \left\{1 - \frac{\left|\mu - \frac{1}{2}(LSL + USL)\right|}{d}\right\} * Cp \tag{14}$$

where:

USL…Upper Specification Limit

LSL…Lower Specification Limit

$$d = 0.5 * (USL - LSL) \tag{15}$$

d... half of the length between the specification limits

If the process is centred relative to the nominal value, Cpk is equal to Cp. In case of a shift of the mean value, Cp stays the same but Cpk is reduced signalizing a deterioration. In practice, such shifts are typically expected (see Figure 13). That is why the nominal distribution respecting such shifts has become the criterion of Six Sigma. Without shifting, a Sigma value of 6 results in a probability value of 99.9999998 % and an DPMO of 0.002. Assuming the location is shifted with 1.5 Sigma to the left and to the right side, the probability value is 99.99966 % and the DPMO is 3.4. Therefore, the 6σ concept is actually a 4.5σ concept in the long term view.

(Töpfer, 2003, 2004, 2007, pp. 58-60)

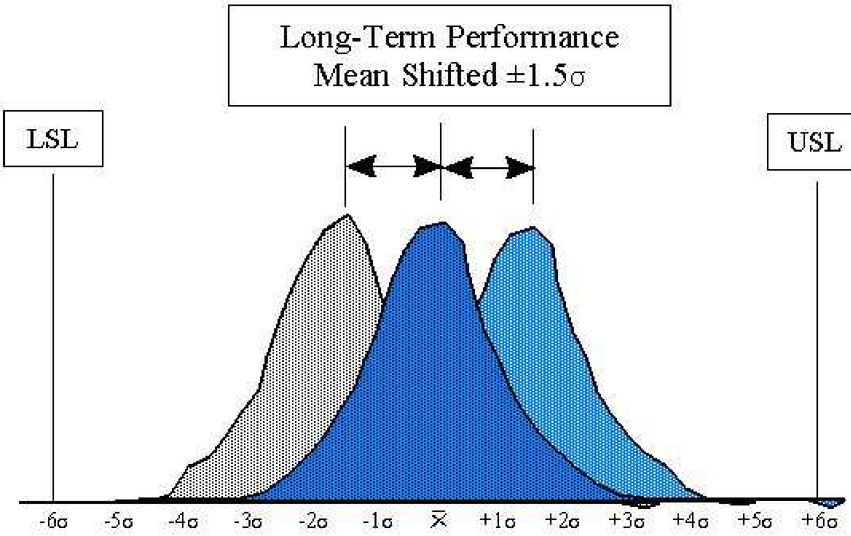


Figure 13: Long-Term Performance for a Single Process (Shifted 1.5σ) (Process Quality Associates Inc, 1996 - 2006)

In practice, a product does not consist of one but several parts meaning the production process includes several assembly steps. The additional processing steps result in a higher number of opportunities for defects. For example, a product which consists of 10 parts and is produced in 9 steps is therefore based on 19 components each with a high quality level of, say, 99 %. This would result in an output of only 83 % defect-free products. This means that a high quality of each component does not guarantee a high quality of the end product.

(Töpfer, 2003, 2004, 2007, pp. 3, 4, 63)

The previous considerations result in 4 opportunities which help to achieve the 6σ level:

- Centring processes in such a way that the target value meets the mean value.
- Reduction of scatter and standard deviation of the real process output.

Further indirect opportunities include:

- Increasing the range of tolerance in accordance with the customer's requirements.
- Reducing the number of components or the complexity of goods and services.

(Töpfer, 2003, 2004, 2007, pp. 62, 63)

2.5.4.2 Six Sigma Projects

Selection of Projects

In literature several criteria for the selection of Six Sigma projects can be found. (Töpfer, 2003, 2004, 2007) summarizes the ones which have been proven in practice. The project should result in an increase of customer benefits but also in a profit for the company determined by a Net Benefit calculation. All relevant variables and parameters need to be identified in order to be able to measure and analyse them. A high probability of success must be proven by certain criteria. Further it is necessary to formulate a clear and precise target and project definition. After the introduction stage of Six Sigma projects, the duration of the project should not exceed 3 months. In addition, the company considers the amount of negative consequences which may occur if a process or product does not achieve the Six Sigma level. Meaning the higher the costs caused by insufficient quality, the greater will be the efforts to realise the Six Sigma level. Therefore Six Sigma will be the target in sensible processes and products, like for example, in aviation and satellite technology or software for medical diagnosis. (Töpfer, 2003, 2004, 2007, pp. 71, 72, 75)

The following procedure of selection is recommended:

1. Process Mapping = Visualisation of sequences and linkages for different processes in the company using flow charts.
2. Data collection to characterize the quality level of the process (i.e.: DPMO).
3. Benchmarking, internal and external, to identify competences as well as constraints in the company.
4. Portfolio Analysis for directed selection of promising projects (see Chapter 2.1.3.1).

(Töpfer, 2003, 2004, 2007, p. 73)

The effectiveness of the projects is significantly increased if they are oriented towards the corporate strategy. (Töpfer, 2003, 2004, 2007, p. 78)

Organisation and Process

The success of Six Sigma processes mainly depends on the well trained Six Sigma actors. Figure 14 shows the necessity to educate and train different numbers of employees depending on their roles and functions. The hierarchy of business functions is defined using a kind of ranking terminology, similar to some martial arts systems, like Kung-Fu and Judo.

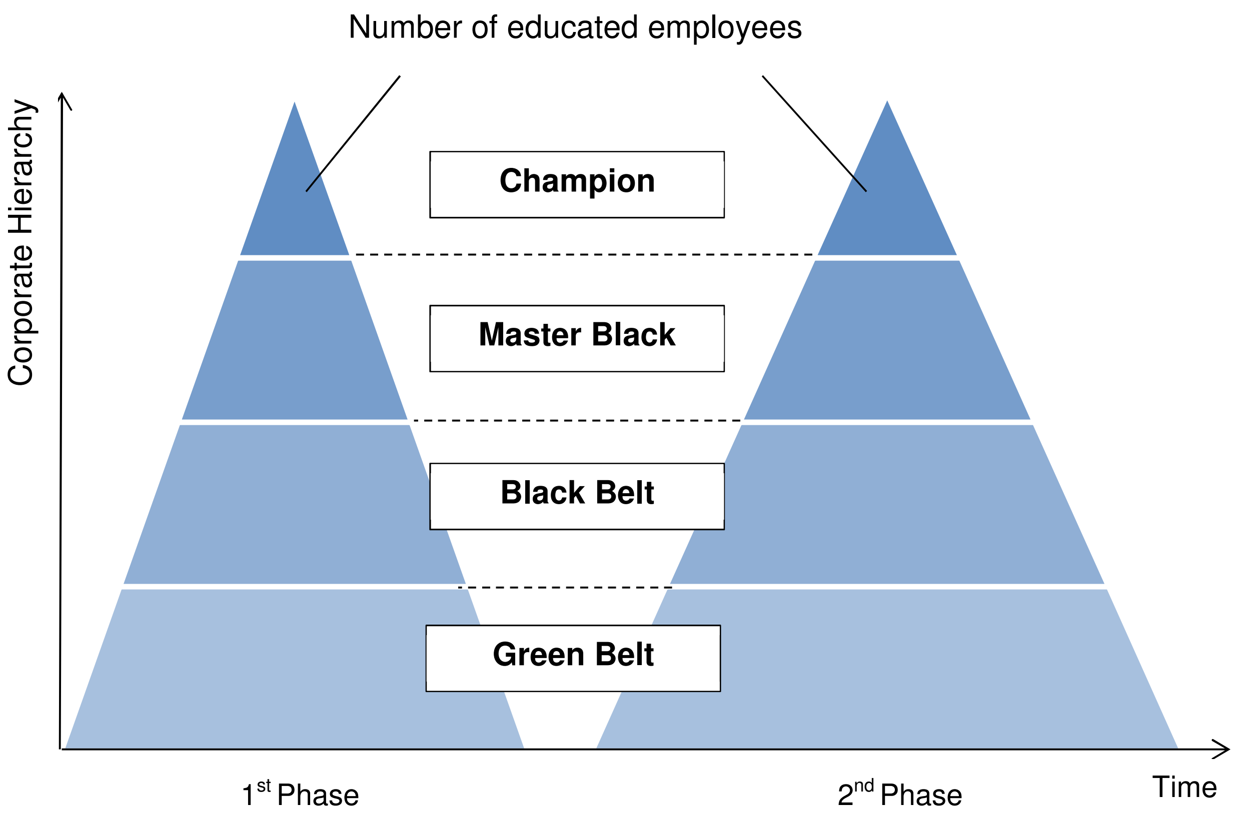


Figure 14: Development of Six Sigma organisation (Töpfer, 2003, 2004, 2007, p. 79)

Green Belts have basic knowledge about the mathematical and statistical methods applied in Six Sigma projects in order to do the analysis in a proper way. Black Belts, as project leaders or project promotors, are experts in applying Six Sigma tools and instruments but additionally they are trained in project management, communication techniques and conflict resolution methods. Master Belts are system promotors; because of their experience in Six Sigma they coordinate the project selection and training and further they act as mentors supporting the black belts in substantial, organisational and technical questions. Master Belts are the direct contacts for the champions who take the operative and strategic responsibility for results. Champions decide about the implementation of Six Sigma projects and then bring in Black Belts.

(Töpfer, 2003, 2004, 2007, pp. 78-80)

Six Sigma projects follow a standardised procedure based on the PDCA cycle (see Chapter 2.5.2). This procedure is called DMAIC cycle (Define, Measure, Analyse, Improve, Control):

Define Phase

After selecting the project according to the already mentioned criteria, the actual problem is defined based on the analysed customer needs (CTQ = "Critical-to-Quality"). Two instruments are applied: SIPOC (Supplier, Input, Process, Output, Customer) and the combined VOC[2]-CTQ-analysis. Using the SIPOC means to analyse the multistage value stream with all input- and output-processes included while the VOC-CTQ-analysis starts at the customer and derives the CTQs directly from the VOC.

(Töpfer, 2003, 2004, 2007, pp. 80, 81)

Measure Phase

Only a company that analyses its processes can measure the process quality and performance. Based on the CTQs analysed in the Define Phase, the current quality level and cost level of the processes and products are determined. The basis of a good measurement is the application of quality management tools and techniques like intensive interviews, VOC, brainstorming, flow charts, cause and effect diagrams (see Chapter 2.1.3.1) or correlation diagrams (see Chapter 2.1.3.1). The Measure Phase helps to identify the most important influences criteria and opportunities for improvement in order to narrow the project scope. Additionally, standardised measurement criteria lay the foundation for decision transparency as well as internal and external benchmarking activities.
(Töpfer, 2003, 2004, 2007, p. 83)

Analyse Phase

The objective of this phase is to structure the measurement data and results; this requires a detailed analysis of the problem through applying mathematical and statistical methods, like variance analysis or regression analysis. This analysis can

---

[2] VOC = "Voice of Customer": is a market research technique to identify the wishes, expectations and needs of the customers which is realised through in-depth interviews using structured scheme of questions. A VOC analysis may also include the prioritisation of the identified needs. (Töpfer, 2003, 2004, 2007, pp. 113-115)

be based on an Ishikawa diagram (see Chapter 2.1.3.1) where it is important to distinguish between causes and effects and also between main influences and minor influences.
(Töpfer, 2003, 2004, 2007, pp. 83, 84)

Improve Phase

After finishing the analysis, an action plan is developed which helps to implement the improvements in order to optimise the processes. Important characteristics of Six Sigma projects are the fast realisation of improvement measures and the achieving of concrete project results.
(Töpfer, 2003, 2004, 2007, p. 84)

Control Phase

The Control Phase supports the stabilisation of the optimised processes or the defect free products. The desired quality level is controlled through checking if the main problem causes have been eliminated permanently and the improvement measures are successful. In addition a re-calculation is necessary to determine and evaluate potential deviations from the project goal; a project data base should be established to facilitate the documentation and analysis.
(Töpfer, 2003, 2004, 2007, p. 85)

After finishing a Six Sigma project, further improvement activities are recommended in order to achieve the transition to a continuous improvement process. (Töpfer, 2003, 2004, 2007, p. 85)

2.5.4.3 Design for Six Sigma (DFSS)

In the development stage, 5 % of the effective costs influence 70 % of the overall costs; this means a poor design of the product and an insufficient development process can have major influences on the total costs. Hence, the starting point of improvements in the development stage and therefore the starting point of Design for Six Sigma is a robust design which forms the basis for robust products and robust processes. In this case “robust” includes a low probability of failure in product life cycle as well as a high reliability of the underlying corporate processes.

Six Sigma projects in different companies have shown that a Sigma level of 4 or 5 can be achieved in a rather short time of 2 to 3 years; in comparison, it is much more difficult to obtain a quality level above 5. If improvements were already implemented in value adding phases, the Six Sigma level can only be realised through conformal R&D processes.

While Six Sigma projects focus on improving processes, Design for Six Sigma concentrates on material or parts in the development stage. DFSS helps to minimise the number of Six Sigma projects in the value chain through eliminating failures internally in the company as well as externally at the customer in the use phase.

(Töpfer, 2003, 2004, 2007, pp. 101-104)

Like Six Sigma projects also Design for Six Sigma follows a standardised procedure based on the PDCA cycle (see Chapter 2.5.2). This procedure is called DMADV cycle (Define, Measure, Analyse, Design, Verify); methods and instrument mentioned in the description of the cycle will be explained in the following paragraphs.

Define Phase

In this phase, the project is defined including project goals and interfaces with other processes. The project team is formed showing the responsibilities and the project charter prepared.
(Töpfer, 2003, 2004, 2007, p. 107)

Measure Phase

After the definition of the project, it is necessary to identify the customer needs as well as to evaluate the current process performance through internal and external benchmarking. The customer needs are then transformed into Critical to Quality Characteristics (CTQs) using Quality Function Deployment (QFD).
(Töpfer, 2003, 2004, 2007, pp. 107, 108)

Analyse Phase

The Analyse Phase of DFSS includes the analysis of the design of product and process alternatives. Based on the CTQs a High Level Design is developed and afterwards reviewed via customer feedback and through application of FMEA (Failure Mode and Effects Analysis) in order to evaluate potential risks.
(Töpfer, 2003, 2004, 2007, p. 108)

Design Phase

In order to develop a robust design which fulfils the customer needs the design of the product or process is specified. The application of a statistical design of experiments (like DOE[3]) helps to optimise the combination of input factors and the consideration of CTQs.

(Töpfer, 2003, 2004, 2007, p. 108)

Verify Phase

After the performance of the new developed product or process is monitored in a test phase, the improvements are implemented in the day-to-day business. At the end, the process capability is continuously controlled via Statistical Process Control (SPC) (see Chapter 2.5.5).

(Töpfer, 2003, 2004, 2007, p. 108)

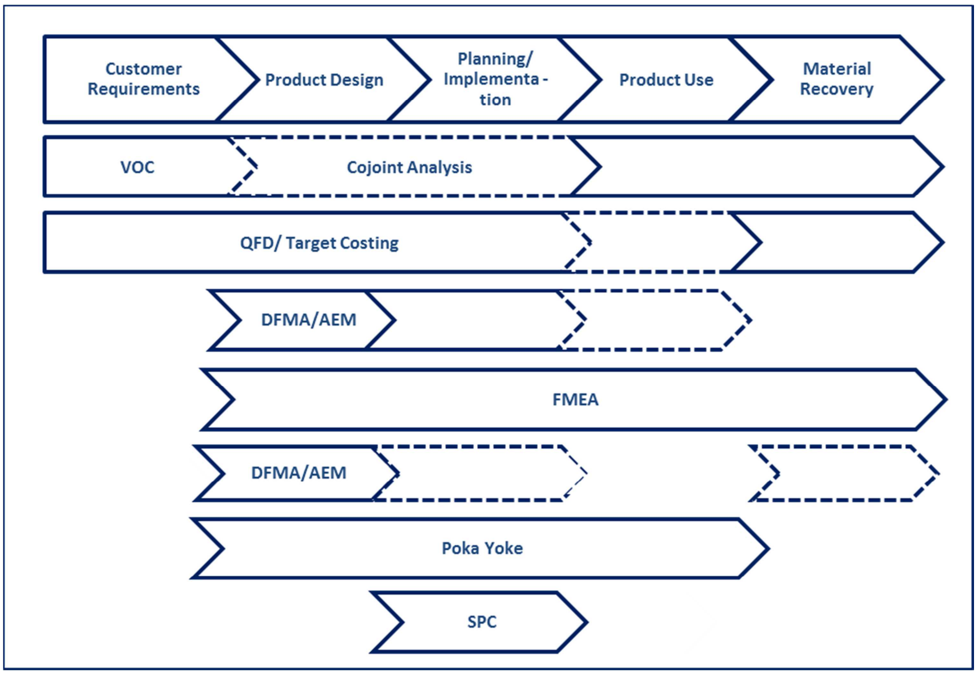


Figure 15: Quality Management methods in the value chain of product development (Töpfer, 2003, 2004, 2007, p. 111)

Figure 15 illustrates the application of the methods and instruments in the different phases of the value chain for product development. The process starts with the identification of customer wants and needs in a VOC analysis and further their

[3] Design of Experiments (DOE) is a statistical technique to identify the necessary number of experiments and to plan their realisation in order to get meaningful results. (Töpfer, 2003, 2004, 2007, p. 138) For detailed information see (Töpfer, 2003, 2004, 2007, pp. 138-149).

distinction and prioritisation; two proven techniques for this prioritization are the Kano Model (see Chapter 2.5.1) and the Maslow pyramid. Quality Function Deployment (QFD) is a method to transform the customer needs into quantitative parameters in order to deploy the quality functions and methods to achieve the design quality. The focus of QFD is the translation of the voice of the customer or market into the language of engineers. This is achieved through quality features (characteristics of products, processes or services) which can be influenced by the engineer and have a direct relation to the success in quality noticed by the customer. This progress is often illustrated via the so called “house of quality” (for further details, special literature is recommended). After this translation it may be useful to do a Conjoint Analysis where combinations of product attributes are determined and further evaluated based on preferences and willingness to pay. If the costs of these combinations exceed the allowable costs, a target costing analysis[4] is necessary. The activities of Target Costing are often supported by a FMEA (Failure Mode and Effects Analysis), a quality management method to identify potential failures and their consequences at an early stage. The FMEA starts with the description of potential failures in features of products, processes and parts, followed by a risk analysis, risk assessment and risk management. The connection of QFD and FMEA is given if the product functions derived from the customer needs in the QFD are all studied in the FMEA.

(Töpfer, 2003, 2004, 2007, pp. 113-133)

2.5.4.4 Six Sigma in the Service Sector

Improvements of service processes are also achieved through Six Sigma projects; but compared to production processes, there are some challenges. In service processes, found in a call centre or technical service department, it is harder to define and quantify phases and sub-steps in the value chain. This complicates the application of statistic instruments and any type of standardisation.

(Töpfer, 2003, 2004, 2007, p. 172)

[4] Target Costing is a product costing method: after determining a target cost based on a market analysis, the product is designed or redesigned to meet it. (WebFinance Inc., 2014)

The basis for achieving Six Sigma also in service processes is a clearly defined and instrumented process control including Six Sigma activities. A five-step procedure is recommended. In a first step the desired standards are derived from the corporate strategy; these standards characterize the intended quality level, like for example answering the phone after maximum three rings. The internal standards are then compared to the external customer requirements, which are identified via VOC analysis (see Chapter 2.5.4.2). This makes it possible to implement measurement parameters for each process phase in order to control the compliance with the standards; it is necessary to define criteria, meaningful measurement contents and measurement points at customer interfaces. Considerable quality deficits require Six Sigma projects with application of the DMAIC cycle (see Chapter 2.5.4.2) equal to improvements in production processes. The focus of all improvement activities is on standardisation in order to reduce the degree of deviation.

(Töpfer, 2003, 2004, 2007, pp. 177, 178)

2.5.5 Statistical Process Control (SPC)

Statistical Process Control (SPC), also called Statistical Quality Control (SQC), is a vital tool used to control and monitor process quality. In a manufacturing process it is necessary to establish a state of control and further to sustain this state through time. Control charts are a proper tool to observe and control such processes. These charts have a centre line which corresponds to the average quality (XCL) where the process should perform; in case of a statistical control of the process, there will be an Upper Control Limit (UCL) and a Lower Control Limit (LCL) in addition. The three limits are computed from the data and the process performance is charted in order to detect out of control situations, trends or other unnatural patterns. (Soin, 2012, pp. 135, 136)

Several types of control charts exist depending on the attributes which need to be measured. For example x, R charts are used for measurements (weight, volume, etc.) while p charts are used for number of defects. As the charts show out of control situations, they should be deployed to monitor critical dimensions of fabricated parts or to track critical process points. However, not the number of control charts in an operation but the way they are used is essential. (Soin, 2012, pp. 135, 136)

3 Further Development of Operational Excellence

Referring to the three definitions of Operational Excellence mentioned in Chapter 1, Chapter 2 concentrates on the second definition, explaining concepts and approaches included in the extensive tool box which is defined as the basis of Operational Excellence. Chapter 3 goes one step further and focuses on the third definition where the term Operational Excellence is widened as it is much more than the application of improvement methods and tools.

3.1 Combined Concepts and Methods

Since concepts and methods, like the ones described in Chapter 2, were implemented and are applied in companies over a certain time, their advantages and disadvantages have been discovered; as a result of this, new forms of concepts have been developed which combine already existing methods in order to profit from all advantages. This thesis picks out one of these new developed concepts to show how the combination takes place.

Lean Six Sigma

Lean Six Sigma is a fusion of the improvement methods „Lean Management"(see Chapter 2.2) and "Six Sigma" (see Chapter 2.5.4). The objective of Lean Management is the elimination of waste through lean organised processes and structures while the application of Six Sigma leads to defect free products and processes. Hence, a combination of the two results in a process with minimized waste and cycle time as well as minimal variation (scattering) and deviation from the mean value of a tolerance range.

In Lean Management all value adding processes are involved in the improvement process as the goal is to eliminate waste in all phases. In contrast, Six Sigma focuses only on value adding processes which show deviations from the CTQs and therefore cause additional costs due to poor quality. As a result, companies who implement Lean Six Sigma start with Lean Management activities and carry out Six Sigma projects (see Chapter 2.5.4.2) selectively only in case of intractable problems.

Figure 16 shows different objectives and their realisation through implementation of Lean Management, Six Sigma, Design for Six Sigma (see Chapter 2.5.4.3) and Lean Six Sigma. As illustrated, the combination and integration of all objectives can only be achieved via Lean Six Sigma.

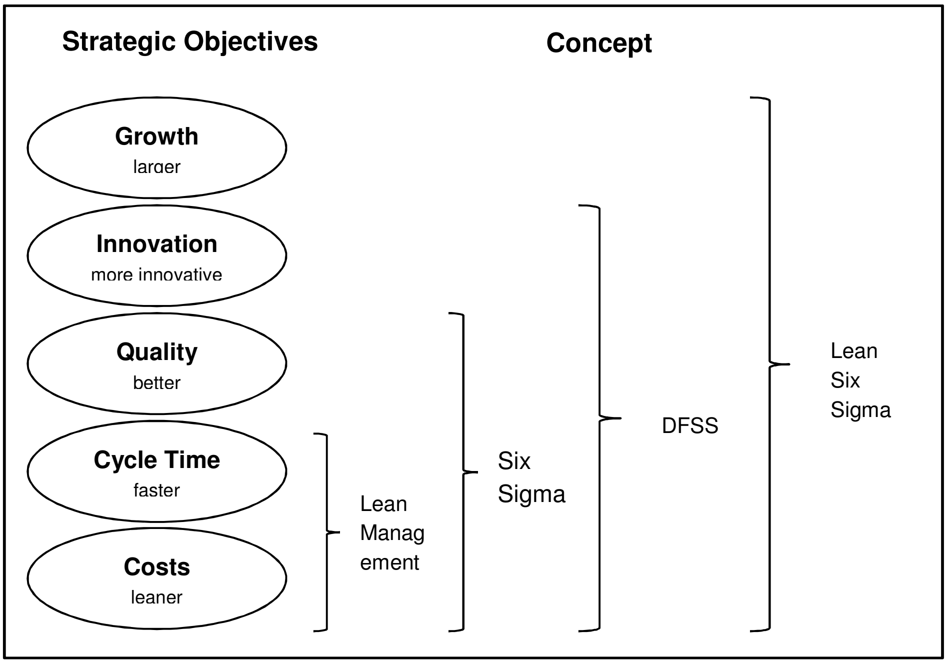


Figure 16: Objective and their realisation (Töpfer, 2009, p. 9)

(Töpfer, 2009, pp. 3, 7, 8, 12, 13)

Basically, three ways of combination can be distinguished:

1. The complex Six Sigma management process is getting leaner through application of Lean Management methods. This way of combination always focuses on Six Sigma; this makes the project process leaner and more efficient but not necessarily more effective.
2. Lean Management is supplemented with Six Sigma. Based on the application of Lean Management methods, like for example Value Stream Mapping (see Chapter 2.1.6), processes as a whole are analysed and optimised. To eliminate difficult defects which require a deeper analysis Six Sigma projects are carried out. Both concepts exist in the company independent from each other.
3. Lean Management and Six Sigma are connected with each other resulting in an overall concept. Based on an effective project selection procedure, both Lean Management activities as well as Six Sigma projects are carried out in the company. Figure 17 illustrates the cross-linked process scheme: basic

improvements are achieved through analysing, designing and optimising process based on Lean Management; afterwards special problems in processes or production are detected and eliminated via a lean DMAIC cycle which does not require too much time. The last step is the "fine-tuning" via continuous improvement/Kaizen activities (see Chapter 2.1.3) in order to optimise the value adding processes.

The third way of combination is the most common one in practice.

(Töpfer, 2009, pp. 57-60)

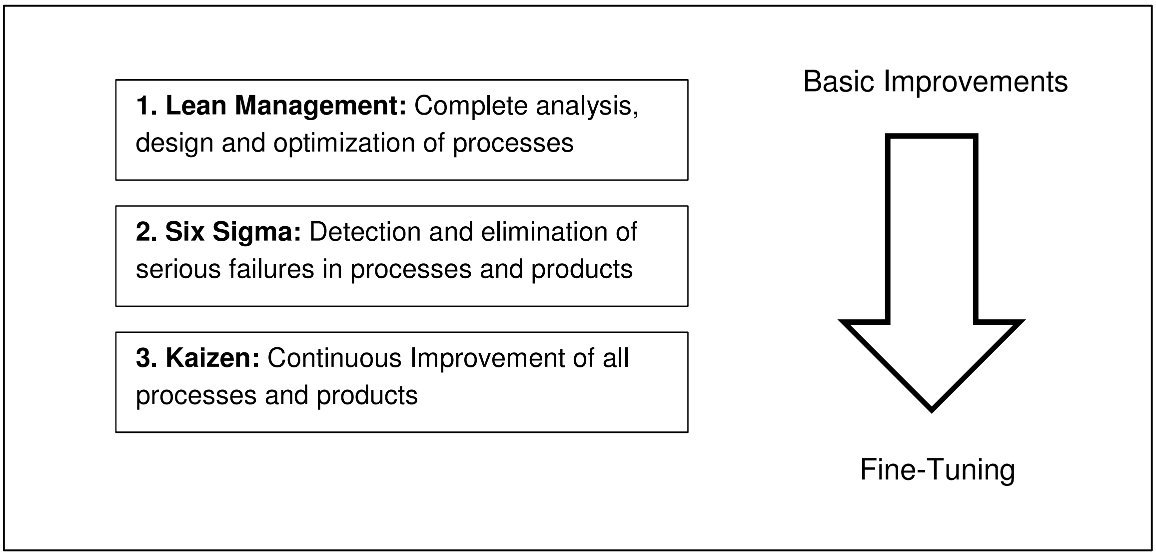


Figure 17: Improvement in 3 steps (Töpfer, 2009, p. 60)

3.2 Lean Leadership at Toyota

In their book „The Toyota Way to Lean Leadership" Jeffrey Liker and Gary Convis reflect the effort of many companies trying to learn Toyota's secret of success; they describe this effort as a hunger for concepts and tools to implement lean which have led to millions of Toyota-and-lean-focused books and seminars run by consulting companies and non-profit groups. Nevertheless, these companies often do not achieve operational excellence. After the processes have been "leaned out" and defects have been eliminated key performance indicators show enormous improvements; but as time passes, the processes seem to turn themselves and degrade, with variability and waste growing again (source: (Liker & Franz, 2011) according to (Liker & Convis, 2012)).

Sustaining improvements requires a combination of top leadership commitment and a culture of continuous improvement. The culture needs to be changed from people who do only look on their own job and their own numbers to people who also focus on the customer and on improving value streams. As cultures evolve slowly, changing them is difficult and takes time.

Even if the process has never been formally codified, Toyota does have a systematic way of identifying and developing leaders over their careers. This is illustrated in Figure 18. Leadership at Toyota starts with understanding and living out the core values of the company, summarized in the middle of the model.

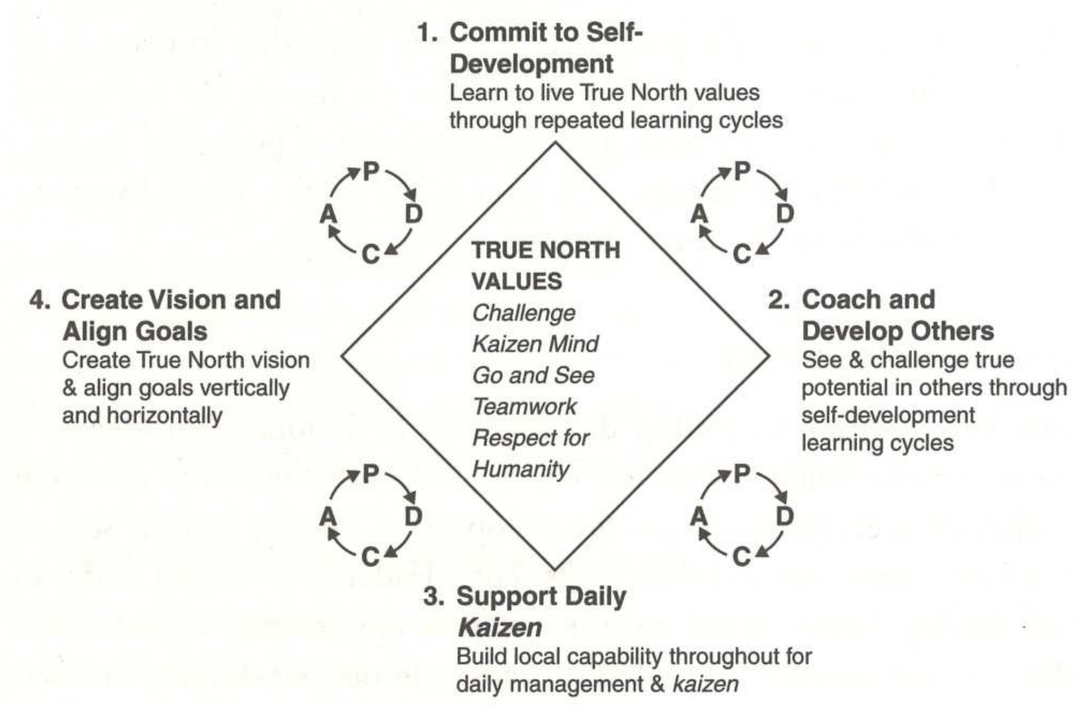


Figure 18: Diamond Model of Lean Leadership Development (Liker & Convis, 2012, p. 39)

The reality is not as linear as the model suggests but there seems to be a logical sequence from developing oneself to ultimately integrating the whole organisation to align on goals. During their career the leaders will go through the stages of this model many times:

- Self-development: Toyota believes that real leaders seek to improve themselves and their skills; therefore, they must be given an opportunity to do so and must get support from others. They do not self-develop on their own – it is required to find the right challenges, to allow space for self-development and to coach at the right time in the process.

- Developing others: according to the motto “the best way to learn something is to teach it”, Toyota expects leaders to be actively engaged in coaching and developing every one of their staff.
- Supporting Daily Kaizen: while the first two stages mainly focus on individual leadership the third stage concentrates on institutional leadership; this means keeping groups of people pointed toward and focused on what is called True North[5]. Leaders need to ensure that their teams are capable for both maintenance Kaizen (see Chapter 2.1.3.3) and improvement Kaizen (see Chapter 2.1.3.3) (source: (Liker & Hoseus, 2008) according to (Liker & Convis, 2012)). Hence, within this stage they do not force Kaizen from top down but they enable, encourage and coach Kaizen from bottom up.
- Creating Vision and Aligning Goals: at the fourth stage bottom-up meets bottom-down. Kaizen at Toyota mean that processes throughout the company are being tweaked and adjusted to get closer to True North, every hour of every day. But there is the danger that the resources of the company may be focused in the wrong goals. Therefore, at this stage leaders and the organization are actively involved in Hoshin kanri (see Chapter 2.4.1); it is essential that leaders are able to break down plans, goals and targets and ensure that each work group understands them and has a clearly defined plan to accomplish these goals.

(Liker & Convis, 2012, pp. 3, 4, 34, 35, 40, 42)

In many companies, leaders are expected to make big changes showing results quickly even before they completed the four stages of development. If they do not succeed, they are often replaced by new blood from outside. While American companies tend to think that only outsiders can lead turnarounds when the company is in a major crisis, Toyota’s success is always led by someone with decades of experience at the company – in Toyota’s nearly 100-

[5] True North is a term introduced by Toyota: the basis of True North is the stable vision of where the company should be headed, meaning the core values; hence, it is not negotiable and does not change with specific goals from year to year. (Liker & Convis, 2012, p. 41)

year history, every president spent his entire career at the company. (Liker & Convis, 2012, p. 44)

3.3 Redefining Operational Excellence

Since the design of the Toyota Production System (see Chapter 2) in the time after Second World War many other methodologies and approaches, like Lean Management, TQM or Six Sigma (see Chapter 2), have been developed supposed to help achieving Operational Excellence. Many of today's companies rely on these methodologies nevertheless they fail to deliver sustainable results. This development raises the question if companies really understand what is meant by Operational Excellence and what is required to achieve it. Based on 15 years of experience in consulting with some of the world's best-known companies, Andrew Miller in his book "Redefining Operational Excellence" explains how organisations can pursue excellence in a new way without reliance on methodologies but with good judgement in the best interest of the organisation and its customers.

"To achieve dramatic results, you must create a different culture for your organization – a culture that questions current operating models and focusses in adding value and optimizing speed." (Miller, 2014, p. 2). As already mentioned in Chapter 3.1 single methods, like Lean Management or Six Sigma, have limitations concerning their ability to drive Operational Excellence and consider holistic strategies. True excellence requires a more comprehensive approach that is focused on people and on effecting change. Hence, Andrew Miller defines Operational Excellence as a mind-set, not a method, being the constant pursuit of improved performance and profitability in all areas of an organisation; he summarizes the necessary components (see Figure 19):

- Attracting and retaining top talent
  Employees are the key ingredient to the success or failure of an organisation. One of the reasons why many companies do not hire well is that the management does often not assess what is needed for the organisation to achieve its goals and decide whether people are in the right function or have the required skills. It should be more important how people deal with certain situations and scenarios than the candidates'

school education or experience. The best retention strategy starts with the hiring process.

- Innovation and collaborating
  Innovation is the engine that keeps an organisation moving in a forward direction therefore the company needs to keep this engine fine-tuned. Innovation does not only mean developing good ideas but also encouraging ideas from many sources, prioritizing those ideas and, most important, turning this ideas into commercial successes. The key is collaboration. Organisations often forget the importance of collaboration with business partners, including suppliers and customers, as they are too focused on their daily issues.
- Aligning strategy and tactics
  While strategy is the what, tactics are the how. It is essential that everyone within the company understands its future vision and further understands what is expected of him/her to achieve that vision. Day-by-day tactics must be coordinated with the desired outcomes of the company.
- Acquiring and keeping the customers you want
  Independent of the corporate strategy the involvement of the customers in the operation of the company is indispensable. The creation of emotional bonds with the customers may require customer panels, sneak previews of new products or also exclusive events.

Figure 19: The Components of Operational Excellence (Miller, 2014, p. 10)

Each of the mentioned components is enhanced by the ability to optimize speed and is motivated by the impulse to maximize profitability (or effectiveness). In addition, companies are currently changing the way they are looking at their own organisation in order to differentiate themselves from their competition. In the past, an organisation was supposed to be a group of departments linked by a common goal and sometimes by common processes, like a supply chain is a chain of events or activities that need to be linked together (illustrated in Figure 20). But isolated units held together by a series of links provide a lot of opportunities for gaps and weaknesses. That is why today there is the trend to look at an organisation as one entity where every department is part of the whole and therefore must operate to maximize the ability of the organisation to achieve results (see Figure 21); excellence needs to make its way into every corporate activity including hiring employees, developing and implementing strategy, generating and commercializing ideas, leverages customer relationships and resolving customer issues.

(Miller, 2014, pp. 1, 2, 7-12, 24-29)

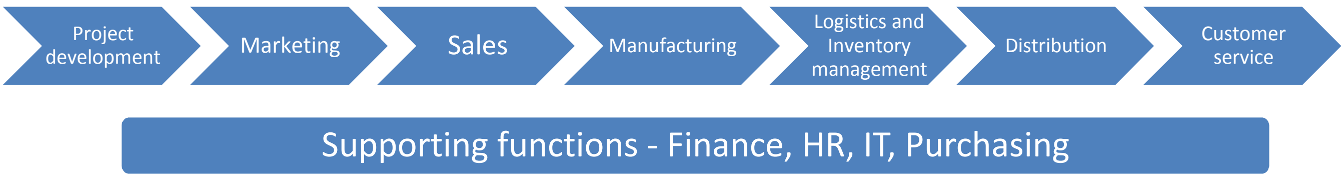


Figure 20: The Old Way: Connecting Links in a Chain (Miller, 2014, p. 25)

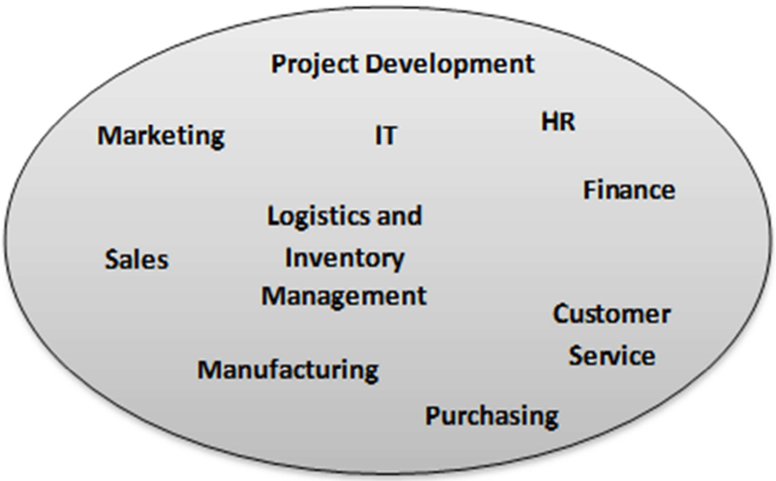


Figure 21: The New Way: A Holistic Approach

3.4 Operational Excellence in Different Industrial Sectors

Initially developed for manufacturing industry approaches to achieve Operational Excellence have been developed or adopted to all other sectors of industry as well. But Operational Excellence does not necessarily mean the same for all industries – some need to focus on people others on constant innovation and still others rely on processes and technology.

3.4.1 Retail

As retail organisations deal with individual customers the key factors in the buying decisions of customers are service and price. The one who deal with customers the most are commonly the frontline employees. From an operational excellence perspective, a retail organisation needs to offer customers something they do not get elsewhere; where the competitors are not only other physical organisations but also online competitors who provide comfort and validation.

Key factors of Operational Excellence in retail:

- An effective hiring and retention process: a retail organisation needs to look for the best frontline people; this requires one of the core components of Operational Excellence mentioned already in Chapter 3.3: "attracting and retaining top talent".
- Employees who are strong at relationship building and who can build rapport quickly with different kinds of customer.
- Employees who are empowered to make decisions that are in the best interest of the customer.
- Employees who take ownership for the success and failure of the organisation.
- Alignment between the strategy of the overall organisation and the tactical work that frontline employees do.

(Miller, 2014, pp. 186-188)

3.4.2 Services

The service business is a people-oriented business including many different types of services from lawyers and accountants to landscapers and hotels. As mostly customers do not buy services but are paying for trust the critical factors of this sector are reputation and trust. For example when hiring a lawyer besides the requisite abilities people need to trust that the lawyer has their best interest in mind.

Key factors of Operational Excellence in retail:

- A focus on the objectives of the customer, not on the company itself
- A constant effort to build rapport and trust with the customer
- Thought leadership
- Having the right people on the front lines and allowing them to use judgment
- Clear communication about the direction the organisation wants to go

(Miller, 2014, pp. 190-191)

3.4.3 Technology

Many technology industries do not have contact with the end customer because if someone is buying a software package or some form of online technology he or she rarely interacts directly with the selling company. As a consequence, the focus of technology organisations needs to be on the delivery of software and the access by the end customer as the customer should be able to implement technology, integrate systems, and even download software easily. In addition, technology organisations need to provide world-class customer service without ever meeting their end customer including for example online chat features for technical support, virtual customer service representatives or easy online help features.

Key factors of Operational Excellence in the technology sector:

- Identification of new ideas and turning the best ones into commercially viable products and services
- Developing products and services according to customer needs
- Clear vision for the future and aligning tactics and metrics for success with that vision

- Providing training and support in the implementation and use of new systems
- Providing support and tools which help the customers to self-diagnose issues and resolve them quickly

(Miller, 2014, pp. 197-199)

3.4.4 Manufacturing

As the concept of Operational Excellence started in the manufacturing industry many aspects have already been discussed in this thesis.

Key factors of Operational Excellence in manufacturing:

- Seamless integration between the various steps of the supply chain
- Formal management of the innovation and product launch process
- Collaboration with customers and suppliers
- Processes with maximized results and minimized environmental impact
- Cross-trained people
- Processes and products focusing in high quality and maximized throughput
- Culture of continuous improvement
- Sales and marketing department closely integrated in the manufacturing process

(Miller, 2014, pp. 201-203)

4 Operational Excellence in Mining – Current State

The concepts, methods and tools of Operational Excellence discussed in the previous chapters were mostly developed out of necessities of the automobile industry or the producing industry in general; the objective of this chapter is to show the applicability of the approaches in the mining industry.

The current application of the methods was determined based on interviews with six personalities from Austrian raw material companies including suppliers of industrial minerals, refractory products as well as cement. The interviewees are currently active in leading positions or have already retired and work as consultants by this time. In a personal interview they were asked about their own definition of Operational Excellence and their experience with the implementation of several concepts. As the extent of implementation of the various approaches as well as the area of application differs depending on the company, the interviews did not strictly follow a standardized questionnaire but were conducted as informal interviews. The aim was to indicate areas within mining companies were Operational Excellence could be implemented successfully and has already led to increased performance. Furthermore the interviews have shown the different approaches of the companies to implement the concepts and necessary adaptions to deal with the specific conditions in the mining industry in contrast for example to the automobile industry. Based on these information it was then possible to identify necessary improvements of existing methods as well as the future potential of applying Operational Excellence approaches in the raw material industry in general.

The interviews have shown that the term Operational Excellence is already well-established in today's industry. Even if not all methods are known by name they are applied in different areas in the companies. The trend towards the implementation of Operational Excellence started around 10 years ago with the overall goal of increasing productivity and cutting costs. Even if the initial wish of achieving excellence through applying various concepts arises from inside the company an external company is often consulted to organise and control the implementation. While some companies are supported externally during the implementation of Operational Excellence as a whole covering all areas of the organisation, in some cases consultants are only called to support the implementation of single concepts. The opinions about the deployment of consulting companies differ – while some believe the lack of technical knowledge leads to a lack of practical applicability of the developed procedures others appreciate this objectivity and trust in the experience of the consulting companies. Based on this experience the applied procedures can be well-chosen and structured which may result in an increased participation of the employees. For example, the implementation of Six Sigma (see Chapter 2.5.4) in a mining company was done consulted by an external company in 5 different sites. At the first site, the implementation was fully led by the consultants; the implementation at the second site was then done by the consultants and a Green Belt who was educated when implementing Six Sigma at the first site. The simultaneous education of Green Belts and further Black Belts made it possible to do the implementation at the fifth site completely without the need of a consulting company.

Toyota Production System

Regarding the Toyota Production System (see Chapter 2.1), not all methods of this concept are considered to be applicable in the mining business. As Just-in-Time is a method to minimize inventory in the stockroom and factory floor, in mining industry it is often seen as a too risky approach. One fundamental difference between the automobile industry and the mining industry is governed by the uncertainties due to nature; uncertainties concerning the shape of the deposit or variations in mineral content have a major influence on all following processes as they have an impact on the quality of the product. The supply risk in case of a dramatic quality change or a huge rock failure is evaluated as too high compared to the additional inventory efforts.

In contrast, Kaizen (see Chapter 2.1.3) and its fundamental idea of continuous improvement are already firmly anchored in many areas of mining companies. As the process of continuous improvement should not only cover all departments of a company but also all levels in hierarchy, ways need to be found to include every employee starting with the operators in the mine or in the production. An effective way of gaining this bottom-up process is seen in establishing a suggestion scheme, as described in Chapter 2.1.3.2. This process has to be well-conceived.

Experience has shown that a letterbox is a good opportunity to include operators and miners into the continuous improvement process as they mostly appreciate to suggest in written form and anonymously. Foremen however are integrated into special meetings where they have the chance to present and discuss their proposals with their superiors as well as to comment on proposals of others. The most important point when inviting employees to bring in suggestions is to give them feedback afterwards; this feedback includes the argumentation why an idea is implemented or not. Often it is accompanied by paying premiums which may depend on the estimated cash savings achieved through the suggestion. The necessity of giving feedback to all suggestions without regard to their quality already identifies the efforts of suggestions schemes. To process the sheets collected in the letterbox or the ideas which have been brought in during meetings requires time, resources and therefore money. A company in a difficult economic situation may not have the necessary resources to response to the bulk of suggestions and will therefore rather achieve a demotivation of the employees as they feel frustrated when their efforts are not recognized. Therefore, companies especially invest in improving their suggestion scheme when they are in a stable economic situation even if this means that the existing potential of new ideas cannot be used.

Another approach of Kaizen which is well-established is the forming of quality circles (see Chapter 2.1.3.1). The advantage of working on problems in teams is taken at all levels in the companies. The teams consist of approximately 10 employees normally of the same level in hierarchy. In contrast to suggestion schemes, quality circles deal with more complex problems and have shown to achieve higher cash savings. A possible challenge could be the optimization of the logistic between the mine and the mineral processing plant. In this case, a team is formed including employees out of the mine, the maintenance department, the quality management, the mineral processing etc. who discuss their ideas, define different requirements and coordinate the planning and further the implementation process. Quality circles are not only a common approach in continuous improvement processes but especially in internal bench marking. Worldwide concerns with various sites in different countries organise circles to identify the best-practices inside their own organisation. In this case, the circles do not consist of employees from different departments but employees of the same position but from different sites. For example, all production managers meet on a regular basis to compare their performance and further to set specific limits, called key performance indicators (KPIs). During this process they visit a number of sites for the time of one week in order to get to know the local organisation; they attend meetings and hold talks with the employees on site. This way of exchanging experience can be applied in all areas related to mining, starting with the performance of the mine itself further to the maintenance department, the quality management and especially also the health and safety management. The reason for huge concerns to do primarily internal bench marking is that the mostly sensitive data is already available and does not need to be exchanged with potential competitors.

As described in Chapter 2.1.4 standards are essential ingredients of manufacturing and are therefore required for the simplest to the most complex job in the factory. The basic idea of Standard Work is to cut costs by clearly defining responsibilities as well as procedures and thereby making processes more efficient. While specific mining related processes require the development of standards inside the company, general procedures are often covered by ISO certifications. This thesis only describes the ISO 9000 series, a family of quality management and quality assurance standards; future ISO standards for example also include procedures like creating applications for leave or travelogues. Companies who want to become ISO certified can mostly follow clear guidelines when implementing Standard Work in their organisation. Another advantage of ISO is that the standards are audited externally which forces organisations to keep the conditions and to update the procedures on a regular basis. The trend of standardisation can not only be found in manual or administrative work but also in machine activities. During production drilling in an underground mine often only one borehole is measured and the drilling jumbos then drill a pre-defined arrangement of boreholes according to the one defined. Mining in the centre of a massive or regular deposit this standardised process saves time and effort; but in case of irregularities or in the border areas of the deposit, the arrangement of boreholes needs to be adapted; this requires well-educated miners and often also smaller drilling jumbos with higher flexibility and smaller degree of standardisation.

Due to the fact that such irregularities occur infrequently there is the danger that the operators are not experienced in arranging the boreholes on their own.

Total Productive Management

In contrast to the Toyota Production System, the methods included in the Total Productive Management (TPM), explained in Chapter 2.2, can mostly be applied in the automobile industry as well as the mining industry. In the last 20 years most of the companies have implemented maintenance management systems which regulate the frequency and procedures of maintenance work as well as the responsibilities in the organisation. Machines are no longer operated until damage occurs but are maintained on a regular basis to check their conditions and already plan necessary replacements. There is no strict separation between the production or mine and the maintenance department anymore; operators are responsible for the cleaning and inspection of their machines in order to maintain their functionality. They do small repair works on their own and often also attend repair works done by the maintenance department in order to gain further knowledge. This way of organisation requires cross-functional trained personal who understand the necessity of well-functioning machines with high availability. Training and education programs for operators need to be developed and continuously improved to provide them with information and to acquire new skills. Specialities of the mineral resource sector are the long and continuous production phases; production facilities, like a rotary kiln, are often shut down only once a year for two weeks to do maintenance work like exchanging the refractory lining. While only a few operators are needed to control the production process during the year, much more workforce is required at the time of shut down in order to guarantee efficient and expeditiously maintenance work. The additional workforce is often external personal or provided by an affiliated company.

The 5S system (see Chapter 2.2.2.8) is a TPM tool with a wide range of use. As it helps to organize and clean the work environment and supports discipline in the workplace it is applied inside the mine as well as in the production plant. The tidiness in machines and control stands but also at storage areas and shop floors is achieved through the well-structured 5-step approach. Experiences have shown that this procedure motivates the employees not only to organise their working area once but also to keep this state of tidiness.

Lean Mangement

As in today's industry "lean management" or "lean production" have become common phrases in all levels of a company, the interviewees were asked about their definition of "lean" and what they associate with this development. "Lean" is superficially related to rationalising of workplaces and therefore seen very critical. Some think the danger of lean organisations is that they may lead to decreasing efficiency because, for example, managers need to do the work of rationalised secretaries; this means, employees are additionally set under stress and do not have the capacities to be creative and innovative anymore. Others believe in the potential of Lean Management to reduce fix costs in countries of high taxes and do not fear the loss of creativity but appreciate the striving after top performance based on the mobilisation of the employees out of their own "comfort zone". Another appreciated development resulting out of Lean Management is the improvement of decision-making processes; lean structures result in a closer cooperation inside the company and therefore help to shorten the path of decision.

When implementing Operational Excellence approaches it is important to continuously monitor and measure the process. If possible, this is mostly done by comparing key performance indicators before and after the implementation; for example the improvement of the maintenance work can be measured through regarding the Overall Equipment Effectiveness (OEE) or the Mean Time Between Failures (MTBF), described in Chapter 2.2.1. The monitoring gets more complex if the success of implementation cannot be expressed in numbers; the changing motivation of employees for instance is evaluated through conducting regular appraisal interviews.

After years of implementing several concepts of Operational Excellence and developing specific methods on their own, most companies believe in the potential of these approaches but have also recognized the efforts related to them. They have realized that Operational Excellence is not only an extensive tool box of improvement procedures and standards, as stated in one of the definitions in Chapter 1, but requires a change in the corporate culture including all areas of an organisation. Even if companies have already started around 10 years ago they do not feel that they have even finished the starting phase of this improvement process. The change of a culture takes time and besides the technical and organisational changes it mainly requires an improvement in internal communication and therefore an improvement in leadership.

Table 2 summarizes the observations gained during the conducted interviews. The five columns represent the fields of activity in a mining company; the coloured frames indicate those fields where the discussed approaches of Operational Excellence have already been implemented. Kaizen or the process of continuous improvement can be found in all areas were Operational Excellence is so far applied. As Lean Management and ISO are company-wide approaches which cannot easily be allocated to specific activities they are not illustrated separately. During the interviews the main focus was on the planning process and the mining operation, therefore the results shown in Table 2 may not completely reflect the use of Operational Excellence for customer management or for the listed support activities.

Table 2: Current Application of Operational Excellence in Mining

Business Strategy and Planning	Mine Strategy, Planning & Development	Mining Operations	Customer Management and Logistics	Support
Vision & mission setting	Detailed exploration & survey	Production planning	Customer & market strategy	Finance, accounts, risks & control
Market & business environment assesment	Geological modelling	Execution: mining, hauling, backfilling, etc.	Customer relationship management	Human resource
Product portfolio planning	Process design & planning	Quality Management	Inventory management	Information technology management
Stakeholder management	Resource planning (capital, equipment, manpower)	Technical engineering services	Logistics planning & execution	Health, safety & environment
Corporate strategy development	Financial feasibility	Asset Management: OEE, maintenance, replacement	Partner relationship management	Research & development
Corporate strategy implementation & monitoring	Mine Development: legal management, land acquisition, infrastructure construction, etc.			Knowledge management & improvement

Key:

Kaizen/ Continuous Improvement: Suggestion scheme, quality circles
Standard Work
Total Quality Management + Six Sigma
Total Production Management

5 Operational Excellence in Mining – Future Potential

After studying the objective and basic approaches of Operational Excellence as well as their current application in the mining industry, this chapter concentrates on future approaches to achieve excellence in the raw material sector. The considerations are based on the knowledge gained during the interviews, discussed in Chapter 4, and further on the personal opinions of the interviewees who were additionally asked to think about the possible potential of applying the described concepts and methods in the future.

In the last several years the mining industry had to face large challenges. While commodity prices continued to fall mining costs increased at a double-digit rate; as a consequence many mining projects have low returns and may therefore no longer be viable. Short term solutions like suspending workers, closing of mines and stopping all spending are not the answers for the future; the whole process of capital allocation needs to be reconsidered and significantly improved. Innovative mining companies are looking towards lessons learnt in other industries which faced the same challenges 20 years ago.

Adaption of existing approaches

During the interviews it became obvious that today's mining companies mostly understand the need of investigating time and money to achieve more efficient processes and products of high quality. The basis to obtain Operational Excellence is knowledge of the different approaches and therefore a proper education of employees. Regardless whether companies call an external consulting company or implement concepts on their own, their employees need to know background information about methods like TPM or Six Sigma. As these approaches are derived from other sectors of industry they mostly cannot be applied directly in the same way but need to be adapted to achieve the desired result. For example, the organisation of maintenance based on the Total Productive Management (TPM), described in Chapter 2.2.1, needs to be reconsidered in a mining operation. In contrast to a machine in the automobile industry which produces parts out of standardized material, the wear behaviour of a crusher does not only depend on the operating time but also on the amount of abrasive minerals in the mined material. This not only applies for crushers but also loaders, trucks or any other form of material transport system. As the amount of abrasive minerals changes within the deposit, the necessary maintenance activities and spare part service change depending on the state of mining. Nevertheless, TPM is applied successfully in mining companies because other aspects like the division of responsibilities between the operators and the maintenance team, described as “Autonomous Maintenance” in Chapter 2.2.1, are equally important and can be directly applied in the mining sector as well.

This example shows the importance of knowing the methods and tools which stand behind the different concepts but also the necessity to adapt the existing concepts to the specific environment in a mine. This means, mining companies who want to implement new systems need to invest time to get to know the already developed approaches and further to fine-tune them.

Application in all parts of the corporate process

As Table 2 summarizes the current application of concepts and methods of Operational Excellence separated in the fields of activity in a mining company, it also shows the areas where Operational Excellence is not yet applied. Regarding the coloured frames, it is obvious that the application is especially found during the mining operation and the activities linked to it, like asset management and inventory management. The conducted interviews have shown a successful implementation in these areas with potential of further improvement and adaption. Considering the chronology of the activities mentioned in Table 2, the concepts and methods of Operational Excellence are first applied when starting with the actual mining activities. As described in Chapter 1 Operational Excellence is by definition not only linked to the operations management of a company but should also influence the strategic formulation process; regarding the coloured frames in Table 2, the first column shows that approaches of Operational Excellence are currently not found in the state of “Strategy and Planning”. Operational Excellence should be integrated in the key mission statement and strategic option of a company; hence, to achieve Operational Excellence all activities of a company also including administration and data management need to be considered; the process starts with the business strategy and ends with the customer management.

The focus of today’s innovative mining companies is on introducing existing technology from other industries; the future potential of Operational Excellence in Mining can be found in adapting the existing approaches to the special conditions in the mining industry which are mainly caused by uncertainties due to nature. Companies should concentrate on elimination of waste rather than exclusively on cost-cutting which may erode an operation’s production ability, in the long run. In order to improve efficiencies and strengthen business processes production management systems need to be implemented which help to provide a holistic view of operations. This thesis indicates that many companies have not yet taken advantage of the potential to include Operational Excellence in the strategic formulation process and in this way to include it in every activity of a company. Today’s focus should be on technology innovation that goes beyond a simple tool optimizing one machine but on operational technology that improves the complete mining value chain. The planning needs to be enhanced by optimizing the process of decision making; at the same time the speed and quality of the capital allocation needs to be improved by automating the process. This means, instead of applying single methods which only affect some parts of the company, there is the need to create a holistic approach which covers all areas of an organisation and can therefore be applied company-wide.

6 Bibliography

Advantage Business Media, 2014. *ALN.* [Online]
Available at: http://www.alnmag.com/articles/2012/10/overview-lean-management-lab-animal-facilities
[Zugriff am 21 September 2014].

Anon., 2010. *December.* [Online]
Available at: http://livingmba.wordpress.com/2010/12/01/toyota-manufacturing-karawang-plant-visit-report/
[Zugriff am 25 August 2014].

Brunner, F. J., 2008. *Japanische Erfolgskonzepte.* s.l.:Carl Hanser Verlag.

Deming, E., 1982. *Out of the Crisis.* Cambridge: MIT Press.

Gleich, R. & Sauter, R., 2008. *Operational Excellence: Innovative Anstätze und Best Practices in der produzierenden Industrie.* München: s.n.

Hopp, W. J. & Spearman, M. L., 2001. *Factory Physics.* New York: McGraw-Hill.

Ho, S. K., 1995. *TQM an integrated approach.* s.l.:s.n.

JMA Consultants Inc, n.d. [Online]
Available at: http://tpm.jipms.jp/tpm/index.html
[Accessed 6 10 2014].

Kano, N., 1984. Attractive Q Vs Must Be Q. *Hinshitsu (Quality)*, pp. 39-48.

Leikep, S. & Bieber, K., 2004. *Der Weg. Effizienz im Büro mit Kaizen-Methoden.* Norderstedt: s.n.

Liker, J., 2004. *The Toyota Way.* New York: McGraw-Hill.

Liker, J. & Franz, J., 2011. *The Toyota Way to Continuous Improvement.* New York: McGraw-Hill.

Liker, J. & Hoseus, M., 2008. *Toyota Culture.* New York: McGraw-Hill.

Liker, J. K. & Convis, G. L., 2012. *The Toyota Way to Lean Leadership.* United States of America: s.n.

Little, J. D., 1961. A Proof for the Queuing Formula: L= λW. *Operations Research Vol. 9 No. 3*, pp. 383-387.

May, C., 2007. Operational Excellence - Mit TPM zu Weltklasseformat. *ZWF*, pp. 479-483.

May, C. & Schimek, P., 2009. *Total Productive Management: Grundlagen und Einführung von TPM - oder wie Sie Operational Excellence erreichen.* Ansbach : s.n.

Miller, A., 2014. *Redefining Operational Excellence.* Uunited States of America: s.n.

Nakajima, S., 2006. *The principles and practice of TPM.* Tokyo: s.n.

Ohno, T., 1993. *Das Toyota-Produktionssystem.* s.l.:Campus Verlag GmbH.

Parasuraman, A., Zeithaml, V. & Berry, L., 1990. Delivering quality service. *Free Press*.

Process Quality Associates Inc, 1996 - 2006. [Online] Available at: http://www.pqa.net/ProdServices/sixsigma/W06002002.html [Zugriff am 18 September 2014].

Shirose, K., 2005. *TPM. New Implementation Program in Fabrication and Assembly Industries.* 6 Hrsg. Tokyo: s.n.

Soin, S. S., 2012. *Winning with Operational Excellence - A practical Manual.* s.l.:s.n.

Spear, S. & Bowen, H. K., 1999. Decoding the DNA of the Toyota Production System. *Harvard Business Review*, Sept.-Oct., pp. 97-106.

Töpfer, A., 2003, 2004, 2007. *Six Sigma - Konzeption und Erfolgsbeispiele für praktizierte Null-Fehler-Qualität.* s.l.:Springer-Verlag Berlin Heidelberg .

Töpfer, A., 2009. *Lean Six Sigma.* s.l.:Springer-Verlag Berlin Heidelberg.

Toyota Motor Corporation, 1995-2014 . *Toyota Website.* [Online] Available at: http://www.toyota-global.com/company/vision_philosophy/toyota_production_system/ [Zugriff am 19 August 2014].

Treacy, M. & Wiersema, F., 1993. Customer Intimacy and Other Value Disciplines. *Harvard Business Review*, January/February, pp. 84-93.

WebFinance Inc., 2014. *Business Dictionary.* [Online] Available at: http://www.businessdictionary.com/definition/operational-excellence.html [Zugriff am 10 September 2014].

WebFinance Inc., 2014. *Business Dictionary.* [Online] Available at: http://www.businessdictionary.com/definition/target-costing.html [Accessed 20 September 2014].

Witcher, B. J., 1990. Total Marketing: Total Quality and the Marketing Concept. *The Quarterly Review of Marketing*.

Womack, J. & Jones, D., 1996. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation.* New York: Simon & Schuster.

Wong, S., 1995. Business Process Re-Engineering or Continuous Improvement?. *Quality World*, January.

7 List of figures

8 List of tables

Annex

1 Toyota Production System

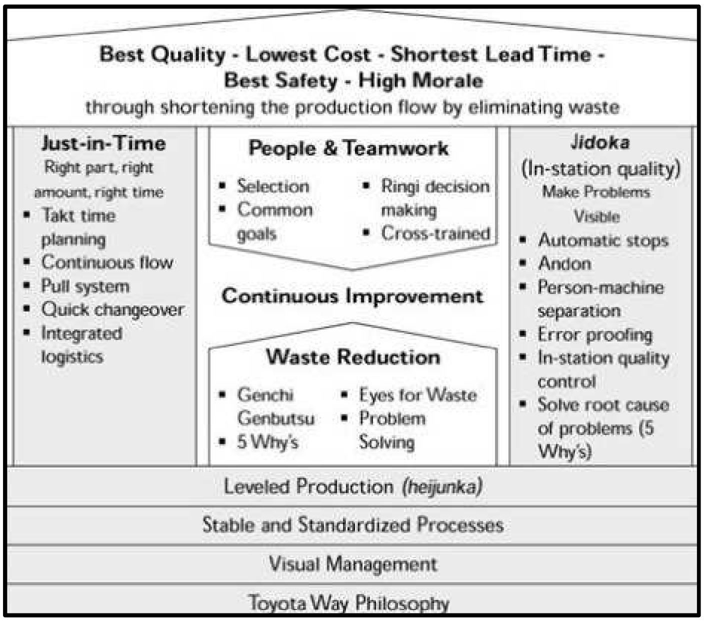
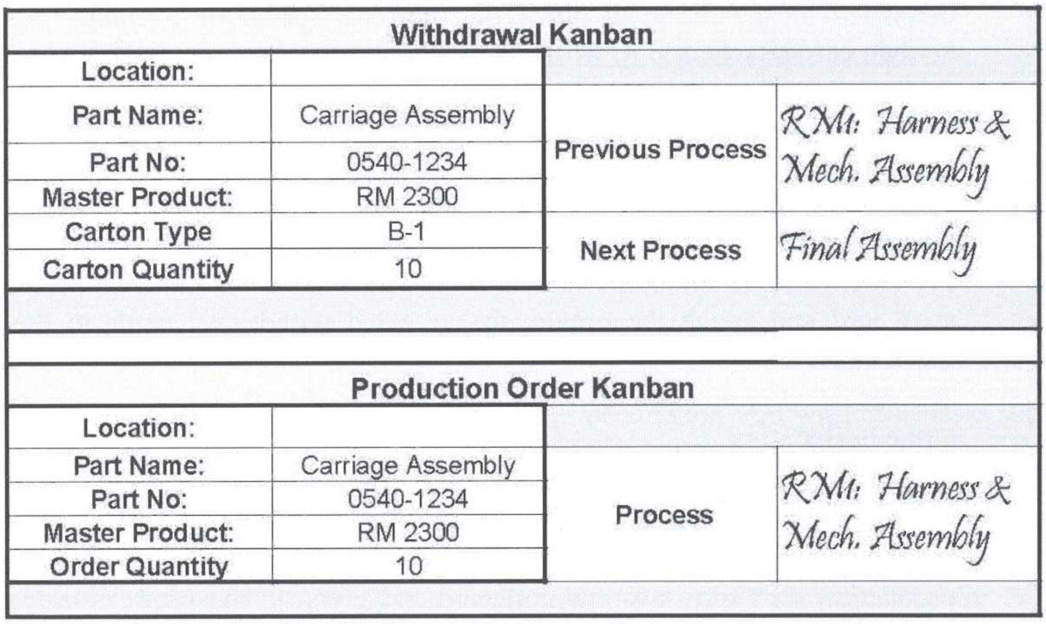


Figure 22: More detailed TPS-house (Anon., 2010)

1.1 Just-In-Time

1.1.1 The Kanban System



Withdrawal Kanban

Location:			
Part Name:	Carriage Assembly	Previous Process	RM1: Harness & Mech. Assembly
Part No:	0540-1234		
Master Product:	RM 2300		
Carton Type	B-1	Next Process	Final Assembly
Carton Quantity	10		

Production Order Kanban

Location:			
Part Name:	Carriage Assembly	Process	RM1: Harness & Mech. Assembly
Part No:	0540-1234		
Master Product:	RM 2300		
Order Quantity	10		

Figure 23: Kanban withdrawal and production cards (Soin, 2012, p. 68)

1.1.2 Takt

<u>Yamazumi Charts</u>

An unbalanced line is easy to see but can be a challenge to fix. In such a line production will be in an unstable stop-and-go phase. Yamazumi charts help to display cycle times and therefore can be used to facilitate line balancing. Yamazumi is Japanese for heap, mound, or stack; hence a Yamazumi chart is a stacked bar chart, which shows cycle times at various stations vs Takt time of the production line or cell. It is used to visualize the work content for a series of assembly operation. Typically, each stacked bar is segmented into the individual tasks at each work station.

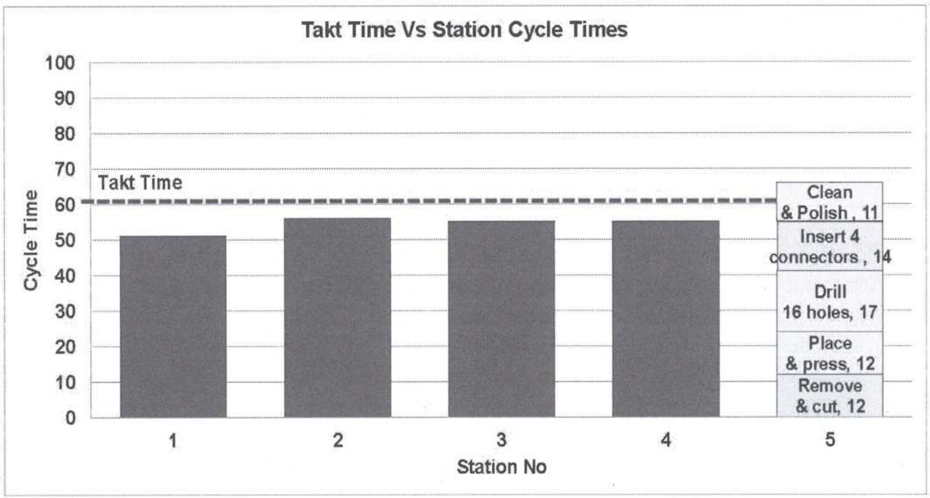


Figure 24: Yamazumi Chart used for line balancing (Soin, 2012, p. 56)

For preparing a Yamazumi Chart all tasks performed by the operator at the assembly stations are observed. The first noticed task at the first station and the time taken for this task is the first segment of Yamazumi stacked bar chart. This observation is repeated for all tasks at the first assembly station and further for the tasks at all following assembly stations. Figure 24 shows a Yamazumi chart displaying cycle times for 5 workstations in a cell. The cycle time for station 5 which exceeds the Takt time is segmented into the assembly steps for that station; to identify improvement typically the assembly steps of all stations are shown.

Charts can be constructed manually on a white-board or on paper with an Excel program; they may be displayed beside a production line or cell and updated real-time for discussion and further improvements.

(Soin, 2012, p. 57)

1.2 Kaizen

The Seven Quality Tools Q7

Type of failure		Number
Scratch	𝍸 𝍸 𝍸 II	17
Cauterization	𝍸 𝍸 II	12
Runner	III	3
Damage	𝍸 𝍸 III	13
Sundries	II	2
Sum	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 II	42

Figure 25: Defect Collection List (Brunner, 2008, p. 17)

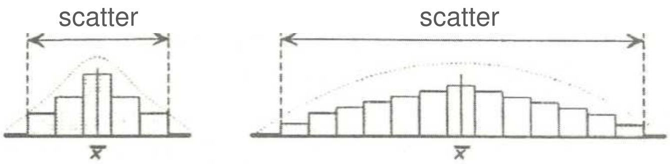


Figure 26: Histogram with mean value $\bar{x}$ and scatter (Brunner, 2008, p. 14)

Failures according to their sources	
Machine	**Number of failures**
Box warehouse	20
Aspirator	41
Box folder	24
Gluing	88
Press-on station	10
Sum	**183**

Figure 27: Detection of the main problem sources (May & Schimek, 2009, p. 97)

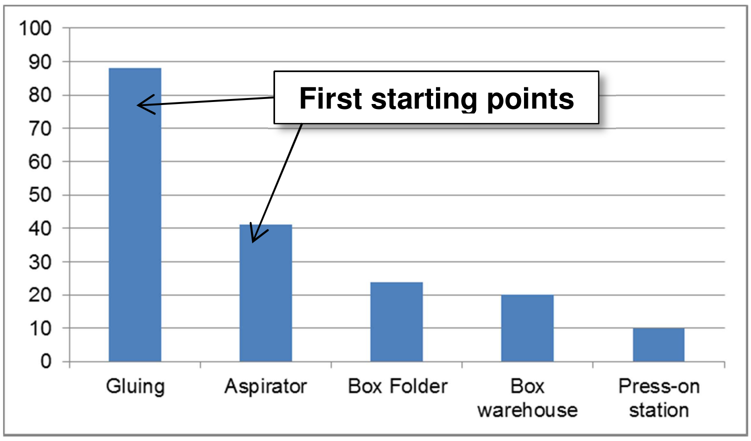


Figure 28: Pareto Diagram: Evaluation of the problem sources (May & Schimek, 2009, p. 97)

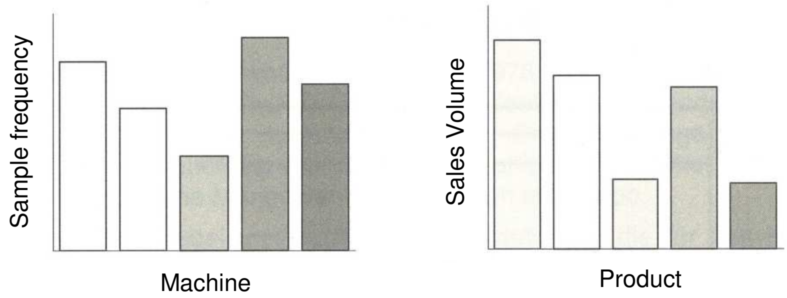


Figure 29: Stratification (Brunner, 2008, p. 15)

Cause and effect are connected with an arrow pointing at the problem. The area of causes is divided into group causes, single causes and secondary causes. Group causes are man, machine, method, material, environment and sometimes also measurement. Single causes are causes of the group causes while secondary causes are causes of the single causes; all of them are connected with arrows. (May & Schimek, 2009, p. 98)

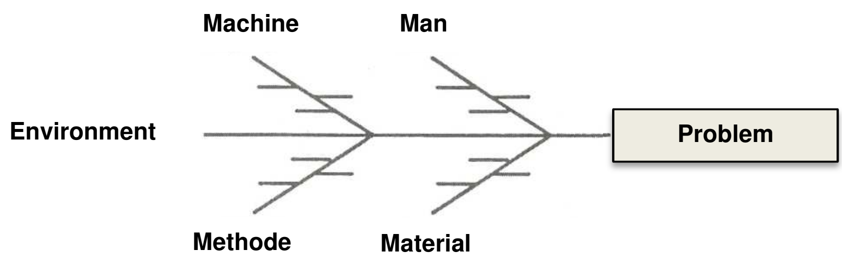


Figure 30: Cause and Effect Diagramm or Ishikawa Diagram (with 5 main sources of problems) (Brunner, 2008, p. 15)

The original four branches of the Ishikawa Chart (human, machine, material, method) can be complemented by three more (measurement, environment, management). Ten questions are asked regarding each branch to find the problem sources. (Brunner, 2008, p. 24)

Figure 31: Correlation Diagram (Brunner, 2008, p. 16)

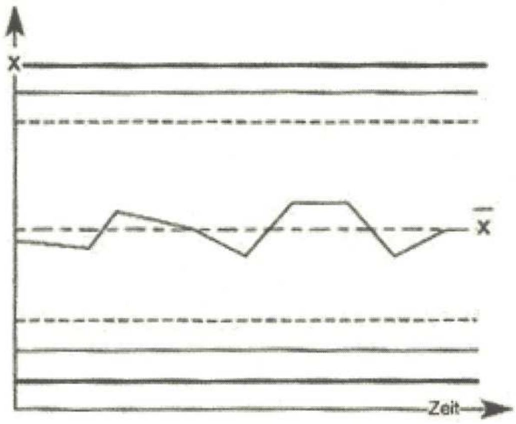


Figure 32: Quality Control Chart (Brunner, 2008, p. 16)

The Seven New Management Tools N7 or M7

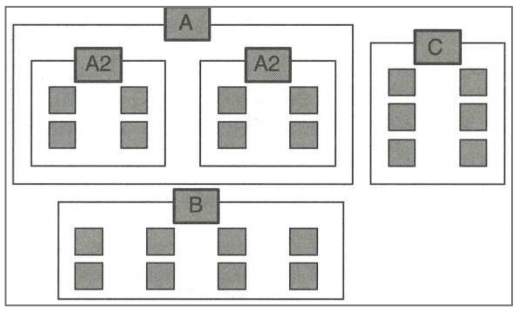


Figure 33: Affinity Diagram (Brunner, 2008, p. 18)

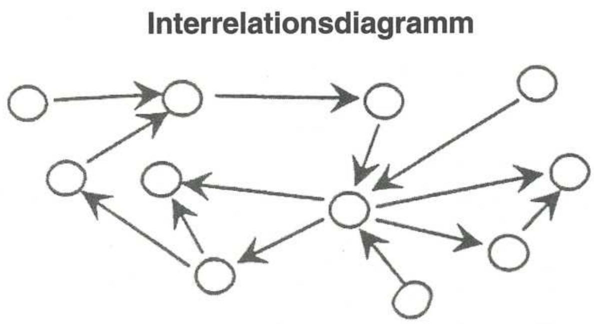


Figure 34: Interrelation Chart (Brunner, 2008, p. 19)

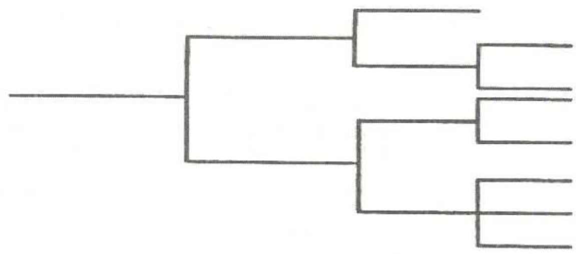


Figure 35: Tree Diagram (Brunner, 2008, p. 19)

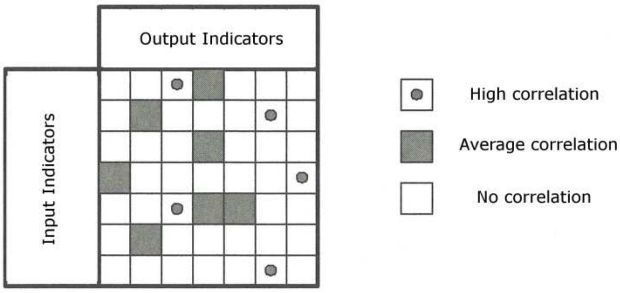


Figure 36: Matrix Chart (Brunner, 2008, p. 20)

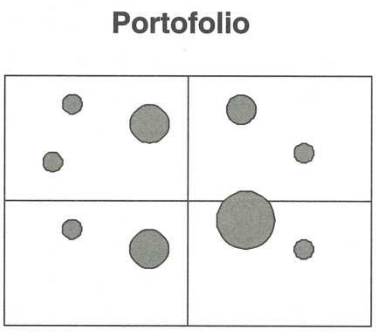


Figure 37: Portfolio (Brunner, 2008, p. 21)

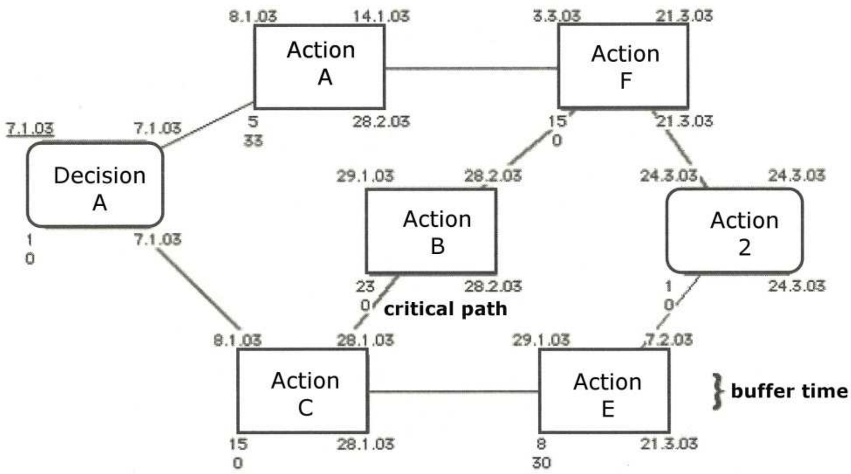


Figure 38: Network Plan (Brunner, 2008, p. 20)

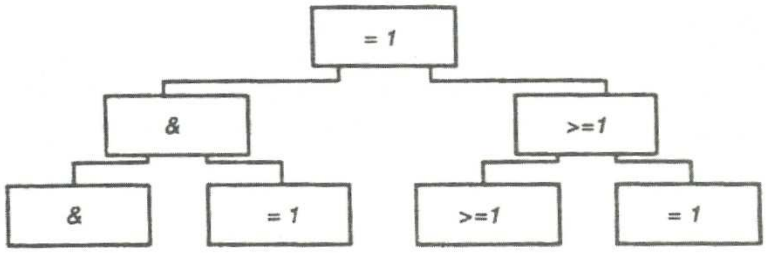


Figure 39: Decision Tree (Brunner, 2008, p. 21)

1.3 Standard Work

Concept

Standard work determines the methodology for work to complete one job, work or process in a multi-process environment. Therefore, any production operator doing the same work will use the same method during any work shift or at any factory. Three components must be included in standard work:

1. All steps in the work sequence
    a. The document title
    b. The work instruction in the right sequence at each station using photos or cartoons to illustrate the work, if possible.
    c. Required tools: screwdrivers, measurement gauge…
    d. Personal requirements of the production operator: gloves, safety shoes…
    e. Quality information specifically for the job
    f. Safety information
    g. Observation log: concerning complex jobs, difficulties and suggestions for improvement should be recorded in order to ensure feedback to the supervisor which may be used for revision of standard work.
    h. Other technical details: author, revision date, approval…
2. The workstation cycle time required to complete the work (see Chapter 2.1.1.2)
3. The required material and recommended inventory level at the workstation: to provide this, parts that are added to the work during the job and quantity required

need to be listed. Photos of each part help the production operator to identify the different part visually.

(Soin, 2012, pp. 28, 29)

Preparation

Preparing standard work is not a one-time project but an ongoing process requiring continuous improvement. Hence, it requires experienced engineers or technician with a trained eye to observe and improve the process. Prior to the new product introduction, the process engineer typically prepares a draft together with the R&D engineer involved in the initial design. All assembly steps need to be recorded in detail and in the sequence the work must be done. The sequence is essential as in certain design wrong sequences of operations may cause errors. In the next step, the cycle time for each station must be measured. This is done by breaking up the work procedures into discrete individual steps. For example:

1) The operator reaches for the work piece or job.
2) The operator prepares to work on the job, reaches for tools and gets parts.
3) The operator works on the job.
4) The operator loads the job into a machine or tester.
5) The operator completes the job and puts it away.

Standard work is best developed with the involvement of the production operators; otherwise the developed procedures and documents may be too far from practice. Previous to the production start, the production operator is selected for each workstation depending on job complexity as well as operator experience and education. During production the actual performance is observed and the draft standards are validated for the entire production line. The data collected in the prototype stage will be used to fine tune the standards for the entire productions line. But the improvement process should not start until the operators have had some time to move up the learning curve.

(Soin, 2012, pp. 31, 33-35, 38)

1.4 Value Stream Mapping

Procedure

VSM project can cover only one or several operation or also can span an entire company.

The basic steps in Value Stream Mapping are:

1. Formation of a VSM project team and appointing a leader: the team members should be familiar with the product and understand the process flow from supplier to manufacturing to the customer. In case of a multi-operation VSM spanning across the company, representatives from each operation should join the team.
2. Selecting the operation of product for the project.
3. Gathering the facts and data at the shop floor: it is crucial to get the information directly from the production floor; for larger operations, affecting several sites, visiting all sites is essential. This is similar to the Gemba walk (see Chapter 2.1.3).
4. Drawing the VSM map representing the product and process flow from supplier to customer: the map shows both physical and information flow.

   The following list of required information is taken out of (Soin, 2012, pp. 232, 233):

   - Incoming inventory and supplier transit times
   - Incoming suppliers and incoming quality inspection
   - Each workstation: defects, cycle time, inventory, one-piece Vs batch
   - Each test station: defects, cycle time, inventory, one-piece Vs batch
   - Each inspection station: defects, cycle time, inventory, one-piece Vs batch
   - Equipment, workstation, and product changeover times
   - Storage locations and quantity between work or test stations
   - Finished goods inventory at the factory and other locations
   - Finished goods inventory at distribution centres
   - Number of operators at stations and warehouses
   - Floor space at each location
   - Transit times to distribution centres and customers
   - Information flow for orders, response times, lead times. (This is especially useful in case of drawing a VSM for multiple locations and geographies.)
   - After all workstations are sketched into the VSM map, a cycle time graph below the stations is drawn to show cycle times, changeover times, and non-value added time. This will help to highlight opportunities.

5. Double-checking and categorization of the important points at each station or location and completing the VSM map including inventory levels, lead times, defect levels, people count, cycle times, changeover times, and floor space. These categories show cost and effort - here waste can be identified. After finalizing the map, it can be shared and discussed with the team.
6. Review and analysis of the data in the VSM map: besides some obvious opportunities, an understanding and intense review of current practices may be required to generate new ideas and priorities.
   Review:
   - Major process areas: cycle time, changeover timer, resources, capacity
   - Bottlenecks in the system due to changeover or capacity
   - Inventory areas in the system
   - Other waste in the system: defect rates, excess transit time, non-value added time, defects, excess people, excess floor space
   - The impact of information flow (electronic and manual) o physical flow

   Important question to be asked: does this activity add value to the customer (not to the company)?
7. Future state map: discussion of potential future state and sketching out target parameters example given for cycle time, changeover time, inventory, or floor space.

(Soin, 2012, pp. 232, 233)

2 Total Productive Management (TPM)

2.1 The Eight Building Blocks

1. Focused Improvement

The step-by-step approach within the first building block follows the PDCA cycle (see Chapter 2.5.2):

1) Analysis of the 16 types of losses
2) Selection of the improvement area using a Pareto-analysis (see Chapter 2.1.3.1)
3) Forming cross-functional improvement teams
4) Root cause analysis
5) Determination of countermeasures including timeframe and responsibilities
6) Control of success through redrawing the Pareto diagram (see Chapter 2.1.3.1) and comparing the initial and new OEE

(May & Schimek, 2009, pp. 18, 26-39)

2. Autonomous Maintenance

A step-by-step approach is recommended to handle the task mentioned above:

1) Basic inspection with the motto “Cleaning means checking”
   Starting with a brief instruction of all participants, the basic inspection should follow the 5S method (see Chapter 2.2.2.8). The output of this first step should be new or optimized maintenance plans.
2) Elimination of sources of pollution and inaccessible places in order to reduce the time required for maintenance and cleaning
3) Implementation of standards for cleaning and inspection
   Standard work is the basis for continuous improvement. In order to increase the acceptance of the employees they should be develop the standards by themselves.
4) Qualification of employees concerning machine and plants
   Workers are trained in autonomous inspecting and maintaining the machines. Due to the required training, this step may take a long time.
5) Conduct of the autonomous maintenance by the operator
6) Systematisation

Measures are taken to standardize and systemize the previous activities and data collected.

7) Full implementation of autonomous maintenance

   This includes the transition to a continuous improvement process without taking any new measures.

(May & Schimek, 2009, pp. 18, 40-49)

3. Planned Maintenance

In planned maintenance a systematic approach in seven steps is recommended:

1) Current status of the plant

   It is important to generate data about the availability as well as the required maintenance effort of the production facilities. Therefore it is necessary to create and keep a plant book; this book comprises basic information like manufacturer or year of construction but further also reports about reconstruction works, autonomous maintenance, realised reinstatement work and information about replacement parts or wearing parts.

2) Elimination of wear marks and weaknesses through work in small groups: success can be checked by comparing MTBF and MTTR.

3) Development of an information system

   This includes systematic collection of plant information, failure classification, type of failure, failed components, cause of failure, taken measures and required resources for the elimination of failures; it is often computerized.

4) Implementation of time controlled maintenance

   Plants and their components are maintained in scheduled time intervals based on experience and independent of their current status; typically, the work can only be done during a shutdown. Therefore the time controlled maintenance is applied for components with known useful time or where time intensive and complex demolition is required. The challenge is to organize this maintenance during the daily production.

5) Implementation of foresighted maintenance

   The status of a component is checked during operation using specific measuring systems. Two conditions are important: appropriate measurement method must be available, to detect changes of state (e.g.:

vibration monitoring, thermography, ultrasonic measurement) and sufficient time to replace the defective component is required.

6) Evaluation of planned maintenance
   Success can be measured based on key parameter; if necessary, corrective measures are taken.
7) Full implementation of planned maintenance

(May & Schimek, 2009, pp. 18, 20, 50-55)

4. Competence Management (Education and Training)

5. Early Management

The step-by-step approach within the fifth building block:

1) Product development: determination of process steps and the system man-machine-material-method (4M) is based on the planned product; the involvement of employees from production and maintenance department is important.
   Tools: QM-Matrix (see Chapter 2.2.1), 4M-Analysis (see Chapter 2.1.3.1), FMEA (Failure Mode and Effect Analysis) (see Chapter 2.5.4.3)
2) Plant concept: besides basic criteria (like capacity, Takt time or investment cost) also the demand for high plant reliability, for good operability and maintainability as well as for process capability must be fulfilled.
3) Plant construction: the target is to minimize the effort for maintenance and replacement parts as well as to reduce part variety. At the end, the construction should be checked by the production, maintenance, technic and construction department.
4) Production: employees get to know the plant already during production.
5) Installation: effected employees are involved intensively to become familiar with the plant before production starts.
6) Start up:
   Start-up time is the time from the production start to a stable serial production; it should be as short as possible. The plant is overburdened temporarily - it is the last chance to detect failures. Standards for operation, setting-up and maintenance are set.

7) Operation: after a successful start-up the goal is to have continuous improvement; this is achieved through permanent feedback of information, experiences and realised improvements to the planning and construction department.

(May & Schimek, 2009, pp. 20, 68-71)

6. Quality Maintenance

Tools:

- 8 Method

  The implementation starts in the left circle (circle of maintenance); if a defect is found, there is a change into the right circle (circle of improvement) in order to eliminate it. The seven steps are performed until all defects have been remedied. (May & Schimek, 2009, p. 74)

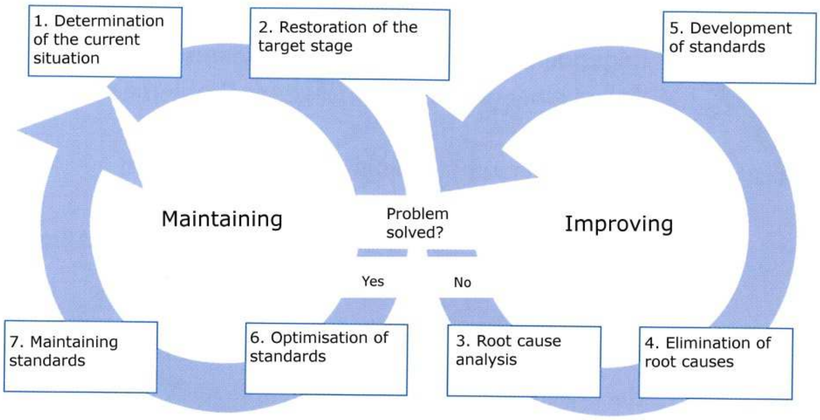


Figure 40: 8 Method (May & Schimek, 2009, p. 74)

Figure 40: 8 MethodFigure 40 illustrates the activities of the steps in detail (source: (Nakajima, 2006) according to (May & Schimek, 2009)):

1. Determination of the current situation supported by numbers and facts: the quality management matrix helps to define the basic conditions of the process
2. Restoration of the target state and checking the results using a QM matrix: if the problem is solved, it can be moved to step 6, if not, the circle of improvement starts at step 3.
3. Root cause analysis: supported by TPM tools like 5W analysis (see Chapter 2.2.2.1); eventually standards are adjusted.
4. Solving of problems and checking of results

5. Redrawing QM-matrix and setting of additional standards
6. Reduction of number of standards and extension of intervals in order to minimize the number of standard checks
7. Controlling and if necessary adjusting of standards through trend analysis

- Quality Management Matrix

  The matrix comprises all process steps including quality requirements and possible defects. The target is to achieve standardized products and processes free from defects.

  The development starts with the conscientious documentation of all processes and activities; the results are separated to identify and analyse possible failures or defects of the different activities. The work is summarized in a clear and systematic way using a matrix form. In the end the failures and defects are weighted according to their negative impacts.

- Statistical tools

(May & Schimek, 2009, pp. 20, 21, 72-76)

7. TPM in Administration

Step-by-step approach (source: (Leikep & Bieber, 2004) according to (May & Schimek, 2009)):

1. Creating a good starting situation via self-organisation: 5S action (see Chapter 2.2.2.8) followed by time scheduling including milestones; audits (see Chapter 2.2.2.9) help to control the process.
2. Improvement of team work through consistent rules and standards
3. Economising through process improvement

   Applicable tools: Process mapping (see Chapter 2.5.4.2), value stream mapping (see Chapter 2.1.6), Makigami (see Chapter 2.2.2.6)
4. Preservation of the achieved status through further optimising in teams: the visualisation of key parameters and targets is important to get an overview over the improvement activities and the trend of each team.
5. Full responsibility for flexible working in teams

   The target is to optimise the use of resources through developing a new room and mobility concept where work places are not personalized anymore but bound to functions.

6. Process control through “Best-in-Class”: additional room for improvements can be found via benchmarking with world-class companies.
7. Full application in the entire company including cross-company processes (involvement of suppliers and customers)

(May & Schimek, 2009, pp. 21, 76-81)

8. Safety, Health and Environment (HSE)

2.2 TPM Tools

2.2.1 5W Method

Example: A failed motorized window of a car

- Why was the car window not working?
  We opened the door panel and found a damaged cable harness wire.
- Why was the cable harness damaged?
  It was cut and damaged because it was trapped between the door panel and the door body when the panel was screwed in.
- Why was it trapped by the panel, hence damaged?
  The harness was very near to the edge of the door panel cover (refer to pictures) and protruding out of the door well
- Why was the wire protruding out of the door well?
  Currently the operator has to judge if the cable harness is in the correct position before screwing in the door panel.
- Why does the operator make a judgement call?
  The standard work instruction does not give any guideline; it only provides a quality alert or warning: “be careful that the harness does not protrude out before you screw in the panel”.

OK, let’s review the standard work document…….

(Soin, 2012, p. 112)

2.2.2 Makigami

The basic procedure starts with the detection of the current state in a so called current-state-map followed by the development of the future-state-map:

1. Description of the affected process
2. Determination of people and departments involved
3. Every process step is analysed by a group pf people
4. Connection of steps using red and green arrows. Red signifies that problems can occur or information is missing. Green signifies that all necessary information is available and no problems are detected.
5. Each process step is brought into question and characterized as value adding or non-value adding.
   Criteria:
   – Does this step enhance the process?
   – Is the customer satisfied?
   – Are there legal regulations which make this step compulsory?
6. Implementation of time axis
7. Determination of action time, time when the activity is carried out.
8. Determination of value adding time (see step 5)
9. Calculation of loss time: Action time minus value adding time
10. Counting of transfers occurring through passing on of information to other persons or departments
11. Counting of data carrier
12. Determination of overall time

(May & Schimek, 2009, pp. 99-101)

3 Planning

3.1 The Planning Process

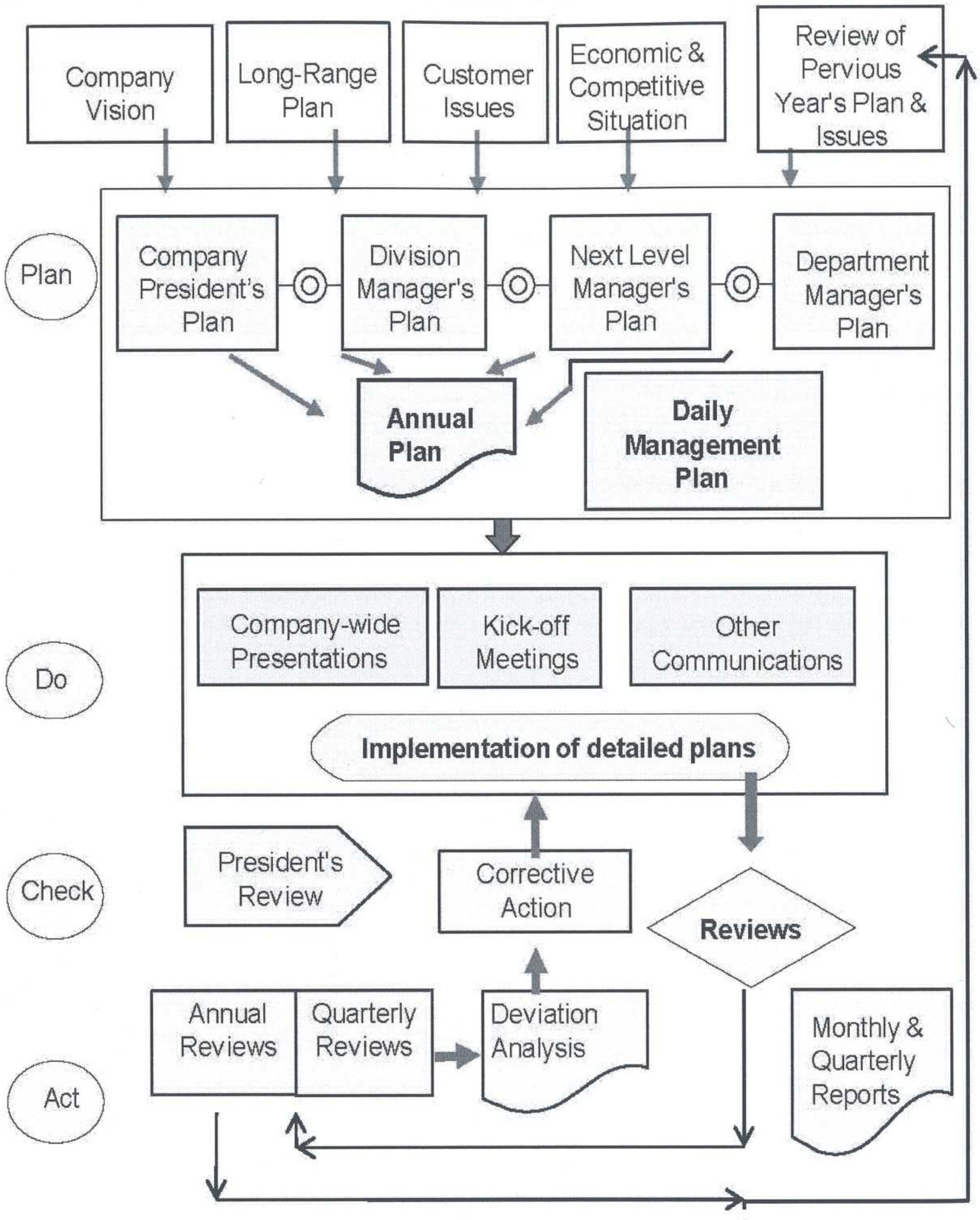


Figure 41: Hoshin Planning Flow Chart (Soin, 2012, p. 196)

3.2 Annual Hoshin Plan

ANNUAL HOSHIN PLAN			
Objective	Target/Goal	Strategy & Owner	Performance Measure

Figure 42: Hoshin Plan Format (Soin, 2012, p. 198)

3.3 Daily Management Plan

Elements in a Daily Management Plan:

- Item: the plan has items which need to be well understood and documented. An average number of ten items for each manager or department is recommended otherwise it may be too difficult to manage the activities.
  Potential items for a manufacturing operation:
  - The daily production plan for: Targets and performance
  - Productivity: Actual data Vs targets
  - Production yields and other wastes
  - Customer satisfaction index, via customer complaint resolution, product usage satisfaction, on-time delivery
  - Product quality and reliability
  - Kaizen or improvement activity
  - Overall cost tracking, including actual expenses Vs targets
  - Safety and employee morale
- Goal and control limit: each item will have a goal with certain control limits. In case of deviations analysis and countermeasures are required.
- Review date
- Data source
- Owner: ownership or responsibility must be clearly defined.

(Soin, 2012, p. 215)

DAILY MANAGEMENT PLAN									
No.	Item	Goal & Action Limits	When Reviewed	Data Source	Actual Performance				Owner
					Jan.	Feb.	Mar.	----	

Figure 43: Format of Daily Management Plan (Soin, 2012, p. 216)

3.4 Implementation or Project Plan

IMPLEMENTATION PLAN								
No.	Strategy and Performance Measure	Implementation Details	Timeline					Owner
			Jan.	Feb.	Mar.	Apr.	-----	

Figure 44: Format of Implementation Plan (Soin, 2012, p. 213)

4 Quality: Improvement and Control

4.1 The PDCA Cycle

PLAN stage

1. Select the theme or project

   The objective of this step is to clearly define problem which needs to be solved.

   a. Project background and reasons for selection

      The project can be selected from the department objectives, customer complaints, or area selected for improvement. However, the background must be very clear. At the beginning, the project team must be formed including relevant experts in process, production, and quality. A team leader, a record keeper and, if necessary, a facilitator or champion must be appointed.

   b. Setting the objective and target of the project

      The targets always need to be reasonable and realistic. It is important to use current and competitive data; therefore the target can also be set after step 3, when more data is available.

   c. Schedule of activities

      The steps in the PDCA cycle are listed including the expected time frame of each step.

   QC tools used for step 1: Trend Chart (see Quality Control Chart in Chapter 2.1.3.1), Pareto diagram (see Chapter 2.1.3.1)

2. Grasp the current status: Get and review the data

   The Objective of this step is to understand the problem and to highlight specific problems. By reviewing the available data, the effects of the problem are studies from several facets, such as time, location and type.

   Example: reduction of failures during the production

   - Time: looking at failures between the day and night shift, and over a period of time
   - Location: identifying those parts of the machine with the highest failure rates and visualizing the results in graphs and Pareto charts (see Chapter 2.1.3.1); in addition, the process flow chart of the product must

be studied in order to understand the current process and highlight the critical locations.

According to Spear and Bowen (source: (Spear & Bowen, 1999) according to (Soin, 2012)), in reviewing production errors at Toyota Motors, typical failure modes or causes for current problems can often be traced to failures in 3 specific areas:

- Standard work (work sequence, work timing, or defective material)
- Customer-supplier connection, communication, and capability are clear regarding mix, demand, specifications, and ability to manufacture
- Clear, simple, and direct pathways for every product and service resulting in good workflow

Methods which support the process of analysing the current status are the 5W method (see Chapter 2.2.2.1) and the 5W/2H method (see Chapter 2.2.2.7).

QC tools used for step 2: Trend Chart (see Quality Control Chart in Chapter 2.1.3.1), Pareto diagram (see Chapter 2.1.3.1), Process flow charts, control charts (see Chapter 2.1.3.1), histograms (see Chapter 2.1.3.1), process capability indices

3. Analyse the cause and determine corrective action
   The objective of this step is to determine the root cause of the problem, and plan for corrective action.
   1. Preparation of a cause and effect diagram (see Chapter 2.1.3.1)
      The diagram can be developed through a brainstorming session.
      In the next step unlikely causes are eliminated based on data obtained in step two and the cause and effect diagram can be simplified and re-drawn.

      Depending on the problem encountered, other applicable tools include a FMEA analysis (see Chapter 2.5.4.3), matrix diagram (see Chapter 2.1.3.1) and 5W (see Chapter 2.2.2.1).
   2. Preparation of a hypotheses and verification of most likely causes
      In this step the most likely are selected causes out of the cause and effect diagram and must be verified. It is recommended to use new data to determine if there is a relationship between the selected causes and the

effect; this may require experiments. The result is a short list of verified causes which are the root causes of the problem.

3. Determination of corrective action

   If the corrective action is not obvious, it must be decided on a specific action. Therefore creative alternatives should be generated using brainstorming or cause and effect diagrams.

   In general, there are 2 types of corrective actions or countermeasures:

   i. Short term fix or containment action: this is typically required at the beginning of a critical failure; but as this is not the most effective solution it may be skipped during a routine continuous improvement project.
   ii. Long term fix or preventive action: this will include the elimination of the root cause and therefore prevents the problem from reoccurring. Due to constraints of implementation the quick fix may be implemented first. For complex project, a implementation plan may be recommended.

QC tools used for step 3: Check sheet (see Chapter 2.1.3.1), Checklist (see Chapter 2.1.3.1), implementation plan (see Chapter 2.4.1.4), stratification (see Chapter 2.1.3.1), statistical design for experiments, cause and effect diagram (see Chapter 2.1.3.1), FMEA analysis (see Chapter 2.5.4.3), Pareto diagram (see Chapter 2.1.3.1)

DO Stage

4. Implementation of the corrective action

   The objective of this step is the implementation of the plan and the elimination of root causes of the problem. It is essential, that the employees executing the correction understand the corrective action. Hence, good education and training will be necessary.

   a. Preparation of instructions and flow charts for complicated procedures
   b. Training
   c. Exactly execution of the plan
   d. Record of any deviation from the plan and collection of data on results

QC tools used for step 4: Check sheet (see Chapter 2.1.3.1), Checklist (see Chapter 2.1.3.1), standard work (see Chapter 2.1.3), Trend Chart (see Quality Control Chart in Chapter 2.1.3.1)

CHECK Stage

5. Checking the effect of the corrective action

   The objective of this step is to check the effectiveness of the corrective action. In this step the overall results are reviewed in order to compare before and after performance; graphical tools can be used. If the target is not achieved some steps in the PDCA cycle need to be repeated. If a failure occurs due to improper implementation, the cycle starts again at step 4; otherwise it starts already at step 3 (analysis). If the overall results are equal or better than the target set in step 1, possible side effects, meaning an increase in another category of failures, need to be identified.

QC tools used for step 5: Pareto diagram (see Chapter 2.1.3.1), histograms (see Chapter 2.1.3.1), control charts (see Chapter 2.1.3.1), Trend Chart (see Quality Control Chart in Chapter 2.1.3.1), and process capability indices.

ACT Stage

6. Taking appropriate actions

   The objective of this step is to ensure that the improved level of performance is maintained.

   a. Documentation, standardization and control: the corrective action should be documented in current operating procedures or standard work. In addition, it is important to identify critical process parameters to control. Hence, the standard work instruction, production control plan, or quality checkpoint chart should be updated.
   b. Training: to guarantee that employees have fully understand all changes and new procedures the new standard work needs to be trained.

QC tools used for step 6: standard work instructions (see Chapter 2.1.3), Check sheet (see Chapter 2.1.3.1), control charts (see Chapter 2.1.3.1), Trend Chart (see Quality Control Chart in Chapter 2.1.3.1), and control plan

7. Decisions on future plans

The objective of this step is to use the experience gained for future projects. The area of the new project can be found in the result of step 5. If there are sharp peaks in the Pareto diagram or trend chart or if side effects have been created, they must be eliminated. But previously, the process must be documented according to the seven steps mentioned above. Whether the current project is continued or a new one is selected has to be based on priorities and resources.

(Soin, 2012, pp. 109-115)

4.2 Total Quality Management (TQM)

Best Practice Benchmarking (BPB)

The process of BPB takes place in five steps. It can be applied to both large and small companies. While large companies will tend to gather greater quantities of information and will be more concerned with issues of competition, small companies will focus on a few critical areas and be more concerned with operational improvements.

1. Selection what to benchmark

   Key questions:

   - What would make the most significant improvements in the relationship with the customers?

     Benchmarks important for customer satisfaction might include:

     – Consistency of product
     – Correct invoices
     – On time delivery
     – Frequency of delivery
     – Speed of service

   - What would make the most significant improvements in the bottom line of the company?

     Benchmarks important for direct impact on costs might include:

     – Waste and rejects
     – Inventory levels
     – Work in progress
     – Cost of sales
     – Sales per employee

2. Listing who to benchmark against

   Important considerations:

   - Do they know the company? (Customers and suppliers should already have a good relationship with the company)
   - Is their experience really relevant?
   - Are they still at the activity which will be measured? A company can live off its reputation for a long time.
   - Is it legally possible to exchange this kind of information with the company?

   In practice, there are four different types of an organisation you can benchmark against:

   - Other parts within the company
   - Competitors: while this is very useful for large companies, small companies should base benchmarking on the customers' standards instead.
   - Parallel industries: this provides many ideas for radical improvements. Companies of the same industry often tackle the same problems in the same way, whereas companies in parallel industries may use different approaches.
   - Totally different industries: this is used to compare against very specific activities.

3. Getting the information

   Previous to company visits, extensive desk research is required to know what to look for and the right questions to ask. A variety of sources is used and double-checked against each other.

4. Analysing the information
5. It is important to filter the information necessary for direct comparison of performance.

6. Using the information
   - Implementing new standards for the expected performance and communicating them to everyone concerned in the organisation including an explanation of why standards have been raised.

- Selection of someone in authority responsible for devising an action plan to reach the new standards
- Providing resources for employees to do additional research
- Monitoring progress to ensure that the plan is implemented effectively.

(Ho, 1995, pp. 114-116)

Total Quality Marketing (TQMar)

TQMar involves continuous improvement in the marketing functions. The following seven-step process is recommended:

- Clarifying the vision in relation to market opportunities, where companies have had difficulties in understanding, developing, communicating and sharing common values, relative to their future growth and the involvement of their people.
  Example: "What sort of business do we want?"
- Setting tangible goals to express what the company wants
  Example: the low cost producer challenge
- Developing awareness and understanding, i.e., where the company is now, how the situation has evolved and what trends and options are open for the future
  Example:

Priority	Customers	Salesmen
1st	Quality	Price
2nd	Reliable Delivery	Quality
3rd	Rapid Delivery	Technical Advice
4th	Price	Product Range

- Maintaining business activities as measure of control
  Example: Application of the PDCA cycle (see Chapter 2.5.2) in strategic planning and implementation
- Setting dynamic standards to create clear and consistent milestones
  Hint: use of 5W1H (see Chapter 2.2.2.3)
- Design of planned implementation to ensure that strategies and policies are put into practice using structured marketing planning system and sequences. Contact with customers must be consistent at all levels.

Example: Deep understanding of the external environment with prioritised marketing activities is required.

– Insisting on creative evaluation – this is more than inspection and involves those who have an input to the results.

(Ho, 1995, pp. 120,121)